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SPACE SHUTTLE APPROPRIATIONS FOR FISCAL YEAR 1979

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NINETY-FIFTH CONGRESS

SECOND SESSION

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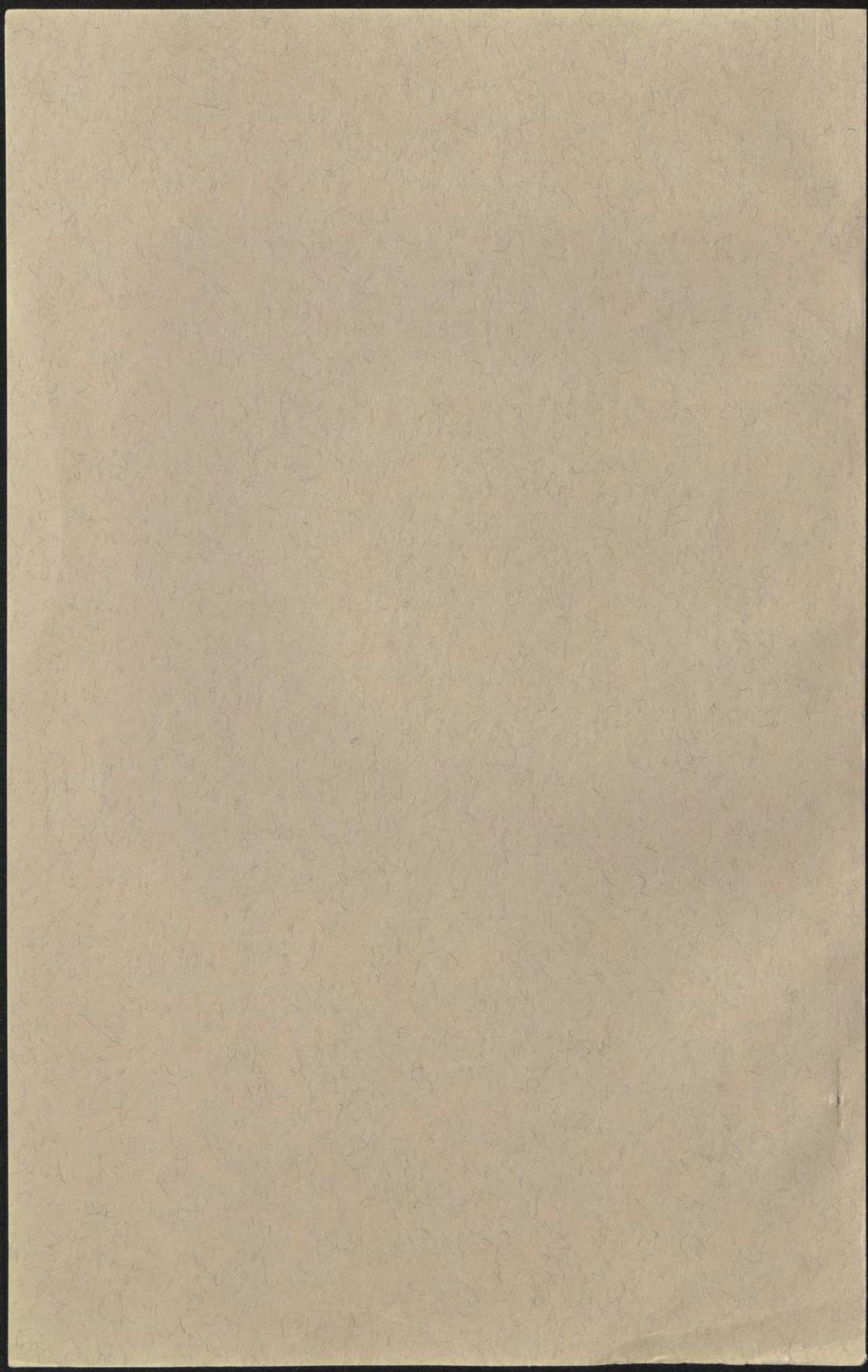
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SPACE SHUTTLE APPROPRIATIONS FOR FISCAL YEAR 1979

HEARINGS BEFORE SUBCOMMITTEES OF THE COMMITTEE ON APPROPRIATIONS HOUSE OF REPRESENTATIVES NINETY-FIFTH CONGRESS SECOND SESSION

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SPACE SHUTTLE APPROPRIATIONS FOR FISCAL YEAR
1979

THURSDAY, MARCH 9, 1978

DEPARTMENT OF DEFENSE APPROPRIATIONS FOR 1979

DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT-INDEPENDENT AGENCIES APPROPRIATIONS FOR 1979

MILITARY CONSTRUCTION APPROPRIATIONS FOR 1979

WITNESSES

DEPARTMENT OF DEFENSE

HON. WILLIAM J. PERRY, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

MAJ. GEN. EDWIN A. COY, DIRECTOR OF SPACE, OFFICE OF THE DEPUTY CHIEF OF STAFF (RESEARCH AND DEVELOPMENT), HEADQUARTERS, U.S. AIR FORCE

MAJ. GEN. WILLIAM E. GILBERT, DEPUTY DIRECTOR OF ENGINEERING AND SERVICES, HEADQUARTERS, U.S. AIR FORCE

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

DR. ROBERT A. FROSCH, NASA ADMINISTRATOR

DR. ALAN M. LOVELACE, NASA DEPUTY ADMINISTRATOR

WILLIAM E. LILLY, NASA COMPTROLLER

JOHN F. YARDLEY, ASSOCIATE ADMINISTRATOR FOR SPACE TRANSPORTATION SYSTEMS

GENERAL ACCOUNTING OFFICE

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DONALD DAY, ASSOCIATE DIRECTOR, PROCUREMENT AND SYSTEMS ACQUISITION DIVISION

JOHN TOLER, AUDIT MANAGER, DALLAS REGIONAL OFFICE

DANNY L. SPROWLS, SUPERVISORY GAO AUDITOR

DANNY R. BURTON, SUPERVISORY GAO AUDITOR

INTRODUCTION

Mr. BOLAND. The committee will come to order

May I open by saying that this joint hearing would ordinarily be handled by the chairman of the full Appropriations Committee, Mr. Mahon, but he is ill. So the task has fallen upon the chairman of the subcommittee that handles the NASA budget. Of course we have been into the program perhaps a lot more than the other subcommittees, that is the only reason why I chair it.

Today the committee will consider the fiscal year 1979 budget request for the Space Shuttle program.

This is a somewhat unusual hearing in that three Appropriations Subcommittees are participating in the hearing. The Committee felt this departure from normal practice was justified since different aspects of the Shuttle are funded in three different Appropriation Acts. By having a joint hearing, we hope to insure that the three Subcommittees will act upon a common body of knowledge.

The Committee felt that a joint hearing was justified because the FY 1979 budget proposes initial expenditures for the Space Shuttle program which if carried to completion will ultimately cost \$3 to \$4 billion, even though the initial expenditures are relatively small. For example, the GAO estimates that building and operating a Shuttle launch site at Vandenberg could cost in excess of \$3 billion between now and the early 1990's. Similarly, the proposal to begin procurement of a fourth orbiter, as is proposed in the President's FY 1979 budget, could cost another \$600 to \$800 million depending upon the pace of future inflation and possible unforeseen technical changes.

A final reason justifying this hearing is that the General Accounting Office has in progress a study which indicates that a Vandenberg launch site may not be necessary, and a 3 orbiter Shuttle fleet may be all that is needed. If these GAO conclusions hold up to scrutiny in today's hearing, there could be a savings to the taxpayer of between \$3 to \$4 billion. That is a very large sum of money, and any proposal which purports to be able to save sums of that size deserves serious consideration by the Appropriations Committee.

In order to fully explore these important issues, we have asked witnesses from all concerned agencies to appear before the Committee to defend their various viewpoints and proposals. We will lead off with a statement by Dr. Robert Frosch, Administrator of the National Aeronautics and Space Administration, who will present the NASA viewpoint. Dr. Frosch will be followed by Dr. William Perry, Under Secretary of Defense for Research and Engineering, who will present the DOD position. We will conclude with an opening statement by Mr. Richard Gutmann, Director, Procurement and Systems Acquisition Division, who will present the General Accounting Office position.

By having all three Subcommittees present, and by having NASA, DOD, and GAO witnesses in the same hearing room at the same time, we should be able to explore all points of view and resolve any contradictions which might exist. I hope that we will take full advantage of this unique opportunity and that all Members will feel free to direct their questions to anyone of the witnesses. By the same token, I intend to ask general questions and any or all of the three witnesses should feel free to comment upon each question upon which they have a particular point of view. I believe this somewhat freewheeling format

will encourage maximum debate. If someone disagrees with a statement, don't just sit there but speak up and give us your point of view.

As I see it, there are three issues which need to be fully explored in this hearing. As the hearing proceeds, I am sure there will be other issues which develop, and, of course, I am sure that other Members have other issues which are bothering them. The three issues I want to develop are:

1. How many orbiters are needed?
2. Is a Vandenberg launch site required?
3. What will be the costs of the transition to the Shuttle era, particularly as relates to the continuing production of expendable launch vehicles?

Since many of the Members have not heard some of the witnesses before, I would ask that all witnesses submit a biographical sketch for the record for themselves and each of their backup witnesses. I would also ask that prior to making his opening statement each witness briefly explain his position in his respective agency and why he has been selected to present his agency's point of view in regard to the Space Shuttle program.

Dr. Frosch, you may proceed with your opening statement.

I understand that you have a rather full and complete statement. We will put that complete statement in the record. Why don't you not brief us on the statement. I understand you have some slides. We will handle it in that manner.

After I have asked some general questions, after the briefings by the three witnesses, I will ask Mr. McKay, who is the chairman of the Military Construction Subcommittee to continue the questioning. We will continue with another Democrat, and then we will shift back and forth between two Democrats and one of the minority on the Republican side.

So Dr. Frosch, why do you not proceed.

BIOGRAPHICAL SKETCHES OF NASA WITNESSES

Dr. Frosch. Thank you, Mr. Chairman.

As the Administrator of NASA, I am responsible, of course, for the NASA program, including the Space Transportation System, and NASA has the responsibility for the National Space Transportation System, although portions of it are being funded in other budgets, as you pointed out.

As you suggested, and with your permission, I will submit the biographical sketches of the NASA witnesses and my proposed statement for the record.

[The information follows:]

DR. ROBERT A. FROSCH ADMINISTRATOR, NASA

Dr. Robert A. Frosch was nominated by the President May 23, 1977, to become Administrator of the National Aeronautics and Space Administration. He is the fifth man to head the nation's civilian space agency. Dr. Frosch took his oath as head of the agency and entered the new post June 21, 1977.

Until he was chosen to head NASA, he was Associate Director for Applied Oceanography at Woods Hole Oceanographic Institution from 1975, continuing in that position until mid-1977.

From 1966 to 1973 Dr. Frosch was Assistant Secretary of the Navy for research and development. He served as Assistant Executive Director of the United Nations Environment Program from 1973 until 1975.

From 1963 to 1965 Dr. Frosch was director of nuclear test detection at the Defense Department's Advanced Research Projects Agency (ARPA) and from 1965 to 1966 he was Deputy Director of ARPA.

He was born May 22, 1928 in New York City. He earned a B.A. degree in 1947, M.A. degree in 1949 and a Ph.D. in 1952 in theoretical physics, all from Columbia University.

While completing his studies for the doctorate, he joined Columbia's Hudson Laboratories in 1951, working on naval research projects as a research scientist. He became Director of Hudson Laboratories in 1956, remaining in that post until 1963.

Since 1969 he served as Department of Defense member of the Committee for Policy Review of the National Council on Marine Resources and Engineering Development. In 1967 and 1970 he was chairman of the U.S. delegation to the Intergovernmental Oceanographic Commission meetings at UNESCO in Paris. He received the Arthur S. Flemming Award in 1966 and the Navy Distinguished Public Service award in 1969. He is a member of Phi Beta Kappa and Sigma Xi honorary fraternities. He is a fellow of the American Association for the Advancement of Science, the Acoustical Society of America and the Institute of Electrical and Electronics Engineers (IEEE). His memberships in professional societies include: American Physical Society, Seismological Society of America, Marine Technology Society, Society of Naval Architects and Marine Engineers, Society of Exploration Geophysicists, and the American Geophysical Union.

He is married to the former Jessica Rachael Denerstein of Brooklyn, N.Y. They are the parents of two teenage daughters.

ALAN M. LOVELACE, DEPUTY ADMINISTRATOR, NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Alan M. Lovelace was born in St. Petersburg, Florida, on September 4, 1929. Shortly after the end of the Korean Conflict, he served in the U.S. Air Force from 1954 to 1956.

Dr. Lovelace attended the University of Florida, Gainesville, Florida, receiving a Bachelor of Science Degree in Chemistry in 1951, a Master of Science Degree in Organic Chemistry in 1952, and a Doctor of Philosophy Degree in Organic Chemistry in 1954. In 1952, he married the former Kathryn Logan of Bridgeport, Connecticut. Dr. and Mrs. Lovelace have two children—William and Denise—and reside in Severna Park, Maryland.

PROFESSIONAL CAREER

Following service in the Air Force, Dr. Lovelace's entire professional career has been in Government service. Most of this time was spent at the Air Force Materials Laboratory (AFML), Wright-Patterson Air Force Base, Dayton, Ohio. There he initially did work in the field of fluorine and polymer chemistry. These efforts on fluorocarbon and inorganic polymers extended the useful temperature range over which polymers can be used.

In January 1964, he was named as Chief Scientist of the Air Force Materials Laboratory. In this role, he worked to realize the potential of very high strength, very light weight fibers being consolidated in a new class of materials called composites.

In 1967, he was named Director of the Air Force Materials Laboratory, and in October 1972, he was named Director of Science and Technology for the Air Force Systems Command at Headquarters, Andrews Air Force Base, Maryland. In this role, he provided technical guidance and management policy to eleven Air Force Systems Command Laboratories, five Liaison Offices, and the Command's European Office of Aerospace Research.

In September 1973, he became the Principal Deputy to the Assistant Secretary of the Air Force for Research and Development. In this role, he advised and assisted the Assistant Secretary in his direction of the entire Air Force Research and Development Program.

In September 1974, Dr. Lovelace left the Department of Defense to become the Associate Administrator of the NASA Office of Aeronautics and Space Technology. As the Associate Administrator for Aeronautics and Space Technology, he was responsible for the management of the research program that will provide the basic science and technology advances that will be required for future military and civil aircraft, and the systems to exploit and explore space.

In June 1976, Dr. Lovelace was appointed Deputy Administrator of NASA by President Ford.

PROFESSIONAL ACTIVITIES, HONORS AND AWARDS

Dr. Lovelace is a Fellow in the American Astronautical Society, and Member of the National Academy of Engineering. He is also a Member of the American Institute of Aeronautics and Astronautics, the Air Force Association, Sigma Xi, and Phi Beta Kappa.

He has also received the following special honors:

Air Force Materials Laboratory Charles J. Cleary Award for Research, 1956.

Arthur S. Flemming Award (Ten Outstanding Young Men in Government) in 1958.

Air Force Meritorious Civilian Service Award, 1959.

Air Force Systems Command Certificate of Merit, 1964.

Federal Civilian Employee Award, Ohio Chapter, Society of Personnel Administration, 1964.

Air Force/Air Force Systems Command Meritorious Award for Program Management, 1969.

Office of Aerospace Research Award for Outstanding Contributions to Research, 1970.

National Civil Service League Career Service Award, 1971.

Air Force Exceptional Civilian Service Medal, 1973.

Von Karman Lecturer, American Institute of Aeronautics and Astronautics, 1974.

JOHN F. YARDLEY, ASSOCIATE ADMINISTRATOR FOR SPACE FLIGHT

As Associate Administrator for Space Flight, Mr. Yardley is responsible for all NASA space flight programs which include the Space Transportation System composed of the Space Shuttle, the Spacelab and the Interim Upper Stage, the expendable launch vehicles and engineering studies related to possible future space flight projects.

Before joining NASA in May 1974, Mr. Yardley was Vice President and General Manager of the Eastern Division, McDonnell Douglass Astronautics Co., in St. Louis, Mo. He joined McDonnell Aircraft Corp. in 1946 as a structural engineer. Other positions Mr. Yardley held at the corporation were Project Engineer for Mercury Spacecraft Design, Launch Operations Manager for Mercury and Gemini, and Manager for Skylab.

Mr. Yardley was born in St. Louis in 1925. He received a B.S. degree in aeronautical engineering from Iowa State College in 1943 and an M.S. degree from Washington University in St. Louis in 1950. During World War II, he served in the U.S. Navy.

Mr. Yardley has received the NASA Public Service Award for his contributions to the Mercury Program in 1963 and for Gemini in 1966. He was awarded the Spirit of St. Louis Medal by the American Society of Mechanical Engineers. He is a Fellow of the American Institute for Aeronautics and Astronautics and the American Astronautical Society.

He is married to the former Phyllis Steele. They have five children and reside in Potomac, Md.

WILLIAM E. LILLY

Comptroller

William E. Lilly was appointed to this position on January 3, 1973. Prior to this appointment he had served as Assistant Administrator for Administration at NASA Headquarters since March 1967. In addition to agency budgeting and financial planning, analysis, and control, Lilly is responsible for the Office of Facilities and the Office of Supply and Equipment Management.

Lilly joined NASA, February 1960, as Chief, Plans and Program Coordination, Office of Launch Vehicle Program and was subsequently appointed Director of Program Control for the Office of Manned Space Flight.

Prior to joining NASA Lilly was Assistant to the Director, Plans and Programs, Special Projects Office, Department of the Navy, from 1956 to 1960. He was Deputy Budget Officer at the National Bureau of Standards from 1954 to 1956, Head of Estimate and Analysis Section at the Navy Bureau of Ordnance from 1952 to 1954 and a budget and program analyst with the Navy Ordnance Test Station, California, from 1950 to 1952.

Lilly graduated from the University of California in 1950 with highest honors in the School of Political Science. He is a member of Phi Beta Kappa and Pi Sigma Alpha. Lilly also completed a year of graduate work at the University of California.

Lilly served in the Navy from 1940 to 1946 and holds the Navy Unit Commendation and served in the American, Asiatic-Pacific and Philippine Liberation campaigns.

Lilly was born at Liberty, Texas, August 25, 1921. He is married to the former Blanche E. Bromert. The Lilly's have two children and live at 2762 South Ives Street, Arlington, Virginia.

STATEMENT BY ADMINISTRATOR, NATIONAL AERONAUTICS AND
SPACE ADMINISTRATION

Mr. Chairman and Members of the Committee. I am pleased to have this opportunity to appear before you to review and discuss our progress in Space Shuttle development and the plans for future operation and utilization of the national Space Transportation Systems.

The Presidential decision in January 1972 to initiate development of the Space Shuttle to maintain a U.S. manned space flight capability and to replace essentially all expendable launch vehicles, characterized the program as a national resource envisioned to meet all national space operational requirements—both civil and defense. This national program is being designed and developed to make possible significant economies in space operations through reduced costs for both transportation and payload development and operations.

The National Aeronautics and Space Administration and the Department of Defense, in January 1977, signed a joint Memorandum of Understanding which sets forth the broad policies and principles that govern the relationships between the two agencies relevant to the development, acquisition, and operation of the national Space Transportation System. Formal policy coordination is accomplished by the NASA/DOD Aeronautics and Astronautics Coordinating Board and the NASA/USAF STS Committee. Additionally, extensive NASA/DOD interface relationships exist at all levels of management to effectively coordinate the day-to-day activities of this national program.

The Space Shuttle development is well underway. The extremely successful Approach and Landing Test Program was completed on 26 October 1977, with the fifth free flight of the first Orbiter. All test objectives were met and this program phase was completed well ahead of the commitment schedule. The first orbital flight test is scheduled for mid-1979. The Space Shuttle, once developed and operational, will make a major contribution toward maintaining the nation's technological initiatives and will be highly effective in terms of offering new capabilities which can lead to more effective civil and military space operations in the future. Exploitation of the fully operational STS promises significant benefits.

To realize the significant advantages that this national resource will provide to the United States, timely steps have been and will be taken to move effectively into the operational phase. Most of these steps are underway in accordance with previous decisions and agreements. For example:

(1) Continuation of the development and construction of the launch, landing and refurbishment facilities at the Kennedy Space Center, Florida to support all easterly and high altitude missions—NASA has this underway.

(2) Development of operational plans and flight and mission control facilities—NASA has these underway.

(3) Facility design and planning for development and construction of the launch, landing and refurbishment facilities at Vandenberg Air Force Base, California, to support all polar and sun-synchronous missions—DOD has this underway and has related funding requirements included in the 5-year defense budget.

(4) Initiation of procurement of the third and fourth Orbiters—NASA has this included in its budget; procurement of the third orbiter was initiated in FY 1977 with Economic Stimulus Appropriations Act funding.

(5) Development of upper stages for missions requiring orbital altitudes exceeding the capability of the orbiter vehicle—DOD has the development of an Inertial Upper Stage (IUS) underway; NASA is planning for commercial development of Spinning Solid Upper Stages (SSUS) for smaller payloads.

The Orbiter, with its main engines, is the major flight element of the Space Shuttle vehicle. The other elements are the Solid Rocket Boosters (SRB) and the large External Tank (ET). The Orbiter is the manned element of the system which

contains the crew and cargo accommodations and is injected into low earth orbit, deploys and retrieves payloads or functions as an on-orbit spacecraft, and returns to earth for refurbishment and servicing for the next mission. These projects are now in their peak development stages leading to orbital flight tests starting in 1979.

During the past year, good progress has been made in many Space Shuttle development and test areas. The approach and landing tests using the orbiter "Enterprise," fabrication of the first external tank test article, and development and initial test firings of the solid rocket motor have all been successfully completed. Facilities to support launch and landing and major tests are also keeping pace with requirements. Although progress to date has been good, we have experienced some technical problems and program costs are somewhat greater than predicted. This has required the adjustment of some internal schedules and has delayed the planned delivery of the first development flight elements to Kennedy Space Center by two months.

A number of problems have been experienced in the main engine turbopump development. Even with these problem areas, the overall main engine development progress during the year has been substantial. Over 14,000 seconds of engine test time have been accumulated, and all engine components have been tested to rated power level. During this period of significant test activity, we have experienced some turbopump design problems. Modifications were incorporated into the high pressure fuel turbopump to solve the subsynchronous whirl and bearing cooling problems. The high pressure oxidizer turbopump also required modifications to solve bearing and cooling problems.

Recent turbine blade failures in the main high pressure fuel turbopump appear to be associated with fatigue and long life. In this case, modifications are being made and test plans developed to demonstrate hardware acceptability.

In summary, the Space Shuttle Program is making good progress. We have experienced problems typical of all development programs and there has been some impact on both cost and near-term schedule milestones. However, we have consistently developed practical solutions to overcome each problem. No major technical problems have been identified that would unduly delay the first launch in 1979.

Two other elements of the Space Transportation System are the Spinning Solid Upper States (SSUS) and the Spacelab. Spinning Solid Upper Stages are low cost stages providing early, easy transition to the Shuttle for those payloads that are currently being flown on expendable Delta and Atlas/Centaur vehicles. The SSUS system includes the stage, airborne support equipment (cradle, tilt table, and spin mechanisms), and ground support equipment for both the SSUS Delta class missions and the SSUS Atlas/Centaur class missions to be delivered by the Space Transportation System.

The Spinning Solid Upper Stages are being developed at no cost to the government, by McDonnell Douglas (MDC) as a commercial venture within terms and conditions, performance specifications, and schedules specified in agreements between NASA and MDC. Funding supports the NASA activities necessary to develop the operations capability for accommodating the commercially developed SSUS-A and SSUS-D systems. This effort includes planning, analyses and preparation for ground processing and flight operations, the NASA effort necessary to monitor the NASA/MDC agreements and contracts, and the procurement of hardware and services for the SSUS-A system verification.

The Spacelab development and procurement cooperative effort between the United States and ten European nations acting through the European Space Agency (ESA) is progressing steadily on two continents.

Under terms of the Memorandum of Understanding (MOU) between NASA and ESA, ESA will design, develop and manufacture the first Spacelab flight unit and deliver it to NASA. Toward that end, the European participants have committed approximately \$600 million. Since last October there has been considerable progress. Under the direction of ESA's prime contractor, ERNO, critical design reviews of most of the Spacelab subsystems were successfully completed. Integration and test of the Engineering Model, which is expected to be delivered to NASA in June 1979, has started at the ERNO Integration Hall in Bremen, Germany. A team of six NASA integration and test specialists is co-located in Bremen to participate in those integration and test activities. Design of the Instrument Pointing System is well underway, and manufacture of an engineering model instrument pointing system has started. A leak test of the scientific airlock development unit was successfully completed at the contractor facility. Acceptance testing of the first electrical ground support equipment set is nearing com-

pletion in the integration facility at ERNO. This equipment is being used to support component assembly activities and will be a part of the support equipment package scheduled for delivery to NASA.

NASA is responsible, under the MOU, for all Spacelab operations activities and for development of selected items such as the transfer tunnel connecting the Spacelab to the Shuttle orbiter and verification flight instrumentation. This work must be completed over the next three years to meet the agreed launch dates of December 1980 and April 1981 for Spacelab 1 and 2, respectively.

The Johnson Space Center (JSC) Mission Control Center (MCC) was modified to support the Orbiter approach and landing test program completed last year and additional modifications are underway to provide for mission control support for the orbital flight test program. Further upgrading will configure the Mission Control Center (MCC) at JSC with the capability to support two orbiters simultaneously, a ground simulation network, and a MCC/launch site interface.

We are refining our requirements for flight operations support facilities at the Johnson Space Center. Hardware design and hardware installation for the command and control sections for the Mission Control Center have been initiated. Design requirements for an automated flight planning system, capable of handling a minimum of 20 flights per year are also being developed. This capability will have to be augmented as the flight rate increases.

During Fiscal Year 1979 we plan to complete development of the flight planning system and to initiate verification procedures. We will also complete design specifications and continue installation of multi-vehicle command, display and control hardware in the MCC.

Mr. Chairman, I believe we are making significant progress in all areas of the Space Transportation System. This progress has been steady, despite some technical difficulties that tend to occur in complex developments. Your continued support will enable us to maintain momentum toward a new era in space flight.

I would now like to move beyond the development phase to the broader aspects of the projected national space activity and its relationship to the evolving posture of the Space Transportation System. Key areas are Orbiter fleet capability, projected payload activity, Orbiter fleet utilization, operational sites, and the cost relations of varying levels of national space activity to various space transportation options.

ORBITER FLEET CAPABILITIES

An extensive simulation analysis of Space Transportation System operations at KSC and VAFB was conducted to determine the launch capability provided by Shuttle fleet sizes of 3, 4, and 5 orbiters operating interchangeably from both KSC and VAFB. Operations at KSC only were examined for 3 and 4 orbiter fleets. The analysis considered mission duration, requested launch dates, mission aborts and reflights, timelines and flows, major overhaul, number of Orbiters, number of pads, priority/non-priority mission subsets, and anomalies related to Orbiter and payload checkout. The evaluation included 5 day/2 shift and 7 day/2 shift work schedules.

The results of this analysis as shown below are given for each fleet size in terms of a range of annual steady-state flight capability depending upon the work schedule (5 day/2 shift to 7 day/2 shift) and the number of launch sites.

	Steady-state annual flight capability				
	KSC and VAFB operations			KSC only	
	5 orbiters	4 orbiters	3 orbiters	4 orbiters	3 orbiters
Work schedule:					
5 days/2 shifts.....	53	38	30	42	32
7 days/2 shifts.....	70	53	36	53	39

The total capability during the mission model period of mid-1980 through 1991 accounts for the build-up period as affected by Orbiter deliveries, VAFB activation and turnaround time variations due to learning. For four or five Orbiter fleets, the total capability ranges from 355 to 597 flights, with 487 flights as the maximum capability for a 4 Orbiter fleet.

It is important to note that Orbiter attrition is not accounted for in this capability analysis. The impact of potential attrition must be considered in establishing the fleet utilization policies which support mission requirements.

NATIONAL PAYLOAD MODEL

The NASA, on a continuing basis, develops several levels of national space payload program activity based on consolidation of NASA payload objectives and program planning with similar projections furnished by the civil community and the Department of Defense. These projections are the most reasonable expectation of both on-going and new programs which would evolve in an environment of continued dependence upon space in support of our national goals.

The payload model is based on an update of the payload program identified in a 1976 Joint NASA/USAF Study. Adjustments in the 1980 to 1985 time frame were made to the NASA model to reflect planning activity during the FY 1979 budget preparation process. Modifications were incorporated in the non-NASA civil program due to near-term commitments and projections. The NASA and other civil payload requirements for 1986 through 1991 are unchanged from last year's input. The DOD payload content is represented by their Revision 6 dated July 20, 1977, and modified September 6, 1977.

The payload model includes three major classes of payloads:

NASA Programs.

Other Civil Programs (U.S. Government, Commercial and Foreign).

Department of Defense Programs.

NASA programs

The NASA program involves space activities in four major areas: General Science, Earth Applications, Technology, and Space Operations Development. The payloads associated with these activities represent one of a number of programmatic options that the agency might choose for the 1980-1991 time frame based on current program objectives and budget projections.

The near-term program is based on payload planning at the time of formulation of the FY 1979 budget recommendation, and is generally consistent with the budget recommendation and the five-year projection. The longer term mission profile is based on a logical extension of the program emphasis and priorities established in the nearterm and is consistent with the payload baseline.

Other civil programs

The non-NASA Civil Program was derived through extensive contacts with representatives of other government agencies and commercial organizations who utilize or plan to utilize space to support their activities and contains only minor adjustments to the payload program defined in 1976.

The validity of the near-term non-NASA Civil Program is strengthened by the receipt by NASA of "earnest money" or formal commitments from U.S. civil and foreign users. There are already firm payload commitments on 23 Space Shuttle flights through January 1982 and discussions are currently underway with over ten additional users desiring payload accommodations in 1981-1982.

STS traffic analysis

Using these payload projections as the user requirement, the total STS traffic was determined along with the expendable launch vehicle requirements during transition. The payload model requires 552 Space Shuttle flights and 48 expendable launch vehicle flights to deliver all payloads, which is only a slight change from last year's 560 flight model. The possibility of the loss of an orbiter must be recognized and accounted for in establishing the Space Shuttle level of capability available to support requirements of the users.

The payload model was reduced in the number of NASA Spacelab missions in order to meet the more conservative capability of the 5 orbiter/2 site operation with attrition, resulting in deletion of about eight Spacelab missions per year from 1986 through 1991. The mission model with these adjustments reduces the number of STS flights from 552 to 487.

LAUNCH/LANDING SITE CONSIDERATIONS

Following an intensive year-long evaluation of some 140 candidate sites for Space Shuttle operations, a review board, in 1972, selected KSC and VAFB as the test and operational sites based on capability to meet performance requirements, lowest cost, and least environmental impact. The selected sites provide for the established performance requirements, water recovery of the solid rocket boosters, inhabited area avoidance of the ascent focused sonic boom, no land overflight in the launch trajectory, external tank disposal in remote ocean areas, and accommodation of abort modes.

Evaluation of the feasibility of accomplishing polar missions from KSC showed that this was not a viable mode of operation in view of the yaw steering performance loss, overflight of heavily populated areas of the U.S., and the political implications of the separated external tank and orbiter overflying the Soviet Union.

COST EFFECTIVENESS ANALYSES

A cost effectiveness analysis was conducted to assess the impact of alternative fleet sizes and the elimination of Vandenberg AFB as an STS launch facility. With the adjusted payload program (487 flights) as the baseline flight model, those cases where STS capability was not available to support the payload program diverted the remaining payloads to expendable launch vehicles (ELV). This criterion for selection of the payloads for launch with the STS was based on the least cost STS/ELV mix required to accommodate the baseline program.

In cases where STS capability was retained at KSC only, all high inclination Spacelab payloads requiring manned involvement were shifted to KSC for flights on the STS resulting in losses in payload effectiveness due to lower orbital inclinations. Full ELV capability was retained at VAFB, and payload requirements exceeding STS capability at KSC were flown on ELV's as well. To the extent practical, the types of ELV's that had to be retained in the inventory were minimized. An important assumption was to provide priority launches for DOD payloads; thus, the full DOD program was flown on the STS in the 5 orbiter and 4 orbiter cases.

Results of the cost effectiveness analysis showed that a four or five orbiter fleet operating from both sites is more cost effective, from the national viewpoint, by from \$4.0 billion to \$7.0 billion, than the alternatives of Space Shuttle/expendable vehicle mixes required to support a common mission model.

REDUCED LEVELS OF SPACE ACTIVITY

The economics of reduced payload levels for Shuttle fleet sizes of 5, 4, and 3 orbiters and one and two-site operation were examined.

Specifically, four levels of space activity were assumed: 487, 425, 360 and 300 equivalent Shuttle flights

	<i>Cases</i>
Baseline.....	487
Spacelab reduced about 30 percent.....	425
Spacelab reduced about 60 percent.....	360
Spacelab reduced about 60 percent.....	300
NASA automated reduced about 40 percent.	
Other civil automated reduced about 35 percent.	

In each of the program levels, the DOD payload requirements were retained.

The lowest level of Space activity, the 300 equivalent Shuttle flight level, is roughly equivalent to the current U.S. experience of 25 to 30 flights per year. The cost considerations include all non-recurring investment, operations and payload delta costs.

The results of these analyses show that a four or five orbiter fleet operating from both east and west coast launch sites is *more cost effective* than any Orbiter/ELV mix for supporting projected payload traffic over a wide range of activity levels.

Within this wide range of activity levels, the payload program content can vary significantly among users and types of programs. Therefore, the fleet size decision does not set the size or content of the national space program nor the budget levels of individual users, and the Congress will continue to exercise its annual evaluation of individual space programs.

CONCLUSIONS

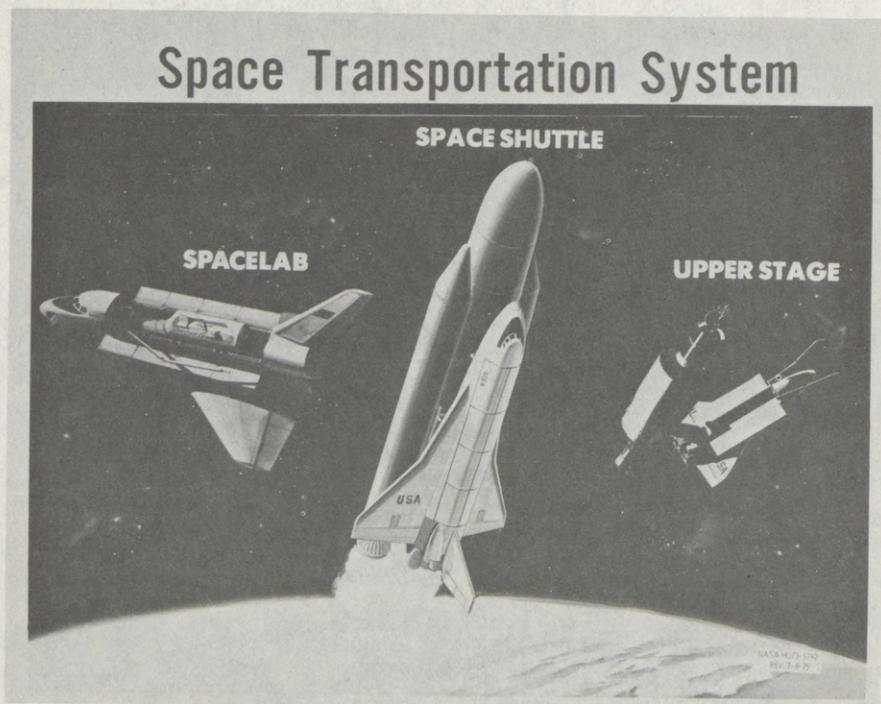
In summary, Mr. Chairman, our analyses show that the requirement for a two-site Space Shuttle operation is national in nature and based on firm performance requirements and sound economic benefits. An adequate Shuttle fleet to serve all users—civil and military—will provide the assured launch capability necessary to promote early transition by all users and to permit phase-out of expendable launch vehicles—actions which provide important economic benefits.

Decisions made now on the Space Transportation System will establish the future level of this nation's space capability for many years. The issues and alternatives are complex and the stakes are high—scientific and technological leadership, national security, and international prestige. Moving forward now with an adequate orbiter fleet/two site operation will enhance this nation's posture in space and provide a means for taking full advantage of new opportunities in the future exploitation of space.

SUMMARY STATEMENT OF NASA ADMINISTRATOR

Dr. FROSCHE. I would propose now to brief the combined Subcommittees on the subject at hand: the Space Transportation System and its relevant aspects. As you know, we have not seen a final report from the General Accounting Office. Therefore, I would prefer to respond to the questions that you previously raised during the question period and in the general discussion, since I have not incorporated the answers to those questions in detail into the briefing or into the statement.

We have some vugraphs, which I will use for my presentation.
[Chart follows:]



SPACE TRANSPORTATION SYSTEM

Dr. FROSCHE. The subject of this presentation is the Space Transportation System. There are several major aspects of this system that have to be considered. The Space Shuttle System, which I will go through in some detail, is shown in the center of the vugraph, with its elements assembled into the launch configuration. The Shuttle orbiter is the winged aircraft-like vehicle attached to the external

tank. This tank contains the propellants required for the main engines. Attached on the sides of the tank are two solid rocket boosters.

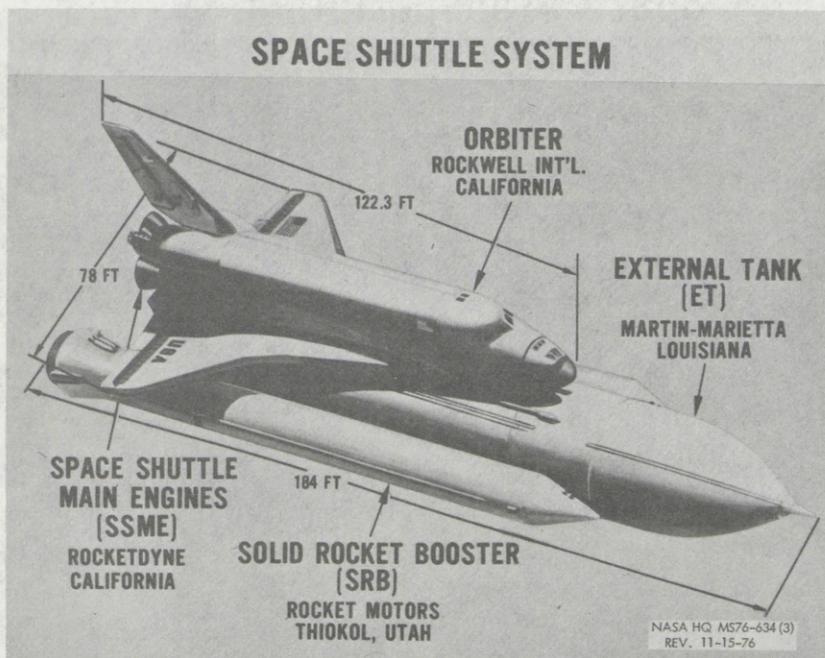
On the left is shown the Shuttle orbiter with the doors of its cargo bay open. Contained in the bay is the Spacelab being built by the European Space Agency. It will be used for experimental work and instrument testing.

On the right is shown the upper stage.

There are several versions of upper stages. These are used to take free flyers and equipment from low earth orbits which the orbiter can reach, into higher orbits, including geosynchronous orbit or for planetary and other exploration orbits out of earth orbit.

SPACE SHUTTLE SYSTEM

Dr. FROSCHE. The next slide shows the Space Shuttle System which I described before with the various pieces labeled. The fully reusable portion is the orbiter, which looks like an aircraft. When it is carried into space, it becomes a satellite of the earth for the period of operations in orbit. We can do work in space from the orbiter itself, and we can place spacecraft into free-flying orbits.



EXTERNAL TANK

The external tank is a liquid-hydrogen, liquid oxygen tank. It carries all of the propellants for the main engines of the Shuttle orbiter. It is the only portion of the system which is expendable. It is disposed of in the sky over a remote area of the Indian Ocean for every flight.

SOLID ROCKET BOOSTERS

The solid rocket boosters are used in the very early portion of the flight. They burn out, are separated, and then the booster casing and engines are retrieved to be used again.

SPACE SHUTTLE MISSION PROFILE

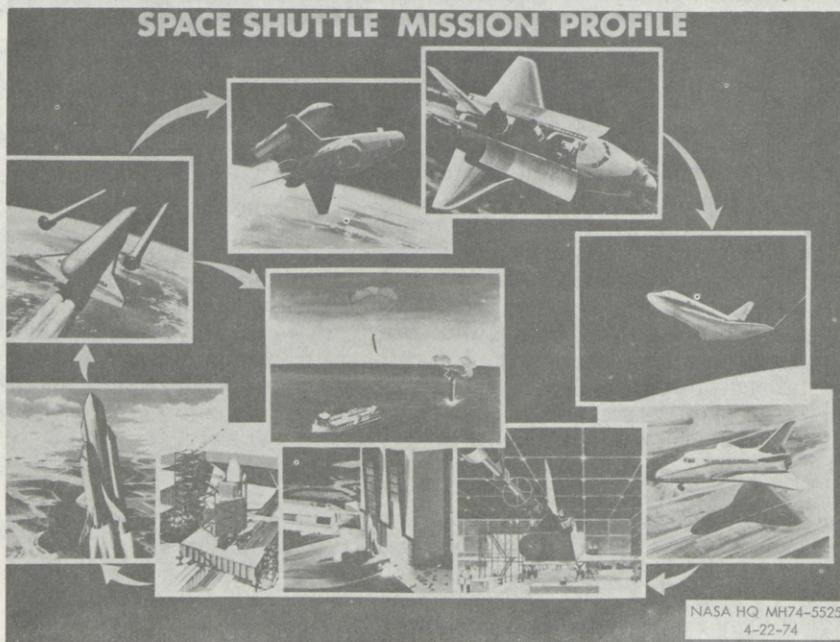
Dr. FROSCHE. The next vugraph shows the Space Shuttle mission profile. Beginning on the bottom at the left, you can see preparation of the orbiter which is placed on one of the mobile launchers that we have at the Kennedy Space Center. They are being modified from those that were used in the Apollo program.

The Shuttle is carried to the launch pad on that mobile launchers and the whole system of the orbiter, external tank and solid rocket boosters is used for launch. Shortly after launch the solid rocket motors are burned out and is shown in the upper left-hand side of the vugraph. The solid rocket boosters then separate from the external tank, and the external tank and the orbiter, with its main engines continue to accelerate in flight. Just before insertion into orbit the main engines are shut off and the external tank is separated. When we launch from Kennedy it travels about halfway around the earth from the launch point, breaks up and lands in a remote area of the Indian Ocean.

The orbiter is then inserted into its final low-Earth orbit. The Shuttle cargo bay doors, as can be seen in the upper right, may be opened and operations in space can then commence. These may be operations using the orbiter itself as a satellite equipped with instru-

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Space Administration

Headquarters
Washington, D. C.



ments in the orbiter. Or, free flyers and satellites may be deployed from the cargo bay, either with simple separations or by using upper stages to place them into higher energy orbits. There is a remote manipulator arm, which you cannot see on this particular picture, which can be used to move payloads in and out of the Shuttle's cargo bay.

In addition, it will be possible to retrieve satellites from low-Earth orbit, place them in the bay and either work on them in space or attach them inside the bay, close the cargo bay doors, and return them to Earth for refurbishment or other work. These new capabilities are an important point in understanding the economics of this system.

After the appropriate time in orbit, which we would expect to be on the average to be 5 to 7 days, but which could be up to 20 or 30 days, the orbiter then does a short engine burn to lower its orbital velocity. It enters the atmosphere, going through entry heating, this heat is handled by the thermal-protection system, which is reusable and is part of the orbiter. After entry, the orbiter becomes an unpowered aerodynamic vehicle and lands on a glide trajectory. The two places intended for landing are the Kennedy Space Center and at Vandenberg Air Force Base. An alternate landing site is at Edwards Air Force Base, located at the Dryden Flight Center in California.

The orbiter is also capable of landing on other airfields if necessary. After it lands, there are facilities for refurbishing it to the extent required and for removing any free flyers or Spacelab payloads that have been brought back and for setting the orbiter up for the next flight. The turnaround time for this activity is also a consideration in the number of orbiters required.

MOTION TO VOTE AND CLOSE HEARING

Mr. BOLAND. Will you suspend for just a moment? Mr. McKay has a motion.

Mr. MCKAY. Mr Chairman, I move that those parts of the hearing today on the Space Shuttle program which involve classified material be held in executive session.

Mr. BOLAND. This motion requires a recorded vote. The clerk will call the roll.

[The clerk proceeded to call the roll.]

Mr. BOLAND. Mr. Reporter, let the record show that on this motion Mr. Boland, Mr. McKay, Mr. Sikes, Mr. Addabbo, Mr. Long, Mr. Stokes, Mr. Beville, Mr. Alexander, Mr. Traxler, Mr. Baucus, Mrs. Boggs, Mr. Edwards, Mr. Coughlin, Mr. McEwen, Mr. McDade, Mr. Robinson, and Mr. Young voted aye. There were no noes. Seventeen is a sufficient number. Those parts of the testimony that are classified will be in executive session.

Thank you very much. Dr. Frosch.

Dr. FROSCH. Thank you, Mr. Chairman.

CARGO WEIGHT AS FUNCTION OF CIRCULAR ORBITAL ALTITUDE AND ORBITAL INCLINATION

Dr. FROSCH. The next vugraph is a graph of the cargo weight in thousands of pounds, shown on the left side, versus the orbital altitude that can be attained. The upper curve is for a launch from Kennedy

which the orbiter may land. That is a limitation due to the structural design and the aerodynamic characteristics of the orbiter. We can lift into orbit higher cargo weights than can be returned from orbit. This is essentially due to the fact that landing aerodynamics and landing on an airstrip provide higher loadings than the takeoff loading. This is largely because the orbiter is horizontal in the landing case whereas in the launch case it is vertical.

So the thrusts and the forces act on it in different directions for each situation.

The amount of fuel required for higher orbital altitudes is greater and, therefore, the amount of cargo that can be carried into higher orbits is less because there is a limitation on the total quantity of fuel and cargo that can be carried into orbit.

STS RESOURCE AND RESPONSIBILITIES

Dr. FROSC. The next chart simply lists the major elements required for the total system. Shown are the agencies responsible for providing those parts of the system and the dates on which we now expect those parts of the system to become operationally available. Going through the list we see the Kennedy launch and landing site, the Mission Control Center at the Johnson Space Center, which will control all of the flights once launched; the first orbiter capable of space flight is designated Number 102; and the spinning solid upper stages used to place spacecraft into higher energy orbits than the orbiter itself can reach. The spinning solid upper stages are being funded by commercial contractors for eventual sale to Space Trans-

RESOURCE AND RESPONSIBILITIES

<u>RESOURCES</u>	<u>RESPONSIBLE AGENCY</u>	<u>OPERATIONAL** AVAILABILITY</u>
● KSC LAUNCH AND LANDING SITE*	NASA	JUN 1980
● JSC MISSION CONTROL CENTER*	NASA	JUN 1980
● FIRST ORBITER (102)*	NASA	JUN 1980
● SPINNING SOLID UPPER STAGES (SSUS)	CONTRACTORS	JUN 1980
● SPACELAB	ESA	DEC 1980
● REMOTE MANIPULATOR SYSTEM	CANADA	JUN 1980
● INERTIAL UPPER STAGE (IUS)	DOD	JUL 1980
● SECOND ORBITER (STA 099)	NASA	MAY 1981
● THIRD ORBITER (103)	NASA	JUN 1983
● VAFB LAUNCH AND LANDING SITE	DOD	JUN 1983
● FOURTH ORBITER (104)	NASA	NOV 1983

* SUPPORTS ORBITAL FLIGHT TEST PROGRAM--MID-1979 TO MID-1980

** OPERATIONAL PERIOD BEGINS MID-1980

portation System users. The Spacelab, as I mentioned, is being developed and produced by the European Space Agency. The remote manipulator system is being developed by Canada.

The inertial upper stage, which has a higher capacity for lifting heavy spacecraft into higher earth orbits, is being developed by the Department of Defense and will be discussed later by them.

The second orbiter is designated as Number 099. It is our intention to use the structural test article, designed for testing the basic strength of the orbiter, as the basis for this second orbiter, rather than testing it to ultimate limits.

The third orbiter, Number 103, will be delivered to the Vandenberg launch and landing site, and the fourth orbiter now planned in the program are also shown on this chart.

OVERVIEW OF STATUS OF SYSTEM DEVELOPMENT

Dr. FROSC. The next series of vugraphs give an overview of the status of the Space Shuttle system development.

ORBITERS 101 AND 102

I think it is important to know that we have successfully tested the landing aerodynamics and systems of the orbiter. We are currently manufacturing Orbiter No. 102. We will very shortly begin the structural testing and complete the quarter-scale vibration tests. The main propulsion test article is now at the National Space Technology Laboratories and we are moving from acceptance tests to full three-engine tests. In addition, we will very shortly start a full-scale ground vibration test, with the orbiter, external tank, and rocket booster motor at the Marshall Space Flight Center.

SPACE SHUTTLE

PROGRESS SINCE FEBRUARY 1977

● ORBITER PROJECT

- APPROACH AND LANDING TEST PROGRAM COMPLETED
- ORBITER 102 — FWD, MID AND AFT FUSELAGE MATES COMPLETED
— WING MATES 90% COMPLETED
- ASSEMBLY OF STRUCTURAL TEST ARTICLE COMPLETED
- QUARTER SCALE MATED CONFIGURATION VIBRATION TEST COMPLETED
- DELIVERED MAIN PROPULSION TEST ARTICLE TO NSTL

● MAIN ENGINE PROJECT

- FUNCTIONAL PROBLEM SOLUTIONS WELL IN HAND
- LIFE PROBLEMS NOW ENCOUNTERED—UNDER STUDY
- APPROX. 14,000 SECONDS TOTAL TEST TIME ACCUMULATED AT NSTL
- THREE ENGINES IN ACCEPTANCE TEST AT NSTL FOR MAIN PROPULSION TESTS (MPT)

MAIN ENGINE PROJECT

Next is the main engine project. We have had a number of basic functional problems during the development of these engines. Those seem all to have been solved in terms of the development. We have now run enough time on the engine so that we have begun to encounter some of the life problems, fatigue problems and the like, and are working on them. They seem to be relatively small but crucial design and development problems and we think we understand how to deal with them during this test program.

We have accumulated over 14,000 seconds of total test time on the engines. The plan for accumulation of test time before the first manned orbital flight is 80,000 seconds of engine test time. It is important to remember that the time for total main engine burn during flight is approximately 450 seconds, about 7½ minutes. The three-engine configuration, as I mentioned, is being assembled in the test area now.

EXTERNAL TANK PROJECT

Dr. Frosch. This vignette discusses first the external tank project. We have completed the tests of loading actual fuel into the main propulsion tank. The structural test articles have been delivered and will shortly start into test. We have also started fabrication of the first flight tank.

SOLID ROCKET BOOSTER PROJECT

In the solid rocket booster project, we have conducted three parachute drop tests. These tests are conducted because we want to retrieve the solid rocket motors so that they can be refurbished and

SPACE SHUTTLE
PROGRESS SINCE FEBRUARY 1977

(CONTINUED)

● EXTERNAL TANK PROJECT

- MPT TANKING TESTS COMPLETED
- DELIVERED STRUCTURAL TEST ARTICLES FOR:
 - LIQUID HYDROGEN TANK
 - LIQUID OXYGEN TANK
 - GROUND VIBRATION TESTING
- INITIATED FABRICATION OF FIRST FLIGHT TANK

● SOLID ROCKET BOOSTER PROJECT

- CONDUCTED THREE PARACHUTE DROP TESTS
- CONDUCTED TWO SOLID ROCKET MOTOR STATIC FIRINGS
- STARTED FABRICATION OF DEVELOPMENT MOTORS 3 AND 4

● LAUNCH AND LANDING PROJECT

- LAUNCH PROCESSING SYSTEMS AND FACILITIES ON SCHEDULE FOR FMOF
- SOLID ROCKET BOOSTER RETRIEVAL TESTS COMPLETED

reused. Two solid rocket motor static firings have been conducted and developed approximately the expected thrust. We have started fabrication of the third and fourth development motors, and we have completed retrieval tests.

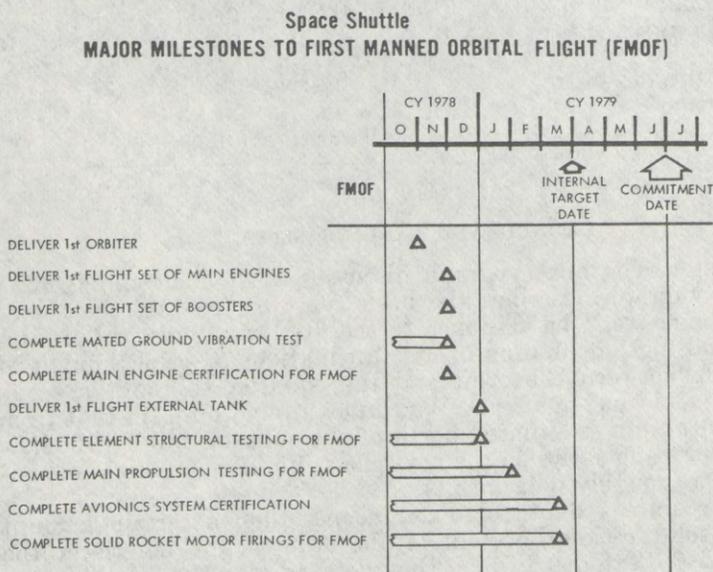
LAUNCH AND LANDING PROJECT

In the launch and landing project, the launch processing system and the facilities for the first manned orbital flight are on schedule. The solid rocket motors are designed to land in the ocean and retrieved by ship. Some engineering problems had to be solved such as putting a plug in the open end of the bottom of the solid rocket motor and pumping the water out so it can float and be towed. Those problems have now been solved and the systems for doing so have been tested.

MAJOR MILESTONES TO FIRST MANNED ORBITAL FLIGHT

Dr. FROSCHE. This vugraph shows the major milestones to be accomplished prior to the first manned orbital flight. Two dates are shown. The date for the first manned orbital flight which was established early in the program, which we call the commitment date, is mid-calendar year 1979. We have been working toward an internal target date, which is near the end of March 1979. I think we would agree that March is tight. Mid-1979 still looks reasonably good, however.

The rest of the chart shows delivery dates of the first orbiter, the flight sets of main engines, the first set of solid rocket boosters, completion of the full-scale ground vibration tests that I mentioned before, completion of engine certification for FMOF, delivery of the first flight tank and so on. We seem to be reasonably well on schedule to meet those dates.



STS INVESTMENT FUNDING

Dr. Frosch. The next chart shows the total investment funding as we now see it: the upper half being the NASA funded, NASA-budgeted investment funding; the lower half, which I will not speak to since the Department of Defense will do so, covers the DOD funding as we have it from them. We have quoted the projected total funding which is funding for various elements, including Shuttle development, production of orbiters, construction of facilities and so on. In the right hand two columns we show the projected total funding in FY 1979 budget dollars and in real year dollars, assuming an annual inflation rate of 7% beginning in FY 1980. It does not take into account inflation beyond FY 1979.

STS INVESTMENT FUNDING

(\$ IN MILLIONS)

	PRIOR FUNDING	FY 1979 FUNDING	PROJECTED TOTAL FUNDING PROJECTIONS IN:	
			1979 \$	REAL YEAR \$
● NASA				
- SHUTTLE DDT&E	5827.2	985.3	7311	7354
- ORBITER PRODUCTION	111.7	454.0	2522	2841
- CONSTRUCTION OF FACILITIES	356.9	32.6	462	472
- OPERATIONS CAPABILITY DEVELOPMENT	71.3	83.0	432	486
NASA TOTAL	6267.1	1554.9	10,727	11,153

			PROJECTED FUNDING THRU FY 83	
			PROJECTIONS IN:	
			1979 \$	REAL YEAR \$
● DOD				
- R&D AND PROCUREMENT	257.5	278.3	1193.5	1309
● IUS	(99.1)	(116.5)	(289.6)	(302)
● VAFB	(80.9)	(115.5)	(582.1)	(651)
● OPERATIONS CAPABILITY DEVELOPMENT	(77.5)	(46.3)	(321.8)	(356)
- MILITARY CONSTRUCTION		145.6	229.3	235
● VAFB		(136.8)	(220.5)	(226)
● KSC		(8.8)	(8.8)	(9)
	257.5	423.9	1422.8	1543

MS78-D

LAUNCH AND LANDING SITES

Dr. Frosch. The next vugraph discusses the launch and landing sites. This vugraph describes the basic features that set the choice of two landing sites. I have spoken to the first two items, the low inclination and high inclination orbits. Inclinations may be thought of as the angle between the orbit and the equator, so that "a zero" inclination would be equatorial. We can't quite accomplish that from Kennedy because it is situated north of the equator, but I will show you what these angles are on the next chart. Vandenberg high inclination orbits are roughly polar orbits.

We also require a depth of water deeper than a certain amount where the solid rocket boosters hit because of the length of the boosters and the extent to which they descend into the water. There is a problem of sonic boom focused on the ascent phase because of

SPACE SHUTTLE LAUNCH & LANDING SITES

- KSC & VAFB SELECTED AS SHUTTLE LAUNCH AND RECOVERY SITES BASED ON -
 - KSC PROVIDES LOW INCLINATION ORBITS
 - 65K LBS DUE EAST REQUIREMENT
 - VAFB PROVIDES HIGH INCLINATION ORBITS
 - 40K LBS SOUTH POLAR REQUIREMENT
 - ADEQUATE WATER DEPTH FOR SRB RECOVERY
 - ASCENT FOCUSED SONIC BOOM - INHABITED AREA AVOIDANCE
 - NO INHABITED AREA OVERFLIGHT IN LAUNCH TRAJECTORY
 - EXTERNAL TANK DISPOSAL IN REMOTE OCEAN AREA
 - ACCOMMODATION OF ABORT MODES

MS78-E

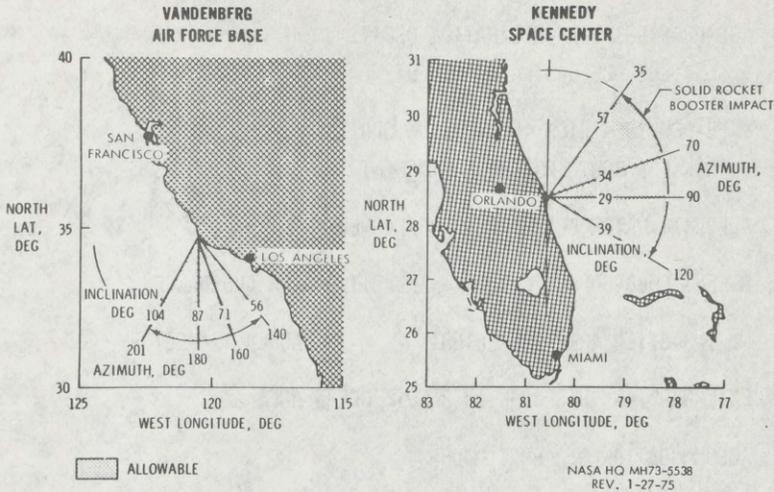
the way in which the flight path occurs during launch, so that too is a consideration in deciding on sites and directions for launch because we don't want that sonic boom to be coming ashore in inhabited areas during normal launch conditions.

We don't want to overfly inhabited areas, particularly during the early phase of the launch, because that is the phase in which the risk to life and property is greatest. We want to have external tank disposal to occur in a remote ocean area, such as the mid-Indian Ocean. In any case, we want to be sure that the early parts of the flight are such that if we have an engine problem and must abort the flight and either return to the landing site, or, if this problem occurs later during the launch phase, go around the earth or go to another launch site, that we have that portion of the trajectory over an area that we consider safe and which will allow us to return-to-the-landing site.

LAUNCH AZIMUTH AND INCLINATION LIMITS

Dr. FROSCHE. The next vignette shows the azimuths and inclination limits that we have been using for expendable launch vehicles, and which we propose to use for the Shuttle. As you can see, the farthest southerly inclination from Kennedy is essentially set by the location of the Bahama Islands and by the requirement of not to fly over them during the early powered portion of the launch. The northerly direction is essentially set by the same kind of considerations with regard to the continental United States. The launch azimuths from Vandenberg are the same thing with regard to the West Coast. These were set early in the space program basically on safety considerations and considerations of noise. We would propose to continue to use them.

PRACTICAL LAUNCH AZIMUTH AND
INCLINATION LIMITS FROM VAFB AND KSC



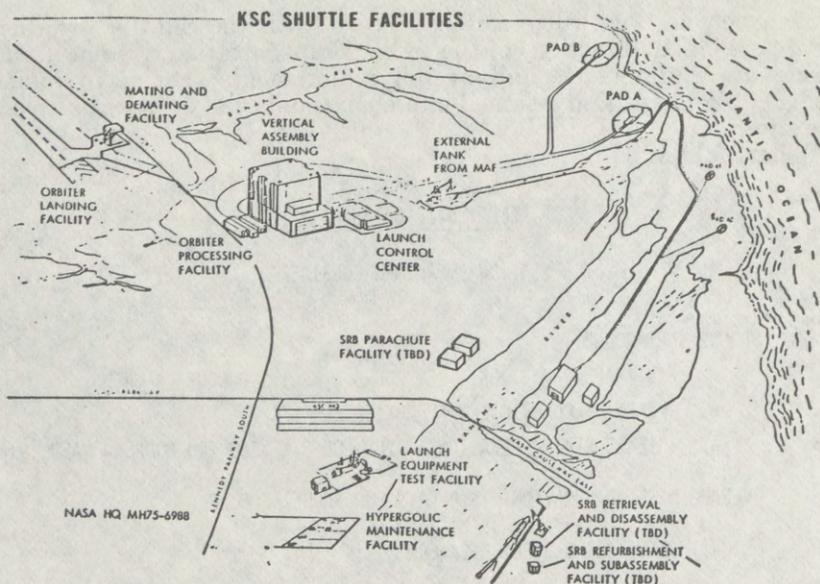
KSC SHUTTLE FACILITIES

Dr. FROSCHE. The next vignette shows an artist's aerial view of the facilities at Kennedy. These facilities are in large measure altered and refurbished facilities that were built for the Apollo flight program. On the left it shows the landing facility built for the orbiter and what is called the mate and de-mate facility, which enables us to take the orbiter and place it on or remove it from the back of the 747 aircraft that we use for ferrying orbiters from one place to another. The orbiter will not be moved in any way other than by flying it out of Kennedy and landing it at Vandenberg. We will not move it from Kennedy to Vandenberg or to any place else without some way of flying it, and that way is to load it on the back of a specially configured 747 and fly it there with the 747. This of course has been done and tested. It was the way in which we did the orbiter approach and landing tests.

The Vehicle Assembly Building was built for the Apollo program. The Orbiter Processing Facility will be used for work on the orbiter, refurbishment and the loading of satellites and the Spacelab into the cargo bay of the Shuttle. The mated Shuttle is carried from the vehicle assembly building on the mobile transporter out to the launching pad.

Launch control is performed in the Launch Control Center shown there. Also shown is the solid rocket booster parachute facility. That facility is used for refurbishing and repacking the parachutes for the solid rocket boosters.

There is the hypogolic maintenance facility and other facilities shown are mostly connected with retrieval, disassembly and rework of the solid rocket boosters.



Dr. FROSCHE. The next chart begins some discussion of the question of Shuttle fleet size and capabilities. There are the kind of operational factors we have to consider in analyzing this problem. One of them is the question of ground turnaround time, that is, how long it takes from the landing of an orbiter before we are prepared to launch the system again. The objective we would like to achieve for turnaround time is 160 hours. Knowing how systems really operate, we have done our initial planning on the basis of a larger number of hours which we consider to be realistic and have put a learning coefficient into the model that suggests that we will start slowly and, as we learn how the operation actually goes, we will become faster and faster. This is typical of such operations. We are projecting now that in a steady-state we will probably reach 200 hours for turn-around at Kennedy, 240 hours at Vandenberg.

Facilities timeliness would be different at the two places. The 160 hours would represent what one could actually do with an orbiter, assuming that everything was on time, that there was no problem with the payloads, that there were no special requirements for payloads, and so on. It is a number which is an ideal number, but not one with which you should plan total system operations. We have assumed a mission duration and a certain number of priority missions. We have had to assume that there will be delays caused by weather conditions. There are problems with winds at both sites and with the weather in terms of thunderstorms and rain. We also have to consider problems with payload malfunctions. That is, you get the system ready for launch and there is something wrong with the payload, which is not uncommon in space operations. We have had it with expendable

launch vehicles, we will certainly have it with the Shuttle together with possible malfunctions of the Space Transportation System itself. There are maintenance and overall requirements that have to be included. We have also assumed interchangeability of orbiters between the sites.

(Chart follows:)

FLEET SIZE CAPABILITY

OPERATIONAL FACTORS CONSIDERED

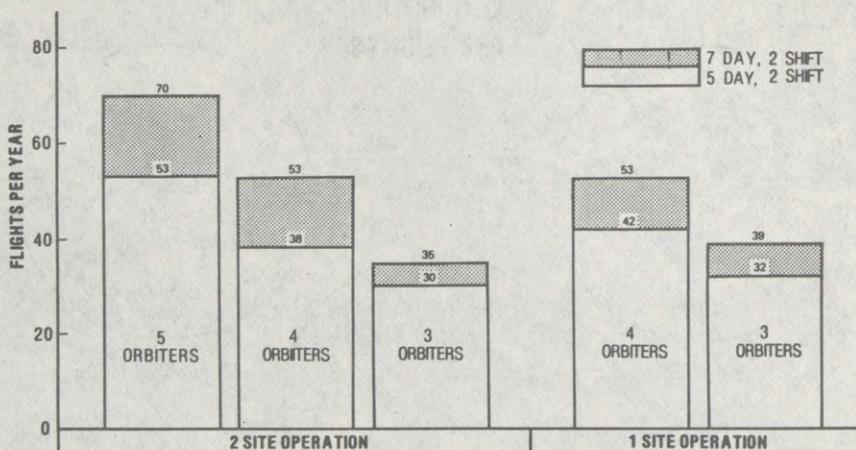
- o GROUND TURNAROUND:
 - INITIAL OPERATIONS: 252 HOURS @ KSC; 296 HOURS @ VAFB
 - LEARNING COEFFICIENT APPROXIMATELY 97%
 - STEADY STATE OPERATIONS: 200 HOURS @ KSC; 240 HOURS @ VAFB
- o AVERAGE MISSION DURATION: 5.4 DAYS FOR BASELINE MODEL
- o PRIORITY MISSIONS 6-9 FLIGHTS/YEAR
- o ANOMALIES CONSIDERED FOR:
 - WEATHER DELAYS
 - PAYLOAD MALFUNCTIONS
 - STS MALFUNCTIONS
- o MAJOR MAINTENANCE AND OVERHAUL
- o FLIGHT DISTRIBUTION APPROXIMATELY 3:1 BETWEEN KSC AND VAFB
- o INTERCHANGEABILITY OF ORBITERS BETWEEN LAUNCH SITES

MS78-F

ORBITER FLEET SIZE CAPABILITY/UTILIZATION

Dr. Frosch. The next vugraph shows how some of these fleet size capability utilization numbers come out. The three bars on the left represent two sites; the two bars on the right represent one site. The basic bar without shading describes what is possible using five days, two shifts. An all-out effort of seven days, with two shifts adds the shaded portion, and this is shown for several different numbers of orbiters; five, four, and three in the two-site case, and four and three in the one-site case. Factors and utilizations shown are listed on the bottom, including some attrition in the system in terms of down-time on orbiters and the possibility that if one started with five orbiters, one would end up with four after a certain amount of flight time had elapsed or, starting with four, one would end up with three.

ORBITER FLEET SIZE CAPABILITY/UTILIZATION



FACTORS ESTABLISHING CAPABILITY:

- KSC/VAFB TRAFFIC DISTRIBUTION
- GROUND TURNAROUND TIME
- MISSION DURATION
- RESOURCES, ANOMALIES, ABORTS

FLEET SIZE UTILIZATION:

- ACCOUNTS FOR ORBITER ATTRITION
- CAPABILITY LIMITED BY THE MAXIMUM FLIGHT LEVEL WITH ATTRITION ASSUMED

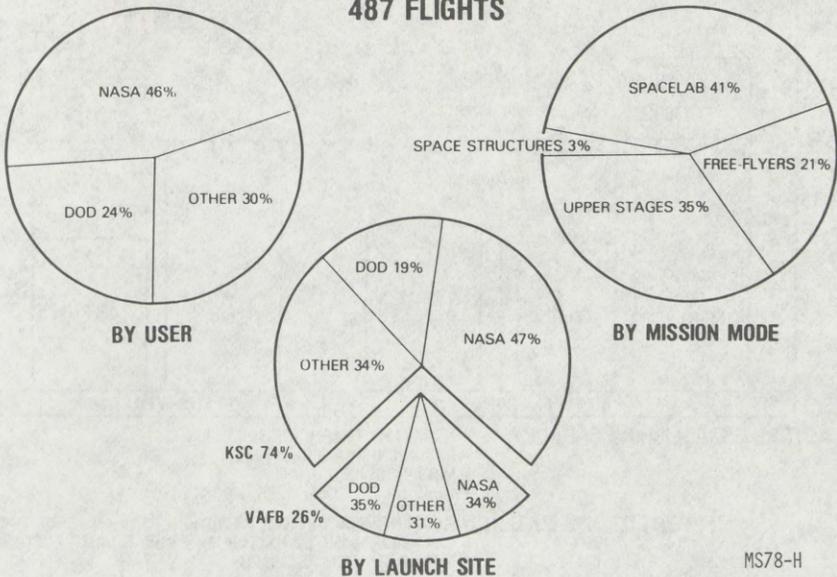
MS78-G

STS TRAFFIC SUMMARY

Dr. FROSCHE. This chart shows the summary of who would use the system for a given set of assumptions about a number of flights. The model from which this is extracted is what we call a parametric model. That is, we can make different assumptions about who uses the system and how often, what the demand is, and extract from it what the flow of users' payloads would be, what the flow of orbiters would be, and what the investment and operation cost of the system would be. What I am showing you is a sample from that model. This is the one which goes, as I recall, with seven-day two-shift operation and four orbiters, two sites. This would represent the maximum of what could be done with these resources.

The upper left-hand pie chart is divided by user; NASA has 46 percent, DOD 24 percent, other users, namely, other government agencies and commercial and foreign users about 30 percent. The mission mode is shown on the right, Spacelab represents the scientific and engineering operations using the Spacelab in the orbiter. Free flyers are spacecraft released from the orbiter or retrieved by the orbiter. Upper stages represent those cases in which free flyers use a propulsion system to move them into a higher energy orbit. The division among users is shown in the lower pie chart which is broken out by launch site.

**STS TRAFFIC SUMMARY
(DISTRIBUTION)
487 FLIGHTS**



MS78-H

ANALYSIS OF REDUCED LEVELS OF SPACE ACTIVITY

Dr. FROSCHE. The next vignette gives you some information on what happens if you use the model which I showed you in the pie charts. The model represents 487 flights over a 12-year life cycle of the system. What happens if you look at a fewer number of flights, and how we would expect to accommodate these flights if it were not possible to fly them all and what the implications would be for the number of missions are also discussed in this vignette.

If one uses the 425 model we would reduce the number of Spacelab flights by almost a third, and so on down to the 300 case, where we would have to reduce Spacelab flights from the proposed model by 60 percent; the free flyers, the automated spacecraft by 40 percent, and the civil, the non-NASA users by 35 percent. This assumes that the security requirements of DOD payloads would have priority in any case, so they are left in the model.

Then we have assumed that the equivalent number of payloads would be supported either by a total Shuttle system in the model or, as will be seen in a moment, by a mixture of Shuttles and expendable launch vehicles. If Shuttle could not accommodate it, and if there were single-site operations for this part of the model one assumes any Spacelab traffic planned for Vandenberg would be launched out of Kennedy, but that would result in deterioration of scientific return because polar orbits flying out of Kennedy over the ocean are not possible. One simply cannot afford the fuel. There is no accommodation for the fuel required to place Spacelab into polar orbit out of Kennedy with corresponding orbits over oceans.

The cost comparisons included investment, operations and payload costs, depending on what kind of operation you use. There would be

ANALYSIS OF REDUCED LEVELS OF SPACE ACTIVITY

- TRAFFIC CAPABILITY AS DEFINED IN FLEET SIZE CAPABILITY ANALYSIS
- PAYLOAD PROGRAM REDUCTION APPROACH FOR REDUCED LEVELS OF EQUIVALENT SHUTTLE FLIGHTS FROM 487 BASELINE
 - 425 CASE - SPACELAB REDUCED ABOUT 30%
 - 360 CASE - SPACELAB REDUCED ABOUT 60%
 - 300 CASE - SPACELAB REDUCED 60%
 - NASA AUTOMATED REDUCED 40%
 - CIVIL AUTOMATED REDUCED 35%
- DOD PAYLOAD PROGRAM RETAINED FOR ALL CASES
- SAME EQUIVALENT PAYLOAD PROGRAM SUPPORTED WITH SHUTTLE OR SHUTTLE/ELV MIX AS REQUIRED
- VAFB SPACELAB TRAFFIC TRANSFERRED TO KSC FOR SINGLE SITE STS OPERATIONS (DEGRADED SCIENTIFIC RETURN)
- OVERALL COST COMPARISONS INCLUDED INVESTMENT, OPERATIONS, AND Δ PAYLOAD COSTS
- RESULTS SHOW FOUR OR FIVE ORBITER/2 SITE OPERATION MOST COST EFFECTIVE OVER RANGE OF 300 TO 487 FLIGHTS

MS78-1

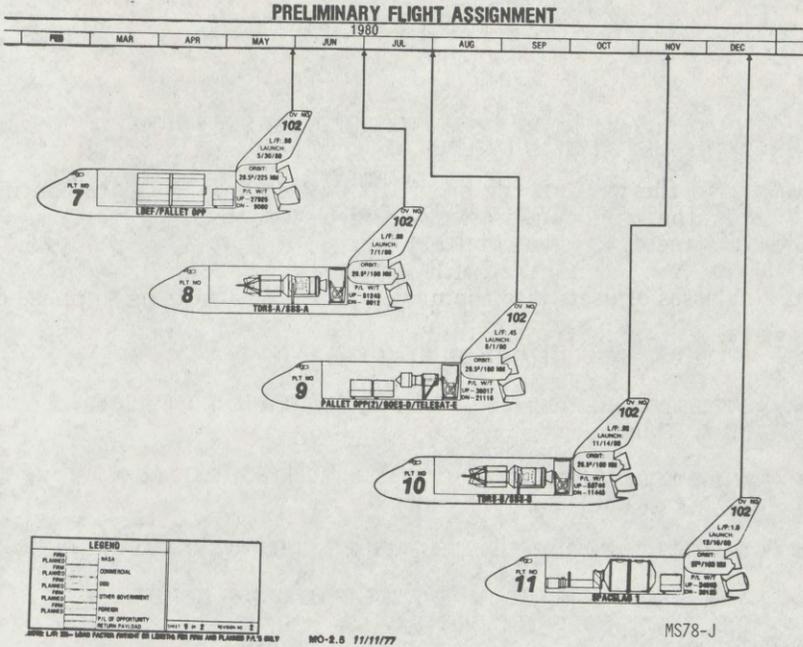
different payload costs if payloads are designed for Shuttle than if they are designed for expendable launch vehicles. This is so because payloads designed for Shuttle are expected to be retrievable and refurbishable; payloads designed for expendable launch vehicle would not be. Then the overall results show that four or five orbiters at two sites are the most cost-effective mix required to satisfy any level of this model.

PRELIMINARY FLIGHT ASSIGNMENTS

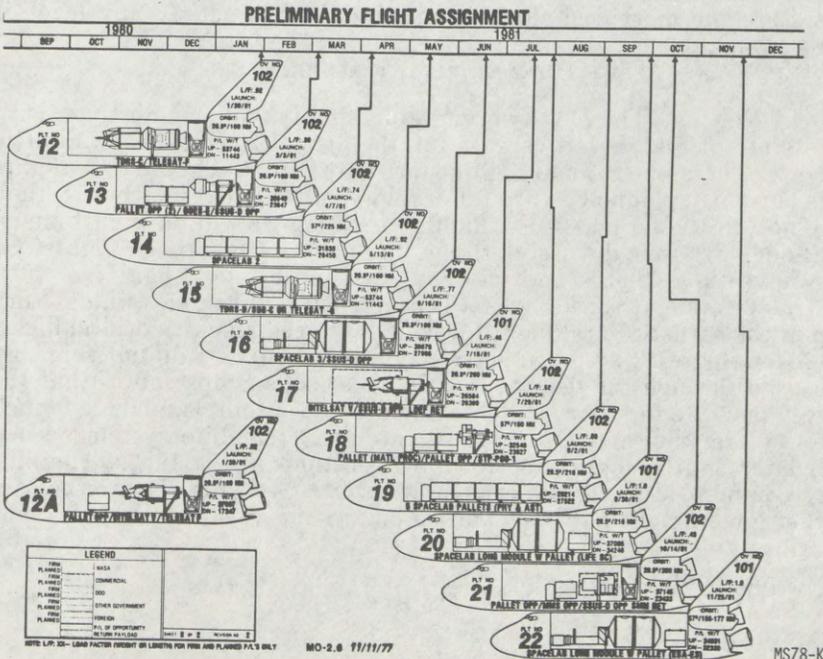
Dr. FROSCHE. The next two vignettes simply will acquaint you with the state of manifested cargoes for the first planned series of Shuttle flights. These operational flights start with No. 7. The first six flights are currently planned as orbital development flight tests, that is, they are not, in the normal sense, flights for which we will have customers, although we will do useful things in space during those flights. So we have those flights and we may reassign Orbital Flight No. 7 on this development schedule as a contingency flight in case things turn up in the earlier orbital flight for which we need an extra orbital flight.

After the test flights, we have paying customers. I do not think we need go through the details, but the color code simply notes that the green ones are for NASA; flights 8 and 10, for example, include launch of the Tracking and Data Relay Satellite, a satellite system needed for later Shuttle flights and for our operations in the 1980s. The blue are commercial payloads, orange are DOD payloads. Then there are other government payloads and so on. So the various colors describe various user classes.

(Chart follows:)



Dr. FROSCHE. The next chart simply continues through 1981, through the first 22 flights. The main point is that most, and effectively all of the assignment space is now booked up by a combination of NASA, DOD, commercial, and foreign users.
(Chart follows:)



CONCLUSIONS

Dr. FROSCHE. The final vugraph is presented simply to state our conclusions. We are moving into a new era with a new system of space transportation, which will give us relatively easy and economical access to putting things into space: it is a key system, we are viewing it as a national resource necessary for the U.S. continuation of its prime position in the world space program. We require with it to continue some of the applications work which we think is very important in terms of environment and earth sensing and communications.

A four or five orbiter fleet with two sites promotes an early transition for all classes of users into the new system. It permits us to phase out expendable launch vehicles and it is more cost-effective than any of the Shuttle expendable launch vehicles mixes that we have looked at for the whole range of possible mission models.

We believe it remains the most cost-effective system for projected payload traffic requirements, well below requirements that we think are minimal in terms of the plans for the future national space effort.

Thank you, Mr. Chairman.

CONCLUSIONS

- STS IS THE KEY ESSENTIAL ELEMENT WHICH ESTABLISHES THE FUTURE SPACE CAPABILITY OF THE NATION AND GREATLY ENHANCES EXPLOITATION OF SPACE
 - EXPLOITATION OF NEW AND UNIQUE SHUTTLE CAPABILITIES TO SIGNIFICANTLY IMPROVE AND EXPAND MILITARY AND CIVIL SPACE ACTIVITIES
 - NATIONAL STRENGTH AND PRESTIGE THROUGH CONTINUED PREMINENCE IN MANNED SPACE FLIGHT AND WORLD LEADERSHIP IN SPACE TECHNOLOGY
 - GREATER DIRECT BENEFITS AND SPIN-OFFS TO IMPROVE THE WAY-OF-LIFE FOR MANKIND
 - ROUTINE, LOW COST SPACE OPERATIONS
- FOUR OR FIVE ORBITER FLEET/2 SITE OPERATIONS
 - PROMOTES EARLY TRANSITION FOR ALL CLASSES OF USERS
 - PERMITS PHASE-OUT OF EXPENDABLE LAUNCH VEHICLES
 - MORE COST EFFECTIVE THAN ANY SHUTTLE/ELV MIX
- FOUR OR FIVE ORBITER/2 SITE OPERATION REMAINS THE MOST COST EFFECTIVE FOR PAYLOAD TRAFFIC REQUIREMENTS WELL BELOW THAT WHICH MIGHT BE EXPECTED FOR A MINIMUM NATIONAL SPACE EFFORT

MS78-L

STATEMENT OF UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

Mr. BOLAND. We will hear from Secretary Perry, Under Secretary of Defense for Research and Engineering.

Secretary Perry.

Dr. PERRY. Thank you, Mr. Chairman.

I am responsible to the Secretary of Defense for the Defense Department's portion of the Shuttle program.

With your permission I will submit my biographical statement and my statement on the Shuttle program for the record, and at this time I will only highlight some of the key points.

Mr. BOLAND. Fine.

DR. WILLIAM J. PERRY, UNDER SECRETARY OF DEFENSE FOR RESEARCH AND ENGINEERING

Dr. William James Perry was nominated by President Jimmy Carter to be Under Secretary of Defense for Research and Engineering on October 21, 1977. He was confirmed by the United States Senate on November 2, and was sworn in on November 4, 1977.

Dr. Perry had served as Director of Defense Research and Engineering since April 1977. That position was redesignated as Under Secretary of Defense for Research and Engineering on October 21, 1977, and Dr. Perry was nominated to fill the newly created position.

As Under Secretary he is the principal advisor and assistant to the Secretary of Defense for Department of Defense scientific and technical matters; basic and applied research; development and acquisition of weapon systems; communications; command and control; atomic energy; and intelligence resources. He serves as the focal point for all test and evaluation matters. He has also been designated the Defense Acquisition Executive. As such, he is responsible for effectively integrating the acquisition of defense systems and equipment within the Department of Defense.

Dr. Perry is one of the founders of ESL, Incorporated, Sunnyvale, Ca., and was serving as President of ESL when nominated on March 11, 1977, to direct Defense Research and Engineering. Besides his management duties, he engaged in analysis of missile systems and the design of electronic reconnaissance systems. His technical specialties include partial differential equations, propagation theory, and statistical decision theory.

Dr. Perry has served on scientific advisory committees for the Department of Defense and the National Security Council. He advised the Government on national security issues beginning with a panel to study the missile gap issue in 1960, and including an analysis of verification problems in Strategic Arms Limitation Talks.

He received the United States Army's Outstanding Civilian Service Medal for "the development of systems for the collection of vitally important intelligence through the use of advanced electronics." He also was awarded the Defense Intelligence Agency's Exceptional Civilian Service Medal for his service as a charter member of the Defense Intelligence Agency's Scientific Advisory Committee.

Prior to establishing ESL, Inc. in January 1964, Dr. Perry spent 10 years with Sylvania Electric Products, Inc., Mountain View, Ca., where he was Director of the Electronic Defense Laboratories. He was mathematics instructor at Pennsylvania State University and a part-time lecturer in mathematics at the University of Santa Clara.

Dr. Perry received his Bachelor of Science and Master of Science degrees in mathematics from Stanford University in 1949 and 1950, respectively, and his Doctor of Philosophy degree in mathematics from Pennsylvania State University in 1957. He has written many classified reports in the field of signal analysis and advanced systems design, and several unclassified papers in mathematics analysis. He is a member of the Scientific Research Society of America, the American Mathematical Society, and the National Academy of Engineering.

He was born at Vandergrift, Pa., October 11, 1927. He and his wife, the former Leonilla Mary Green, have five children.

Statement by
Dr. William J. Perry
Under Secretary of Defense for Research and Engineering
Department of Defense
Before the House Appropriations Subcommittees
on Defense, Military Construction, and Housing and
Urban Development and Independent Agencies,
in Joint Hearing on March 9, 1978

Mr. Chairman and members of the Subcommittees on Defense, Military Construction, and Housing and Urban Development and Independent Agencies. I am pleased to be a principal witness for the Department of Defense before your three subcommittees. I believe a joint hearing such as this is unique, and attests to the importance of the Space Shuttle to the technological future of this nation. MGen Coy is with me representing the United States Air Force. The Air Force has been designated within DoD as the lead agency responsible for DoD Shuttle use. MGen Coy will brief you on our major acquisition activities in preparation for the Shuttle era. I believe it is important that Defense and NASA provide you a total, coordinated view of Shuttle activity. The total appropriations being requested in FY 1979 are large. The DoD request totals \$423.9 million.

The DoD has strongly supported the NASA Space Shuttle development program from its inception. We participated in the Presidential Space Task Group in 1969 which recommended that the nation should develop a means of space transportation that would make space more accessible. By early 1972 when the President authorized NASA to proceed with the Space Shuttle, the Air Force already had a group of planners dedicated to seeking ways to use the Shuttle to achieve improved military space operations. Initially, our annual funding commitment to Shuttle use amounted to about four million dollars per year. In this planning process we became convinced that the Shuttle could lead to more effective and flexible military space operations.

During the period when the Shuttle design was evolving, we provided NASA our spacecraft requirements. We maintained then and continue to maintain now extremely close coordination with NASA. Effective coordination on the Shuttle program is maintained through the Aeronautics and Astronautics Coordinating Board which is co-chaired by Dr. Lovelace, Deputy Administrator, NASA, and myself. Through this Board, Dr. Lovelace and I are able to address major issues of interest to both agencies and to provide broad policy guidance within our respective agencies. The Space Transportation System (STS) Committee provides a means for detailed top management coordination on the Shuttle. The STS Committee is co-chaired by the Air Force Assistant Secretary for Research, Development and Logistics and the NASA Associate Administrator for Space Transportation Systems. Also, we have strong day to day field level coordination and joint activity on the Shuttle; and, in addition, Air Force officers have been detailed to NASA to assist NASA in specific areas of Shuttle development.

As a result of this careful coordination over an extended period, our requirements have been made known to NASA and carefully considered in the Shuttle design. The Space Shuttle orbiter is sized for DoD missions and can meet all of our launch requirements for the foreseeable future. We expect the Shuttle to be an integral part of our future military space operations.

DoD space systems are all extremely important to our military forces and some enjoy the highest national priority. These systems provide support to our operational forces in areas such as navigation, communications, ballistic missile early warning, surveillance and weather forecasting. These space systems evolved because they offered a unique capability, such as denied area surveillance, or a lower cost approach to achieving a desired capability, such as worldwide high data rate communications. We are continuing to improve our current space systems and to introduce new systems where they offer new capabilities or make our

operations in space more effective. The Space Shuttle itself promises both new capabilities and the opportunity to make our space systems more effective.

We are now fully committed to using the Shuttle, exploiting its new capabilities, and - once the manned, reusable Shuttle is fully operational - to phasing out our current expendable launch vehicles. Present plans are to transition all DoD space system payloads from launch on current expendable space boosters to Shuttle launch after the Shuttle becomes operational in 1980. The Air Force is developing an Inertial (formerly Interim) Upper Stage (IUS) which will be operational by mid-1980 for use on both the Shuttle and the TITAN III booster during the transition period. The Air Force is also developing the Shuttle launch and landing capability at Vandenberg AFB (VAFB), which will be operational in June 1983. We are also making extensive preparations for launching our payloads from Kennedy Space Center (KSC) using the Shuttle. Through FY 1978 we will have spent \$257.5 million in support of our activities leading to DoD Shuttle utilization. In FY 1979 we are requesting \$423.9 million, and through FY 1983 we estimate that our total investment will be \$1,543.3 million. The \$423.9 million in FY 1979 will be applied as follows: IUS development - \$124.8 million; Vandenberg Shuttle facilities - \$252.3 million; and, all other DoD preparations for Shuttle use including KSC launches - \$46.8 million. The \$423.9 million is made up of \$169.5 million RDT&E, \$108.8 million Procurement, and \$145.6 million Military Construction funding.

I would now like to present the reasons for DoD interest in the Shuttle and then highlight our current program for Shuttle use emphasizing those areas which I believe will be of special interest to your Subcommittees.

As I said before, the Space Shuttle can support the launch of all projected DoD space systems in the foreseeable future. The Shuttle provides significant new capabilities which can lead to more effective and flexible military space operations. The Shuttle can deliver significantly more payload weight and payload volume to orbit than the largest of our current boosters. We can use this increased capability to incorporate redundancy in critical subsystems, thereby improving the life of our spacecraft in orbit. We can also improve the capability of our spacecraft by prudently adding sensors and communications links. We can improve the survivability of our space systems, in a natural or hostile space environment, by selecting from a number of Shuttle-related options. These survivability options include placing spare spacecraft in orbit, carrying additional on-board propellants for spacecraft maneuvering, or perhaps placing in orbit more spacecraft of a simpler, lower cost design. The Shuttle capabilities offer the opportunity to achieve greater spacecraft modularization and standardization of subsystems while avoiding costly weight reduction programs. The reliability of placing a satellite in its desired orbit projected for the Shuttle/IUS (.97) is higher than the average we are experiencing today on our current expendable boosters (.93). We anticipate that the Shuttle can be used routinely as a development test bed for various sensors and subsystems thereby reducing the development time for new space systems and enhancing our capability to respond rapidly to changing needs.

Initially, we will use the Shuttle in the same way as we would a larger expendable launch vehicle. However, should the Shuttle arrive on orbit with a payload that did not check out properly, most payloads could be returned to earth for adjustment or modification. In the future, we can design our payloads so that the Shuttle can retrieve them from low orbit when the mission is complete, and return them to earth for refurbishment and reuse, diagnostic purposes, or technological update. Another option which might be equally attractive in the Shuttle era is on-orbit servicing of payloads. Spacecraft designed for automated subsystem replacement could be serviced while in low orbit depending on mission requirements. In the long term, the Shuttle will open the way for many new technical advances in the military use of space.

The Department of Defense Space Mission Model for the period FY 1977-1991 reflects 195 launches, 109 of which are projected Shuttle launches. Initial DoD use of the Shuttle is planned for an experimental payload (TEAL RUBY) within the

first year of Shuttle operation. Launch of DoD operational payloads begins in FY 1982, and by the mid-1980s all DoD payloads will have transitioned from launch on current expendable boosters to Shuttle launch. During FY 1979, the Defense Support Program, Satellite Data System, Defense Meteorological Satellite Program, and Global Positioning System spacecraft will undergo design modifications and begin necessary developmental tests to assure spacecraft compatibility with the Shuttle payload bay environment. The new Defense Satellite Communications System III spacecraft is being designed from the outset for Shuttle launch.

Since DoD plans to make extensive use of the Shuttle, the timely availability of an adequate national fleet of orbiters to support military as well as civil users of the Shuttle has been a matter of serious concern to us. The fleet size must be based on total traffic - foreign and domestic, civil and military - projected for the Shuttle. Extensive studies conducted by NASA, with Air Force support, plus detailed reviews within the Administration have led to the decision that NASA should proceed with the production of a four orbiter fleet. Additional orbiters can be considered for funding in future years in the event that projected flight rates (or loss of an orbiter) warrant augmentation of the operational fleet. We plan to work closely with NASA over the coming year to develop a practical, acceptable plan to assure that a capability will exist to produce an additional orbiter in a reasonable period of time when that decision is made. The high priority of critical DoD missions is well recognized, and orbiter scheduling should not be a problem for DoD. We believe that the four orbiter fleet will be adequate during the early years of Shuttle operation.

This is an appropriate point to discuss our plans for backup launch vehicles. We will procure a minimum number of TITAN III vehicles so that we can launch our higher priority payloads if the Shuttle is delayed, or experiences difficulties during the early operational period. This backup inventory will consist of three complete TITAN III vehicles, four partially assembled vehicles, and four complete sets of parts. We feel that this backup inventory should be adequate even with a four orbiter fleet so long as we retain the capability to produce an additional orbiter.

We are providing a Shuttle launch and landing capability at Vandenberg AFB (VAFB) so that we can continue to support high inclination DoD launches. The spacecraft which we will launch on the Shuttle from VAFB include our heaviest spacecraft which support missions of highest national priority. These spacecraft flown on the Shuttle will be improved versions of operational spacecraft now being launched from VAFB. Launches into high inclination orbits (sun synchronous, polar, near polar) cannot be achieved from Kennedy Space Center (KSC) without unacceptable overflight of populated land areas during launch, potential international problems, and unacceptable performance loss.

On a northerly launch from KSC to polar orbit the Shuttle would overfly the eastern U.S. and Canada. This would routinely entail possible casualty expectations (risk to life and property) greater than now considered prudent. I feel sure that the Shuttle will become the most reliable rocket powered vehicle we have ever developed, however, it is not possible to determine how long it will take this vehicle, with its new technology, to mature and demonstrate this very high reliability. We are certainly not at the point now where we can ignore casualty expectations and commit ourselves to routine overflight of densely populated areas during Shuttle launch. We should remember that we had three launch failures of conventional vehicles in 26 attempts last year. While the mature Shuttle can be expected to have a near perfect launch record, it will be some time before we demonstrate that kind of reliability.

Even if we neglect such safety considerations there are other problems. We cannot ignore the fact that northerly high inclination Shuttle launches which pass over the Soviet Union, even with prior notification, will be disconcerting and perhaps objectionable to the Soviets. No matter how sophisticated the Soviet radars, the similarity of such northerly Shuttle launches to potential U.S. ICBM launches can lead to adverse Soviet reactions, if done routinely. Under worst case conditions, such as Shuttle breakup during ascent, a severe Soviet response

cannot be discounted. I do not believe that we should pursue a course that could lead to such problems.

Further, these northerly trajectories from KSC result in severe degradation of Shuttle payload delivery capability. The Shuttle could be launched so as to fly off the east coast of Florida. This way, the sonic boom on launch would not impinge over populated areas and the two large solid rocket motors would drop into deep water for recovery and subsequent reuse. Then the Shuttle could be turned inland to achieve the desired inclination. This maneuver results in performance losses. For example, according to NASA, a fully capable Shuttle could deliver only about 22,000 lbs to a 98° inclination, 150 nm orbit using this trajectory. We are aware that it may be possible to increase Shuttle performance by several hundred pounds on certain flights without significant risk by off-loading some items from the standard Shuttle flight manifest. If the Shuttle is configured to deliver a payload but not retrieve a depleted satellite on the same flight, performance may be increased to perhaps 25,000 lbs. However, from these Shuttle performance figures we must deduct the weight of a cradle to properly support our payload. The resulting Shuttle performance from KSC is less than that of current boosters - 24,300 lbs to 98° inclination, 150 nm - from VAFB, and is totally unacceptable for the mid 1980 period.

In summary, safety, international, and performance considerations lead us to conclude that KSC polar launches are not acceptable and that we must have Shuttle launch and landing facilities at VAFB.

The Inertial (formerly Interim) Upper Stage (IUS), which is being developed so that DoD spacecraft can be delivered to the required orbital altitude and inclination using the Shuttle from Kennedy Space Center, is now in validation phase and will enter full scale development in March 1978. The IUS will be available in mid-1980 and will be used on both the Shuttle and the TITAN III launch vehicle. Using the IUS on TITAN III will greatly enhance mission success and reduce costs during the early transition period when a number of our spacecraft will still require TITAN III launches.

For launches from Kennedy Space Center, payload ground processing and flight control procedures are being defined. Work will continue in FY 1979 on development of payload interface documentation, and definition of common support hardware, and required security provisions. In addition, we will initiate procurement of a minimum number of TITAN III vehicles as a backup for launching priority DoD payloads should the Shuttle encounter difficulties during the early operational period.

Present DoD planning for Shuttle launch is predicated on the use of NASA's Johnson Mission Control Center (JMCC) for simulation, training, and Shuttle flight control for all DoD missions. However, as currently designed, JMCC cannot concurrently handle classified and unclassified payload data. A number of options for accommodating classified DoD launches in the JMCC have been evaluated over the past year by both DoD and NASA. Recently we have tentatively agreed with NASA on a low cost approach to modifying JMCC which should adequately protect classified payload launches on the Shuttle with minimum disruption to civil users. We expect to complete the validation of this approach, which we call the "controlled mode" concept, and assuming that our validation is successful, proceed in FY 1979 with necessary modifications to JMCC.

In FY 1979 we will procure some IUS ground support and logistics support equipment. We will also procure unique ground support equipment for Vandenberg AFB, and continue coprocurements with NASA of common Shuttle ground support and launch processing equipment. The construction of Vandenberg AFB Shuttle facilities is planned to begin in April 1979. Our FY 1979 Vandenberg AFB construction program includes the Shuttle landing field, mate/demate facility, launch pad area, and the launch control center. We are also modifying our Solid Motor Assembly Building for IUS processing at Kennedy Space Center.

In summary, I would like to emphasize that DoD is fully committed to use the Shuttle to launch all of its space systems once the Shuttle is fully operational.

These space systems are most important since they support our military forces worldwide. Some of our spacecraft are of highest national priority. We believe that the DoD Shuttle launch projections are realistic - perhaps even conservative. The four orbiter fleet with a standby capability to produce another orbiter when required is essential. FY 1979 is a critical year in our program for Shuttle use. It is a peak funding year in the IUS development, and it is the year we start construction of the VAFB Shuttle launch and landing facilities. I ask that you fully support our request for FY 1979 funding.

SUMMARY STATEMENT OF THE UNDER SECRETARY OF DEFENSE FOR
RESEARCH AND ENGINEERING

Dr. PERRY. It is very appropriate, I believe, that you are holding this joint hearing. It symbolizes I think the excellent cooperation which the Department of Defense and NASA have had in this program, and I am very happy to be here as part of a joint testimony.

Our cooperation with NASA has been quite close. We have established through the years two different committees, the Aeronautics and Astronautics Coordinating Board, which coordinates the general programs between DOD and NASA, and more specifically, the Air Force-NASA Space Transportation System Committee.

I would like to make a personal comment about these committees: It is one thing to say that the committees exist, and it is another to question how effective they are.

I would like to give you a personal statement that these are vital active working committees, they are quite effective. We meet together, we put the problems on the table, and we hammer out the details for an effective solution.

In particular, in the early years on the Shuttle program, we did hammer out solutions and worked our a joint program which is turning out to be quite effective. One aspect of that was the agreement as to what role the Defense Department would play in the development of this system.

As a consequence, we are developing what Dr. Frosch referred to as the Inertial Upper Stage, a major element which is carried by the Shuttle.

We are also developing the facilities at the Vandenberg Air Force Base.

These two developments, the Inertial Upper Stage and Vandenberg facilities will be available to all users of the Shuttle, not just the Defense Department.

As indicated in Dr. Frosch's charts, Defense is only a minority user, in fact, of the Vandenberg facility as the plan is presently projected. We anticipate by the time these developments achieve an operational capability that Defense will have invested approximately \$1.5 billion in the program, roughly \$300 million of that for the development of the Inertial Upper Stage; roughly \$900 million for Vandenberg Air Force Base, and another \$300 million for development of an operations capability.

We have, therefore, a very strong commitment to the Shuttle program. We intend to place our first experimental payload on the Shuttle in the first year of the Shuttle operation, which would be early in 1981.

We intend to put our first operational system on board in 1982, by 1985 we will have made a complete conversion of our space systems to the Shuttle.

So there will be a period between 1982 and 1985 which would be a transition. During that time some of our space programs are going to be launched by the Shuttle, some of them will be launched by expendable launch vehicles. Therefore, we are proposing to procure not only the expendable launch vehicles necessary to accommodate some of our payloads during this transition period, but we have also

made provisions for a number of additional expendable launch vehicles for contingency purposes.

You have raised the question as to what should be the appropriate number of orbiters. That will depend to a very great extent on an analysis of the mission model, which was presented by NASA. I cannot testify on all aspects of that model, but I can give you an authoritative statement on DOD contribution to the model.

We have stated our requirements in what I believe is a very conservative way for Shuttle use between the beginning of the Shuttle program and 1991, the period over which the model extends. We have stated a requirement for an average of 12 flights per year and a peak of 14.

I would like to contrast that with the history in the last decade in which we have been launching on the average of 14 a year. So we are not projecting a significant increase in our program; we are rather projecting approximately the history that we have had in this program.

If there is an error in our estimating, and it is certain that they are estimates and they are not perfect, my judgment is that we are probably on the low side in the data we provided to NASA for this model.

A fundamental point from the Defense Department's point of view is that during the last decade we have made a very significant commitment to space; we have been gradually transferring important missions in defense to space systems, and during the next decade we plan to continue that.

As a consequence, we have a major dependence today in the fields of communications systems, navigation systems, weather systems, surveillance systems, and ballistic missile warning systems. More and more the capability in Defense to perform these functions is dependent on space.

We are making that conversion because of the capabilities of the space systems to provide these missions in a more cost-effective manner. Nevertheless, I will point out to you that because we could not afford to provide both space systems and nonspace systems, we have been making the transition. Therefore, we are arriving at a place where we are totally dependent on space to perform critical defense missions.

Therefore, as we go into the Shuttle program, that dependence is going to increase toward the Shuttle. By the mid-1980's, the performance of these missions in Defense will rest on the Shuttle system, completely.

Therefore, when you are considering the number of orbiters needed, when you are considering the validity of the models being presented, I wish you would take into account the very significant dependence which the Defense Department will have on the Shuttle program from about the mid-80s forward.

Another issue that you raised was on the use of the Vandenberg Air Force Base as a second launch facility for the Shuttle program.

Most of the programs which we have projected to be launched from Vandenberg are programs which are not only our highest priority in Defense, but I would assert are the highest national priority, and I believe they will continue to enjoy highest national priority during the Eighties and the Nineties.

The launch of these systems from Kennedy is not an acceptable solution from the Defense Department point of view. Quite aside from the range safety considerations which Dr. Frosch mentioned, and quite aside from the potential risk of confusing the Soviet missile warning radars, it is simply a fact that the performance of the Shuttle will not be adequate to deliver these systems to the orbit which is required; that is, a Shuttle launch of these systems from Kennedy will not deliver our present systems, much less then, our future systems to the required orbit.

Therefore, if we have only a Kennedy launch facility, it will be necessary, from the Defense Department's point of view, to continue to maintain expendable launch vehicles that can launch these systems from Vandenberg for the indefinite future. Moreover, it will be necessary to develop new expendable launch vehicles during the Eighties in order to accommodate the new systems which will be coming into the inventory at that time. So any assessment of the cost of installing the Vandenberg facility will have to also take into account the offsetting costs of maintaining expendable launch vehicles if we do not build the Vandenberg shuttle facility.

In the administration of this program within Defense, the United States Air Force has the role of lead agency. It is responsible for the development of the Inertial Upper Stage, for the development of the Vandenberg Air Force Base and for making the conversion of our payload systems as necessary for Shuttle use.

I would like at this time to introduce Major General Coy, who is the Director of Space, Headquarters United States Air Force, to describe what we are doing in this program.

SUMMARY STATEMENT OF DIRECTOR OF SPACE SYSTEMS, HQS. USAF

General Coy. Mr. Chairman, with your permission I will submit my biographical sketch also, and I would like to proceed in front of the screen to brief from that position.

[Biographical sketch follows:]

MAJOR GENERAL EDWIN A. COY

Major General Edwin A. Coy is Director of Space in the Office of the Deputy Chief of Staff, Research and Development, Headquarters U.S. Air Force, Washington, D.C. The Directorate of Space is responsible for Air Force space research and systems development activities and support of the space activities of other Government agencies.

General Coy was born in McKeesport, Pennsylvania, on December 26, 1927. After high school graduation he enlisted in the U.S. Army and served in the Ordnance Corps until August 1947. He received a bachelor of science degree in chemical engineering from the University of Pittsburgh in 1950; holds master of science degrees in both engineering management and business administration from the Air Force Institute of Technology; and is a graduate of the Air Command and Staff College and the Air War College.

As a distinguished military graduate of the Reserve Officers Training Corps program, General Coy received a Regular commission in 1950. Upon completing the Armament Officer's Course at Lowry Air Force Base, Colorado, he was assigned to the 136th Fighter-Bomber Wing being deployed to Japan and Korea. He served for 13 months in the Korean War with the 136th and 8th Fighter-Bomber Wings. From June 1952 to January 1954 General Coy was a project officer at the Air Force Armament Center, Elgin Air Force Base, Florida, testing chemical warfare munitions.

After completing graduate school at the U.S. Air Force Institute of Technology in August 1955, he was assigned to the Office, Chief of Ordnance, Pentagon, where

he provided technical direction on several Air Force-funded rocket and missile development programs.

In August 1957, General Coy joined the Western Development Division, Inglewood, California, where he served as a member of the pioneer teams that developed and deployed the Thor and Minutemen I weapon systems.

Graduating from the Air Command and Staff College in June 1963, General Coy was assigned to the Defense Atomic Support Agency, Sandia Base, New Mexico, where he was responsible for developing a family of multistage rockets, launchers, and blockhouse equipment to support the National Nuclear Readiness-to-Test Program.

After graduation from the Air War College in June 1967, General Coy was assigned to the Directorate of Operational Requirements and Development Plans, Headquarters U.S. Air Force. He served initially in the Aircraft Division and then became Chief of the Missile Division, where he was responsible for formulating and advocating improvements for the Minuteman and Titan intercontinental ballistic missile force.

Transferred to the Space and Missile Systems Organization at Los Angeles Air Force Station, California, in July 1971, General Coy served successively as System Program Director, Standard Launch Vehicle Program Office, and as Deputy for Launch Vehicles. He was appointed Deputy for Space Communications Systems in June 1973 with management responsibility for all satellite communications programs, including the Defense Satellite Communications System, the Air Force Satellite Communications System, the Navy's Fleet Communications System, and the NATO Phase III Program.

In September 1976 General Coy assumed his present position as Director of Space in the Office of the Deputy Chief of Staff for Research and Development at Headquarters U.S. Air Force.

He is a member of several professional, civic and fraternal organizations and is the author of papers on technical matters and international affairs.

His military decorations and awards include the Legion of Merit with one oak leaf cluster, Joint Service Commendation Medal, Air Force Commendation Medal with one oak leaf cluster, Air Force Organizational Excellence Ribbon, and the Master Missileman Badge.

General Coy was promoted to the grade of major general on February 1, 1977, with date of rank November 1, 1973.

He is married to the former Doris E. Jones of Raleigh, North Carolina. They have two daughters: Mrs. Rebecca Lynn Henry and Miss Roberta Ann Coy.

DoD

SPACE TRANSPORTATION SYSTEM DEVELOPMENT AND ACQUISITION

PE 63411F/12449F

General Coy. As Dr. Perry has already indicated, the DOD role in the National Space Transportation System Program is a dual role. First, as a limited partner, we are responsible for developing the Inertial Upper Stage and for activation of the Vandenberg Air Force Base facilities.

Also, as a partner with NASA, we are supporting the NASA Shuttle system acquisition activities. We are establishing our requirements, and we are investigating the use of the unique Shuttle capabilities, things we will be able to do in the future with the Shuttle that we cannot do at the present time with expendable launch vehicles.

DoD STS Development and Acquisition Responsibilities

- ESTABLISH DOD REQUIREMENTS
- SUPPORT THE NASA SHUTTLE SYSTEM ACQUISITION
- DEVELOP CAPABILITY FOR PAYLOAD TRANSITION
- DEVELOP THE INERTIAL UPPER STAGE
- PROVIDE VANDENBERG AFB FACILITIES
- INVESTIGATE DOD USE OF UNIQUE SHUTTLE CAPABILITIES

General Cox. The Inertial Upper Stage and the activation of Vandenberg are the major parts of our program. As part of the total system we are supported by a system program office at the Space and Missile Systems Organization in Los Angeles, and the Air Force Satellite Control Facility, specifically the Satellite Test Center at Sunnyvale, California. We will be using the NASA Johnson Space Center at Houston and are currently evaluating the accommodation of our classified payloads from that location with the cooperation of NASA.

The Kennedy Space Center will support our synchronous equatorial missions as well as 12-hour orbits.

The NASA Spaceflight Tracking and Data Network supports the overall activity, as does the NASA Tracking and Data Relay Satellite System. Shown here is a picture of one of our satellites.

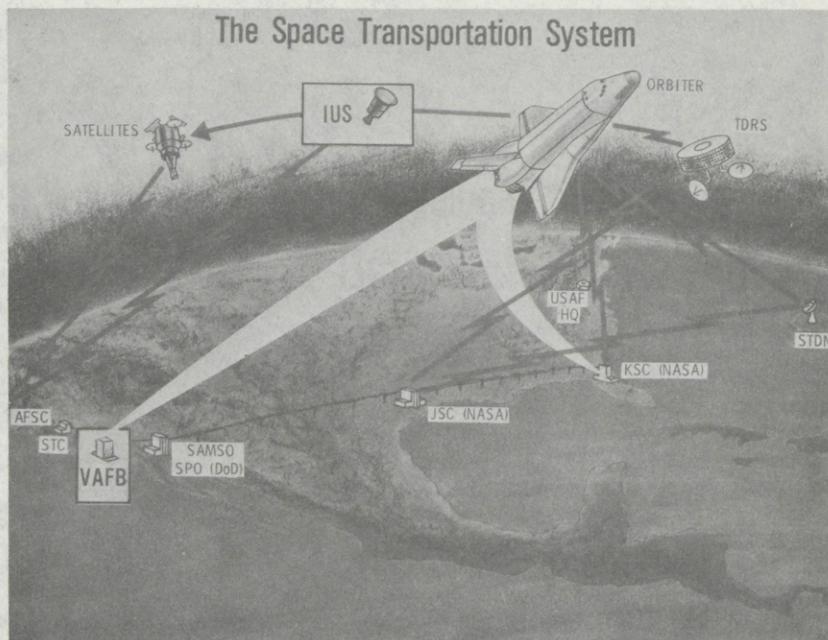
So it is a rather comprehensive system with many facilities involved.

General Cox. Shown here is our budget that we are requesting authorization and approval for in fiscal year 1979, a total of approximately \$424 million. I think it is important to note that our investment in the program within our Space Shuttle utilization program elements is better than a quarter of a billion dollars through the end of fiscal 1978.

So, as Dr. Perry has indicated, we have a significant investment already in the Shuttle program. We are projecting through the fiscal 1983 time period, which includes the IOC or initial operational capability at Vandenberg, a total of approximately \$1.5 billion.

General Cox. I would like to turn now to the Inertial Upper Stage activity. The Inertial Upper Stage will be used both with the Shuttle and with the TITAN III, (34D) in order to put payloads into synchronous orbits and 12-hour orbits.

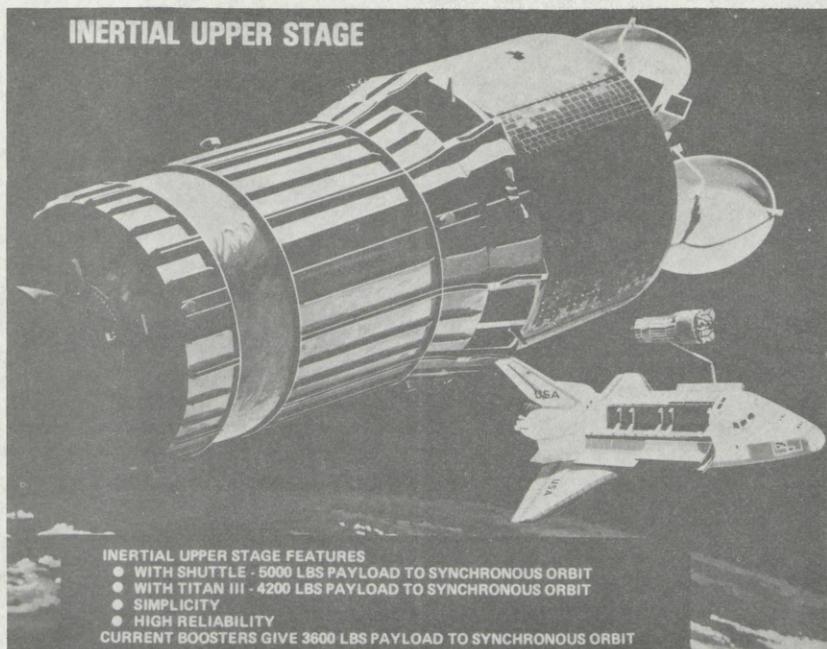
It is a solid propellant upper stage and in that sense it is much simpler than our liquid upper stages which we have used so much on



DoD Space Shuttle Utilization

APPROVED PROGRAM (THEN YEAR \$ MILLIONS)

	PRIOR YEARS	FY78	FY79	TOTAL THRU FY83
INERTIAL UPPER STAGE				
3600	30.6	67.5	87.6	260
3020	0	1.0	28.9	41
3300	0	0	8.3	8
SUBTOTAL	30.6	68.5	124.8	309
VANDBERG				
3600	31.2	24.3	39.9	338
3020	0	17.2	60.4	269
3080	0	8.2	15.2	44
3300	0	0	136.8	226
SUBTOTAL	31.2	49.7	252.3	877
OPERATIONS CAPABILITY DEVELOPMENT				
3600	45.0	32.5	42.0	318
3020	0	0	2.4	36
3080	0	0	1.9	2
3300	0	0	0.5	1
SUBTOTAL	45.0	32.5	46.8	357
TOTAL PROGRAM				
3600	106.8	124.3	169.5	916
3020	0	18.2	91.7	346
3080	0	8.2	17.1	46
3300	0	0	145.6	235
TOTAL	106.8	150.7	423.9	1543



our expendable launch vehicles. Because of the inherent simplicity of a solid motor stage and redundant avionics which we have on board, we project much higher reliability for this upper stage than we enjoy with our present upper stages.

General Cox. We have a total of 90 flights projected in the 1980-1991 time period for the DOD and NASA that will require the Inertial Upper Stage. This is approximately 18 percent of the total flight model. The Shuttle is limited to a near-earth circular orbits of 100-400 nautical miles, so it is necessary for us to have an upper stage that will permit us to take these payloads into the higher orbits that are required, such as the geosynchronous, 12-hour, and in interplanetary orbits.

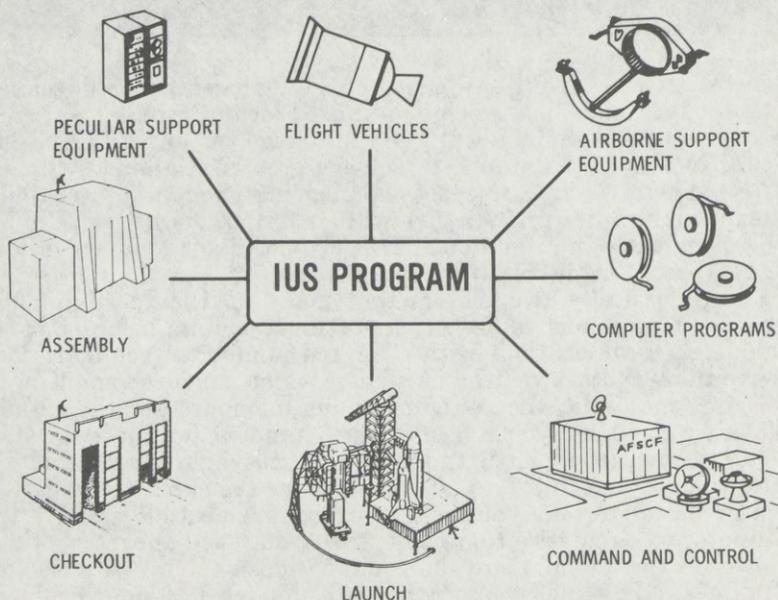
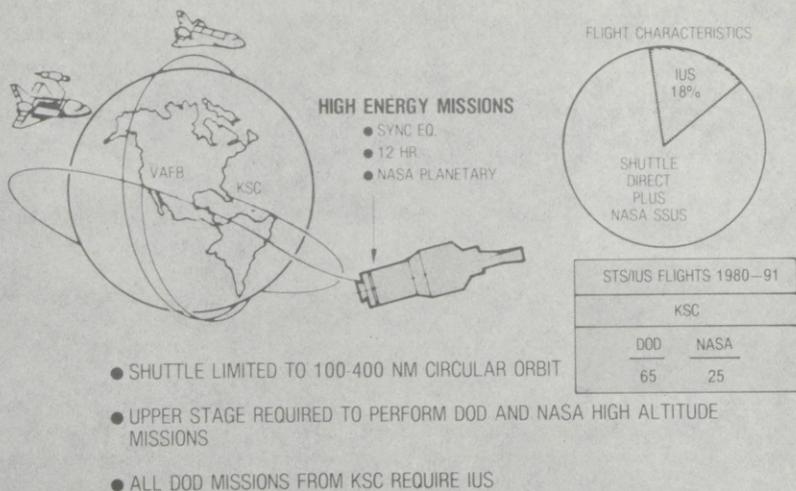
All the DOD missions from Kennedy Space Center require this Inertial Upper Stage.

General Cox. However, lest you think that it is a rather simple program, it is more than just development of the vehicle itself. It includes the development of the peculiar support equipment. It includes the modification of the east wing of the Solid Motor Assembly Building and modification of the Vertical Integration Building at Cape Canaveral for the check out of these IUS's. It includes some modification of the launch facilities and the Air Force Satellite Control Facility command and control capabilities as well as development of Computer programs and airborne support equipment such as cradles to actually hold the upper stage within the Shuttle.

General Cox. We have just completed our validation phase and are ready to proceed with full-scale development on the Inertial Upper Stage. We have had a significant amount of testing in the propulsion area including testing at Arnold Engineering Development Center where we have tested a motor in a simulated space environment.

The avionics and software have gone through a number of tests, and we have verified the feasibility of a redundancy management

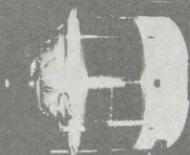
Need for Inertial Upper Stage



approach. We will have two computers on board the Inertial Upper Stage, and achieve enhanced reliability through redundancy. In addition, we have gone through a number of separation and acoustics tests and have defined the environments the operating components will see under thermal vacuum conditions. We are proceeding at the end of this month to a DSARC, Defense Systems Acquisition Review Council, meeting where we hope to obtain approval to proceed with full-scale development.

Validation Phase Major Accomplishments

PROPULSION



- AEDC LARGE MOTOR
 - CASE FABRICATION
 - PROPELLANT FORMULATION
 - NOZZLE FABRICATION
- SUCCESSFUL MOTOR OPERATION AT SIMULATED SPACE ENVIRONMENT

AVIONICS, SOFTWARE



- AVIONICS TEST ARTICLE
 - BRASS BOARD
 - REDUNDANT HARDWARE
 - PRELIMINARY SOFTWARE
- VERIFIED FEASIBILITY OF REDUNDANCY MANAGEMENT APPROACH

STRUCTURES, ENVIRONMENTS



- DEVELOPMENT TEST VEHICLE
 - SEPARATION
 - ACOUSTICS
- DEFINED ENVIRONMENT
 - THERMAL VACUUM
 - COMPONENTS OPERATING

General Coy. I might say that the IUS is not being developed strictly for the Shuttle. It is being optimized for the Shuttle, but we do plan on using the same Inertial Upper Stage on our TITAN 34D vehicles. In this way we hope to achieve greater reliability with the TITAN. Where we are presently experiencing about a 0.9 reliability with expendables, we project that will go to 0.97 with the IUS. We will be using the same common Inertial Upper Stage avionics in both the TITAN and in the Shuttle applications.

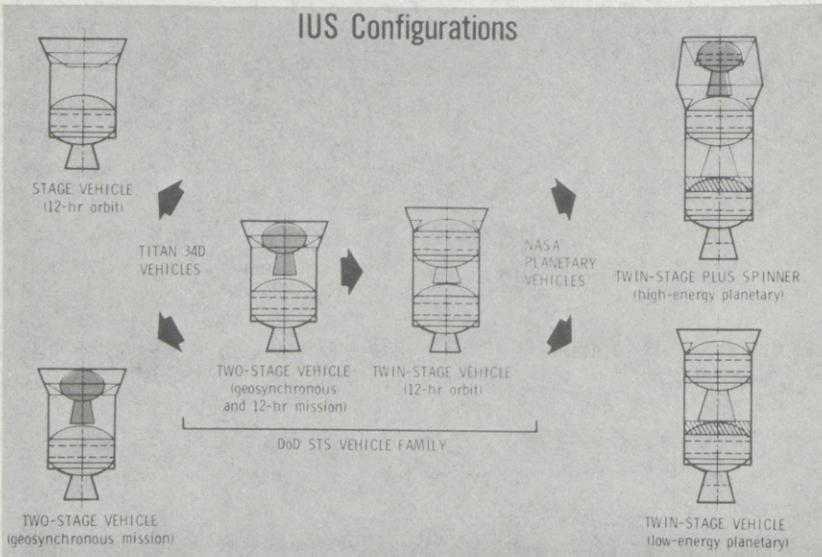
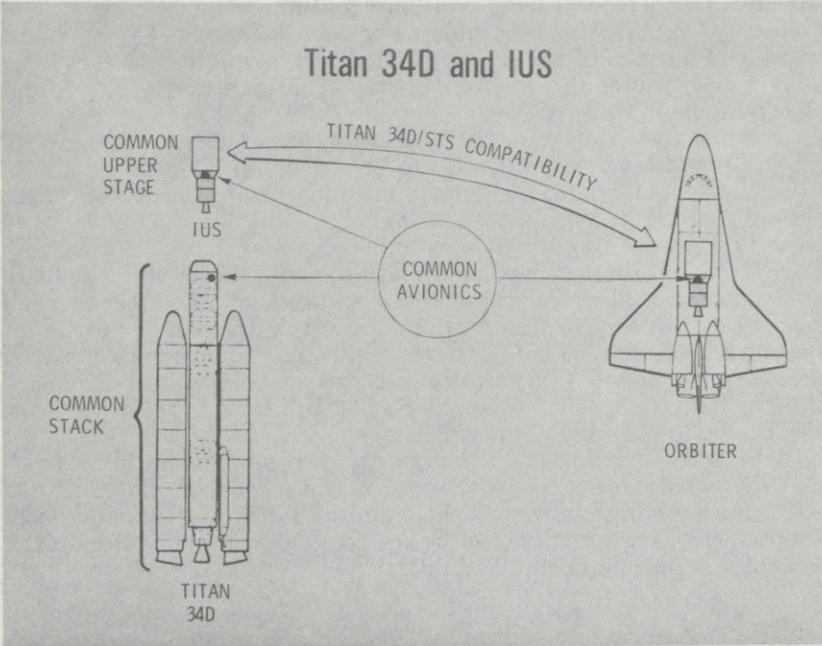
We have basically two motors that make up the Inertial Upper Stage. We use various combinations of those motors in order to accommodate all applications with a limited number of configurations. We have the two-stage vehicle shown here which includes a small motor and a large motor for the geosynchronous missions. For the 12-hour missions we use the two large motors in tandem for the twin stage vehicle. As mentioned, in the case of the geosynchronous orbit, the Shuttle will get you to 100 to 400 miles above the earth and you need this large motor to take you up to synchronous altitude and fire this small motor to circularize that orbit when you reach apogee.

Shown on the left here are the combinations that we will use with the TITAN 34D vehicles. With the 34D unit for a 12-hour orbit, we need only the one large stage since we can launch at a more favorable launch azimuth and don't have to make as much inclination correction as we do in Shuttle launched 12-hour orbit missions.

The NASA planetary missions will also require versions of the twin stage vehicle, and you notice we have a longer nozzle on these con-

figurations to get the higher velocity that is required for the high energy planetary missions as well as the low energy planetary missions.

In addition, we include a spinning third stage on the top for the most demanding NASA missions.



Mr. BOLAND. Will you suspend while we answer the roll call? We will have roll calls throughout the day. It is frustrating to us and I know it is to the witnesses who are here, but it is one of the penalties you have to pay when you come to the Hill.

We will recess for a few minutes.

Mr. BOLAND. General Coy, you may continue.

General COY. Sir, this is my last slide on the Inertial Upper Stage. It gives you an idea of the size of it. It is approximately 15 feet long, 7- $\frac{1}{2}$ feet in diameter and in the two-stage configuration weighs about 32,000 pounds or 16 tons.

As I mentioned, we are in the validation phase now proceeding toward full-scale development and are on schedule. The first flight of the Inertial Upper Stage is scheduled for mid-1980 to support a NASA Tracking and Data Relay Satellite launch.

I would like now to turn to Vandenberg.

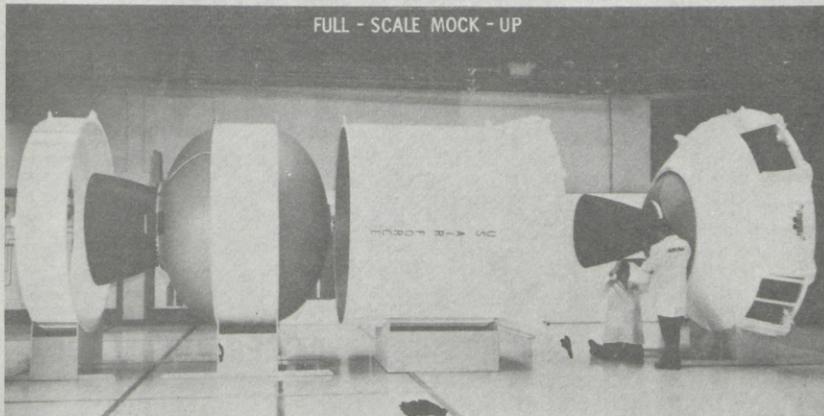
The DOD position regarding polar launches from the Kennedy Space Center is shown in these three statements. We believe such launches pose an unacceptable safety hazard to the major portion of the eastern half of the United States, as well as unacceptable risk of international incident, since anything launched polar out of Kennedy would be flying suborbital over the Soviet Union. It also provides an unacceptable loss in Shuttle performance.

I might add parenthetically that in my own view it would be progress in the wrong direction in that we would have less capability to launch in this mode than we presently possess today with expendables.

Vandenberg does provide the Space Transportation System with an acceptable polar launch capability.

Inertial Upper Stage

FULL - SCALE MOCK - UP



- PROGRAM STATUS
 - IN VALIDATION PHASE NOW
 - ON SCHEDULE
- FIRST FLIGHT SCHEDULED FOR MID - 1980 CONCURRENT WITH NASA SHUTTLE OPERATIONAL STATUS



Need for STS at VAFB

● POLAR LAUNCHES FROM KENNEDY SPACE CENTER RESULT IN

- UNACCEPTABLE SAFETY HAZARD
- UNACCEPTABLE RISK OF INTERNATIONAL INCIDENT
- UNACCEPTABLE SHUTTLE PERFORMANCE LOSS

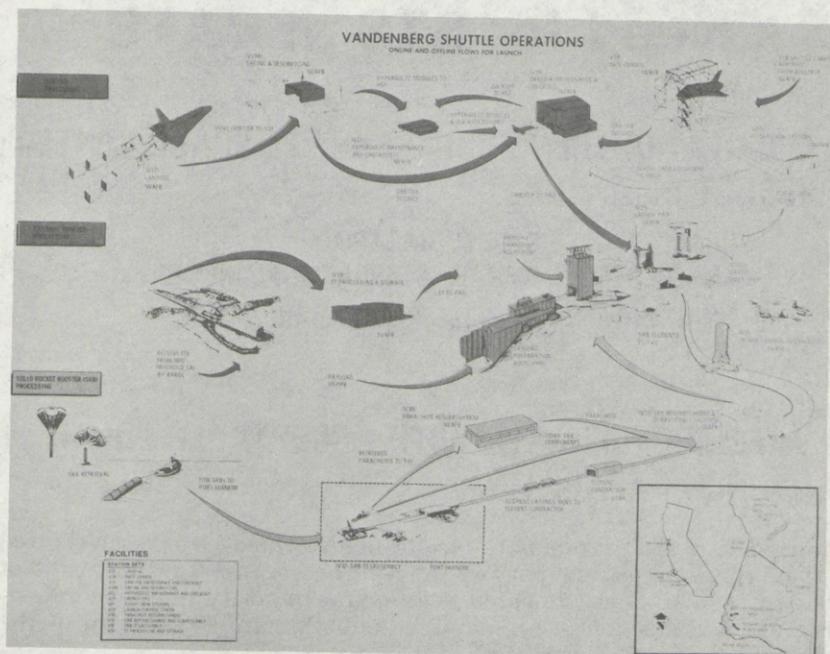
● VAFB PROVIDES STS WITH ACCEPTABLE POLAR LAUNCH CAPABILITY

Shown here is a portion of the traffic model which Dr. Frosch showed earlier, the Vandenberg portion. As you can see, the Department of Defense, as had been indicated before, is a minority user of Vandenberg but a rather key user. We have approximately one third of the total launches at Vandenberg.

VAFB STS Traffic Model

	FISCAL YEARS										TOTAL
	83	84	85	86	87	88	89	90	91	92	
NASA	1	4	6	5	5	6	4	6	6	1	44
U.S. GOVERNMENT	1	1	1	2	2	4	2	4	2	1	20
U.S. COMMERCIAL	—	—	—	1	1	—	—	—	1	—	3
FOREIGN	—	—	—	2	3	1	2	1	1	1	11
DOD	2	4	5	4	6	6	6	4	6	1	44
SUBTOTAL	4	9	12	14	17	17	14	15	16	4	122
REFLIGHTS	—	—	1	1	1	1	1	1	1	—	7
TOTAL	4	9	13	15	18	18	15	16	17	4	129

I won't bother going through this chart other than to say that we have a number of facilities at Vandenberg to support orbiter processing whether the orbiter actually lands at Vandenberg or whether it comes in on the back of the 747, external tank processing, payload processing, solid rocket booster processing, and launch of the Shuttle.



Shown here in orange are the facilities that represent new construction. We are trying to minimize the amount of construction required at Vandenberg and make use of existing facilities, but we will need new facilities for orbiter maintenance, hypergolic pod maintenance, external tank storage and checkout, safing and deservicing, and mate/demate operations.

Shown with the asterisks on them, the airfield, the mate/demate facility, the launch area, which is SLC-6 or Space Launch Complex 6, and the Launch Control Center, are those parts of the Vandenberg complex for which we are requesting money in our FY 79 Military Construction program.

I would like now to briefly show you what is involved in the '79 MCP. We plan to extend the runway to 15,000-foot length with 200-foot width.

Mr. EDWARDS. What is the length now?

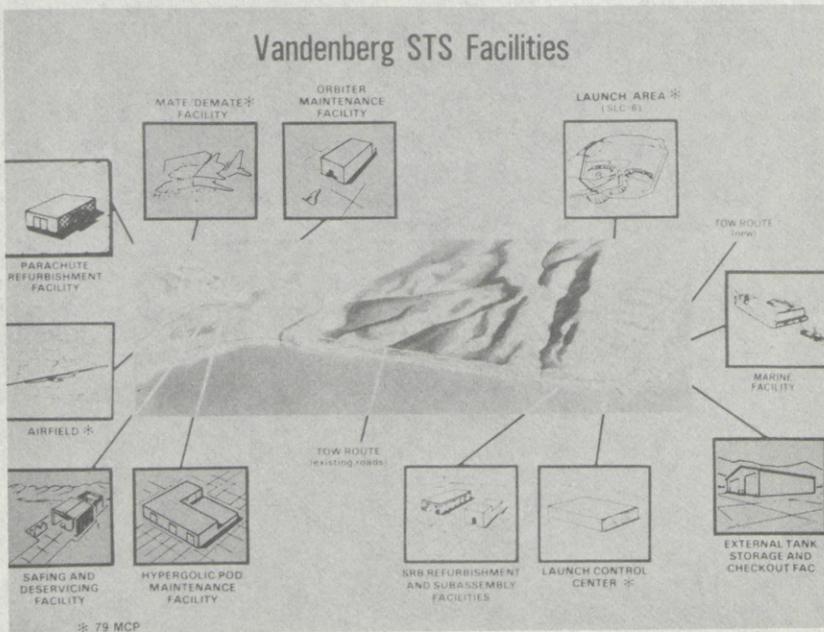
General COY. The length now is 8,000 feet.

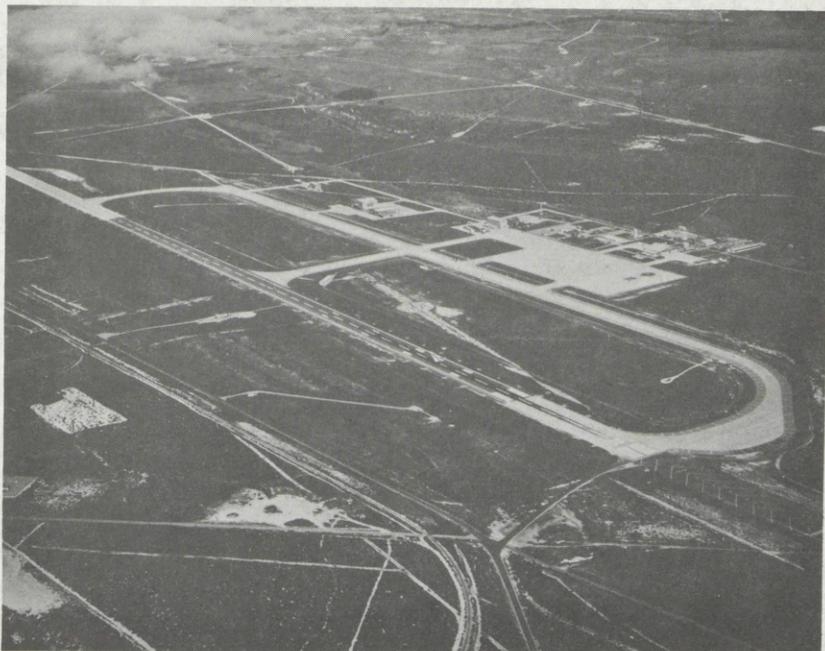
We will be pouring the concrete pad here for the mate/demate facility which will be required to take the orbiter off the 747 and put it on the 747.

This is a view of the Space Launch Complex 6 referred to as SLC-6 as it presently exists.

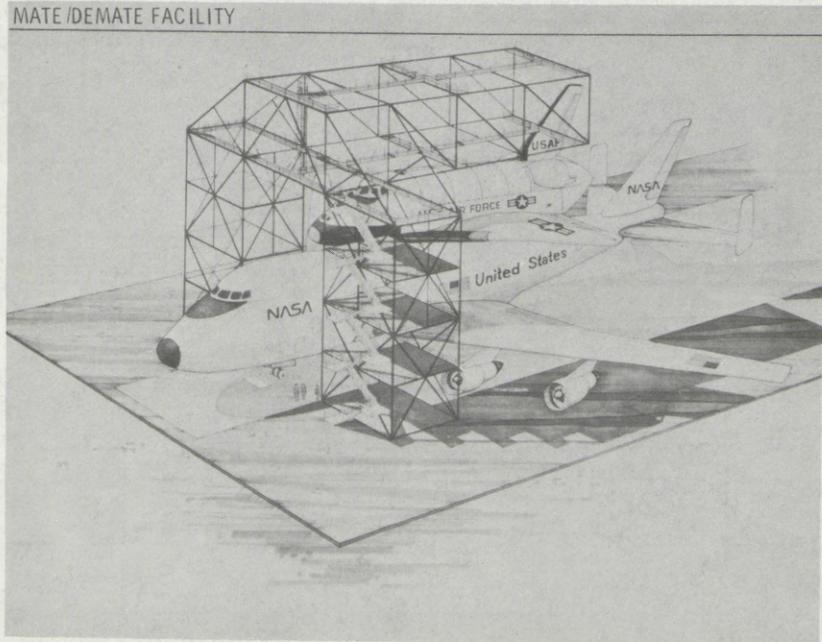
This is our view of how it will look when we complete construction.

Shown here is the mobile service tower, the orbiter on the stack including the expendable tank and solid rocket boosters, the payload changeout room, and the payload preparation room.

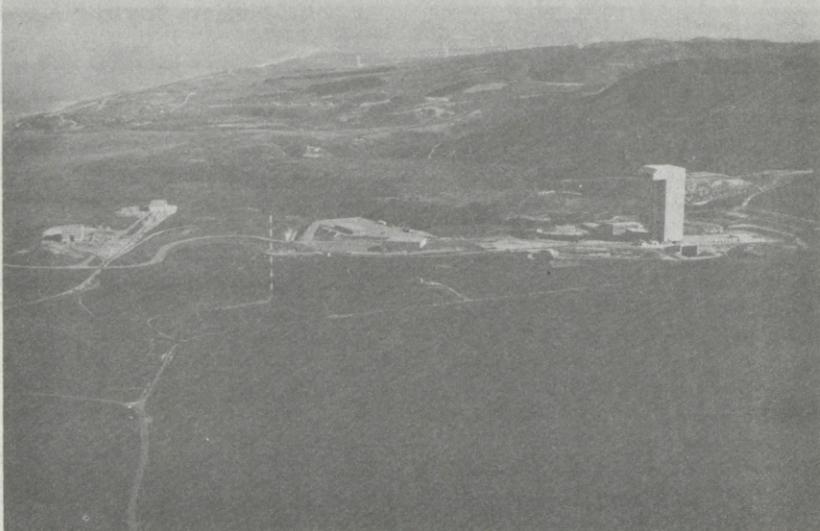




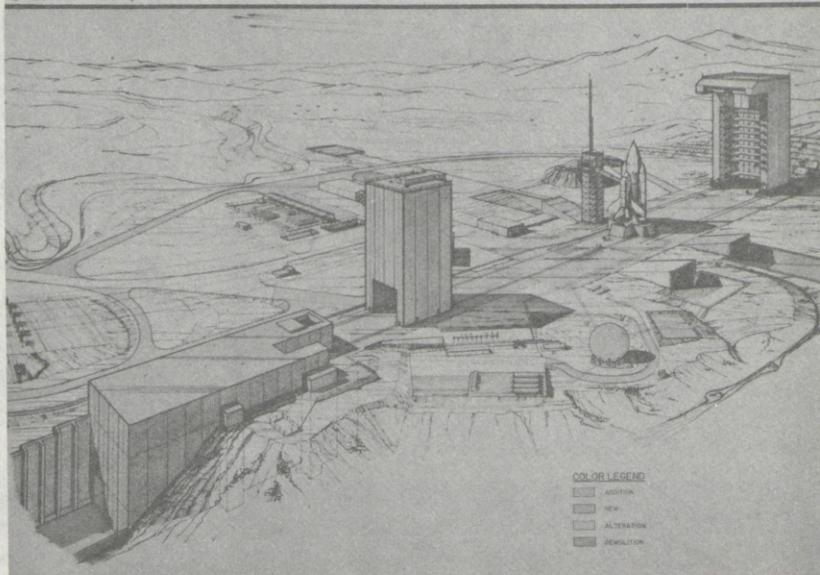
MATE /DEMATE FACILITY



SOUTH VAFB - EXISTING FACILITIES



LAUNCH AREA, STATION SET V23



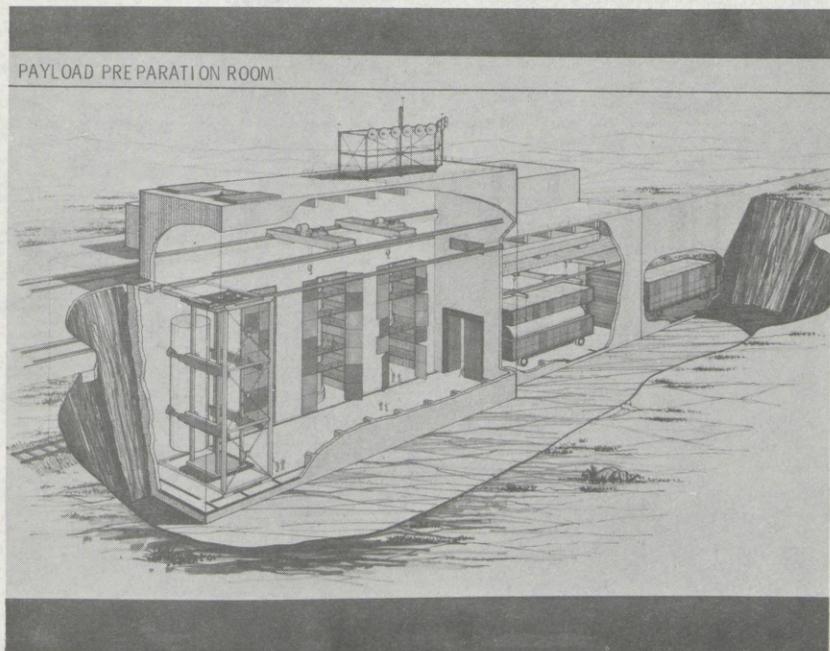
Here is a more detailed view of the payload preparation room where the payloads will come in horizontally, be rotated to the vertical position, be serviced and raised through this hatch into the payload changeout room.

The payload changeout room then will translate horizontally to move the payloads into the orbiter bay.

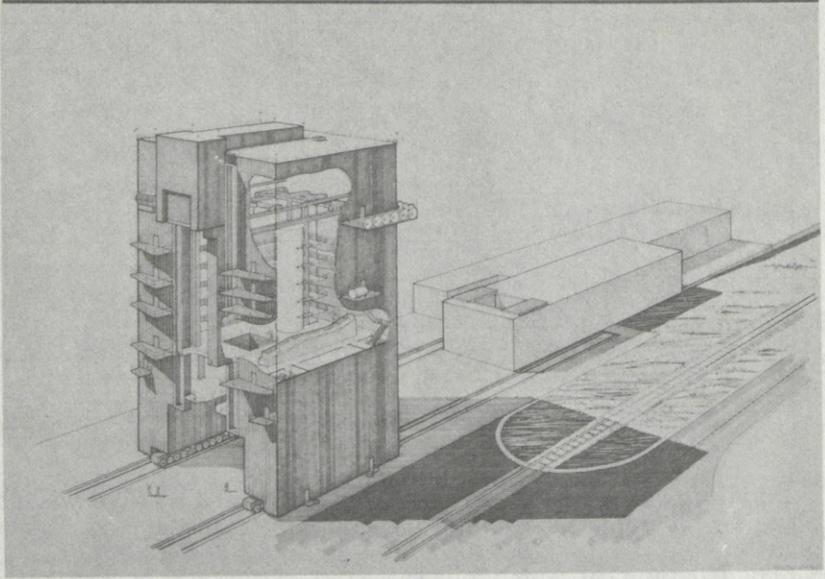
The Launch Control Center exists. We are requesting MCP funds for air conditioning and heating modifications, and we will provide launch equipment under procurement appropriations.

My last vugraph shows our acquisition schedule. We have keyed Inertial Upper Stage activity as well as the Vandenberg activation to the overall NASA development schedule.

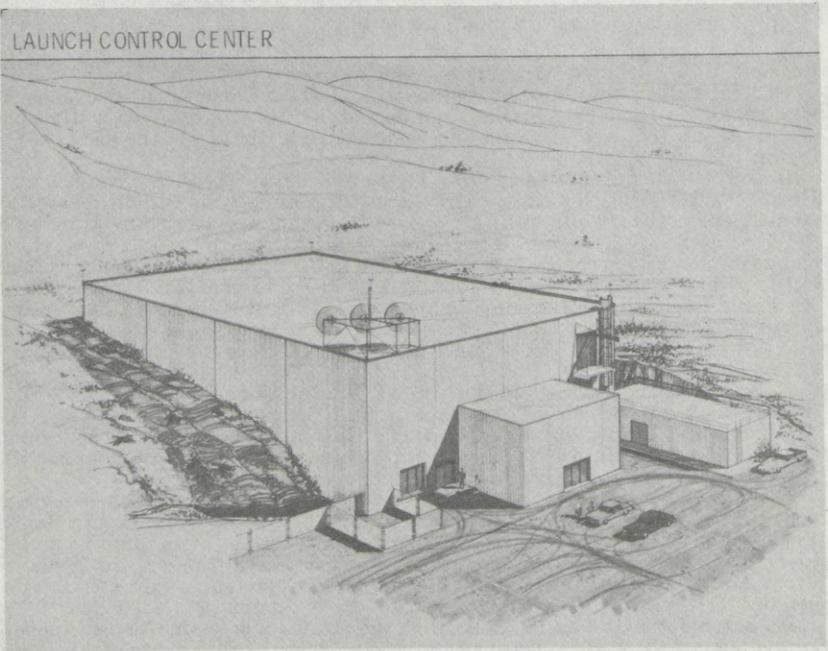
Shown at the top are the key activities like the approach and landing tests that have occurred already, delivery of orbiter 102, which will be the first orbiter to fly, the first manned orbital flight in mid-1979, the initial operational capability (IOC) at Kennedy in mid-1980, and orbiter deliveries. We will proceed with the Inertial Upper Stage following DSARC approval to proceed with full-scale development and on into production. At Vandenberg we have been in a facility design stage now for some time. We have a program review this fall leading to the start of facility construction in approximately April of next year. Vandenberg AFB activation is keyed to the delivery of orbiter 103 in September 1982 to support a mid-1983 IOC.



PAYLOAD CHANGEOUT ROOM, V23



LAUNCH CONTROL CENTER



August 1967 to June 1971 he was assigned to Headquarters U.S. Air Force in the Office of the Deputy Chief of Staff, Programs and Resources, first as Executive to the Deputy Director for Construction and later as Executive to the Director of Civil Engineering.

General Gilbert next was transferred to Wright-Patterson Air Force Base, Ohio, in June 1971 where he became Director of the Civil Engineering Center. In May 1972 he joined Headquarters Military Airlift Command at Scott Air Force Base, Illinois, for duty as Deputy Chief of Staff for Civil Engineering.

In September 1973, General Gilbert was assigned as Deputy Chief of Staff for Civil Engineering, Headquarters Pacific Air Forces, at Hickam Air Force Base, Hawaii. In May 1975 he was reassigned to Headquarters U.S. Air Force, in the Office of the Deputy Chief of Staff, Programs and Resources, to serve as Deputy Director of Civil Engineering. As a result of a USAF-directed reorganization, he was designated Deputy Director of Engineering and Services in August 1975.

His military decorations and awards include the Legion of Merit with two oak leaf clusters, the Air Force Commendation Medal with one oak leaf cluster, and the Army Commendation Medal.

General Gilbert was promoted to the grade of major general on January 18, 1977, with date of rank November 1, 1973.

He is married to the former Dorothy Sue Toombs of New Orleans, Louisiana. They have three children: Rebecca A.; William D., Jr.; and David T.

Mr. BOLAND. Now we will have the witness from the General Accounting Office, Mr. Richard Gutmann, Director of Procurement and Systems Acquisition Division for the GAO.

Mr. Gutmann.

SUMMARY STATEMENT OF DIRECTOR PROCUREMENT AND SYSTEMS
ACQUISITION DIVISION, GENERAL ACCOUNTING OFFICE

Mr. GUTMANN. Thank you, Mr. Chairman.

Before getting to my formal statement, Mr. Chairman, I would like to make a few comments to put GAO's role in perspective.

For many years, as you all, I am sure, are aware, the Comptroller General has been a strong supporter of science and technology in many, many fields, from the early days of the Office of Science and Technology Policy in the Eisenhower Administration up to and including his support of the restoration of that office quite recently. He established a science and technology group in my division because of his interest in research and development and science and technology in general. He has been a strong supporter of the NASA programs throughout the life of NASA.

The problems inherent in this program are highly technical in nature, and one might ask how can a Certified Public Accountant deal with issues of this nature?

Many of you, on the other hand, I am sure are aware that GAO now has a multidisciplinary staff. We do have engineers of a variety of kinds. We have systems analysts. We even, in our Human Resources Division, have an M.D. full time.

In addition to that, we have a roster of highly qualified consultants that we call upon for advice when we get into areas where we do not visualize a long-term need for this kind of skill, on which we can use a consultant on a temporary basis.

In this case, I would like to tell you a little bit about the consultant that we used. His name is Marshall Kaplan, who is an Associate Professor of Aerospace Engineering at the Pennsylvania State University, and he has consulted several spacecraft organizations including COMSAT. Recently he completed a textbook entitled "Modern

Spacecraft Dynamics and Control" which was released in October 1976.

He has authored more than 60 papers and reports on various aspects of astronautics. At the present time he is Associate Professor at Penn State University, a half-time research and part-time teaching program. His responsibilities include organization and management of aerospace science and management of research programs. His teaching areas include aerospace, vehicle dynamics, control, spacecraft design, propulsion, and many, many other things. But actually we use these technical people from the standpoint of enabling us to understand the technical data that is made available by the agencies, and I might say at this point that NASA has been on this program and has always been, most cooperative in providing us assistance and data, assistance in terms of how to interpret that data.

I want to go back to our general support of science and technology, and more specifically NASA's. I think that NASA's program has been extraordinarily successful for a combination of reasons. Certainly the support of this committee and the Congress, its vision, imagination and foresight, has meant a great deal, and is very, very much the driving force behind the success of the program.

NASA has had outstanding administrators throughout its life, from Jim Webb to, now, Bob Frosch.

I mention these things because very often the General Accounting Office, being cast in the role of a critic, is looked upon as being against everything, and that certainly is not true. We are *for* these programs which we criticize, constructively, we hope, and we hope to make them better as a result of our criticism, so we really are not against them.

If I could turn now to my formal statement, we very much appreciate the opportunity to appear today and present our viewpoint on the Space Transportation System. The General Accounting Office (GAO) has issued six reports on the Space Transportation System (STS) since 1972. Generally, our past reports have dealt with the cost benefits and issues relating to cost, schedule, and performance that have been of ongoing interest since 1972 when the President and the Congress approved system development.

In 1972, the two expected principal users, the National Aeronautics and Space Administration (NASA) and the Department of Defense (DOD), agreed that the program, to be fully operational would require two launch sites—Kennedy Space Center (KSC) in Florida and Vandenberg Air Force Base in California. NASA's plans called for a total of five orbiters, operating interchangeably between the sites.

The program has progressed a long way since 1972. The contractor "rolled out" the first orbiter (101) in September 1976 for approach and landing tests. A second (102) is to be delivered in October 1978, for the first orbital flight the next year; and NASA's fiscal year 1978 budget included initial funds for a third orbiter (103). NASA's fiscal year 1979 budget request includes production funds for two additional orbiters, which will consist of the structural test orbiter upgraded to operational status and a new vehicle, orbiter 104. These two vehicles are expected to cost about \$600 million and \$850 million, respectively, in real year dollars, that is, actual amounts which will be paid, including inflation at 7 percent per year. This will bring the

total number of orbiters to five. Under current planning the approach and landing test orbiter will not be refurbished and used as an operational vehicle.

NASA is constructing Shuttle facilities at KSC, the primary launch, landing, and orbiter refurbishment site. This is scheduled to become operational in mid-1980. The second site, Vandenberg, would be funded by DOD and is expected to become operational in June 1983 at a cost of about \$1.1 billion.

We have some updated information now on that figure. Additionally, \$2.6 billion in manpower costs would be needed to operate the Vandenberg complex through 1992. DOD's fiscal year 1979 budget request includes funds to begin STS facility construction at Vandenberg. Thus, 1979 funding decisions will probably establish the operational parameters of the STS in terms of launch sites and the number of orbiters. These parameters, in turn, will influence the Nation's space activities throughout the next decade.

After learning that the cost to construct and operate Vandenberg to serve the DOD Shuttle activities during 1983-92 would be \$3.7 billion, we decided to look into this matter. The DOD justified the Vandenberg site on the basis that it was needed for launching defense payloads into a polar orbit. The GAO, working with DOD and NASA, determined that it is possible to achieve a polar orbit from KSC and satisfy DOD's requirements.

Here we mean it is *physically possible* to do that.

Thus, a KSC based Shuttle will be able to accommodate all the payloads currently projected—civil and military. We think the potential for saving \$3.5 billion—another updated figure—by not funding the construction at Vandenberg warrants your close attention. We also question the need for five orbiters to carry out the Shuttle missions as presently perceived by NASA and DOD. I would like first to address the launch site issue.

WHY A SECOND LAUNCH SITE?

Kennedy Space Center is planned for Shuttle launches to the east; launches to polar orbits are presently scheduled to be from Vandenberg. Two principal arguments are offered by NASA, DOD and the State Department as to why polar orbits from KSC are not practicable, first, such launches from KSC involve unacceptable land overflight and secondly, such launches could cause an adverse reaction from the Soviet Union. We think these reasons should be critically examined.

LAND OVERFLIGHT CONSIDERATIONS

The first reason, land overflight considerations, centers around the possibility that injury to persons or damage to property could occur in the event of a mishap. Historically, the U.S. has used coastal launch sites to avoid having space vehicles ascend over the continental United States.

In our opinion, given the nature of the Shuttle—which is a partially reusable and man-rated vehicle, with commensurate high reliability—an absolute land overflight constraint seems unwarranted. Generally, launches over water are considered relatively safe but those over land masses purportedly involve more risk. While there are no official

criteria for acceptable risk, the most critical factor involves assessing the statistical probability of mission failure during powered flight—that is, during ascent into orbit.

Casualty expectation statistics for the Shuttle show a relatively low risk of launching from KSC to high inclination orbits. For instance, a study by a DOD contractor cites a 1 in 166,667 chance of an individual on the ground being harmed during a northerly Shuttle launch from KSC. In comparison, the worldwide casualty expectation associated with random re-entry of low orbital debris from a KSC launched Titan IIIC is 1 in 6,250. Thus, the re-entry of debris from a Titan launch presents a much greater risk of harming people on the ground than does a Shuttle launch.

Actual Space Shuttle reliability, of course, must be demonstrated. By June 1983, however, when polar Shuttle launches are scheduled to begin from Vandenberg, the STS will have had over 3 years' experience, entailing over 50 Shuttle flights. This would seem to be sufficient experience to gauge the Shuttle's reliability. From the standpoint of land overflight considerations, it seems questionable to us that there will be a need for STS facilities at Vandenberg if the Shuttle is as operationally reliable as expected by NASA and DOD.

Actually, while the land overflight issue is raised with respect to northerly launches from KSC, even the routine easterly launches will overfly land areas—either Africa or Europe and the Middle East. These launches purportedly pose fewer risks because the overflowed land areas are far from the launch site. Regardless of launch direction, however, Shuttle experts agree the most critical phase of a Shuttle launch is between lift-off and solid rocket booster (SRB) separation. The critical phase of northerly launches from KSC will be over the approximately 345 miles of ocean between KSC and the coast of South Carolina. In fact, the critical phase will have been completed long before land overflight occurs because the SRB's are jettisoned approximately 31 miles from the launch site. Then the orbiter and external tank will continue ascending over the remaining 314 miles of ocean and be about 70 miles high when land overflight begins. Moreover, for all phases of powered ascent, the Shuttle has been designed to return the orbiter, crew, and payload safely to the launch site for those failures which have the highest probability of occurring, such as loss of a main engine.

It is clear to us that NASA, with its usual care, has taken into consideration almost every possible chance of a failure of these equipments.

INTERNATIONAL IMPLICATIONS

The second concern about northerly Shuttle launches from KSC operations is how the Soviet Union might react to the orbiter and external tank coming over the North Pole's horizon. During a normal northerly KSC flight the orbiter, after separating from the external tank over the Great Lakes region, would continue ascending. The external tank would continue halfway around the world, over the Soviet Union, and splashdown in the Indian Ocean. Because the Arctic area is of special strategic importance in terms of nuclear missile targeting, a concern has been voiced that northerly Shuttle launches could perhaps be miscounstred. This concern, according to State

Department officials, would remain even if Russia's early warning radars are sufficiently sophisticated to specifically identify the orbiter and external tank and not misinterpret them as hostile missiles. DOD officials have also said that northerly Shuttle launches from KSC could be disconcerting and perhaps objectionable to the Soviets, even with prior launch notification and no matter how sophisticated the Soviet radars.

Accepting the State Department's view that northerly KSC launches could raise a radar misinterpretation issue, we feel that resolution through multilateral cooperation should be thoroughly explored before spending large sums on Vandenberg. In this regard, there is a 1971 U.S.-Soviet agreement which seems very applicable to this issue.

The bilateral understanding, officially known as the "1971 Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics", established procedures for prior notification in situations where unidentified objects could activate early warning systems. Because all STS missions require advance planning, there would seem to be ample time for notifying the proper Soviet authorities as called for in the agreement, especially since less than 14 polar missions per year are required. Furthermore, it should be noted that the STS is international in scope and will be even more so during the operational phase, involving many cooperative space endeavors. The U.S. and the Soviet Union are presently discussing prospects for joint Shuttle missions.

Nevertheless, the concern over Soviet reaction to Arctic overflight is difficult to assess conclusively because the issue involves essentially unquantifiable foreign policy or national security considerations. Further congressional inquiry may be needed to determine if this concern is sufficiently serious to justify the cost of the Vandenberg site. As previously noted, we believe the 1971 agreement provides a mechanism for precluding problems in this area.

CONCLUSIONS AND RECOMMENDATIONS

Considering the information just presented, we believe that the Congress should not fund Vandenberg modifications to accommodate the Shuttle unless there are compelling international or technical reasons for the West-coast STS site that are unknown to us at this time.

ORBITER FLEET SIZE

Turning now to the fleet size issue, how many orbiters are needed depends upon the extent of STS traffic that can reasonably be expected during the next decade. Traffic levels, in turn, will depend upon congressional willingness to fund space projects and applications because most payloads (as many as 80 percent) will require Congressional appropriation and authorization.

By that we mean that NASA and other government agencies will bear about 80 percent of the cost of operations.

To date, specific space program objectives for the 1980s have not been set forth. However, it is obvious that space goals must be flexible so that program plans can be adjusted to meet changing

fiscal, political, and technical circumstances. Flexibility is, to some extent, a function of the number of orbiters available. Acquiring too few orbiters and related support equipment could place undue constraints on the numbers and types of useful space exploration and applications programs.

On the other hand, given a finite budget for space activity, the more funds allocated to investment in orbiters the less will be available to plan, design, and develop useful space payloads and programs—during the early years of Shuttle operations as well as later. Procuring too many orbiters would be uneconomical in the sense that idle equipment would have to be maintained. More significantly, it could create pressures to utilize the available capacity, perhaps diluting the quality of space endeavors and impacting on other national priorities.

Both DOD and NASA say five orbiters are needed. This view is based largely on national payload mission models put together by NASA, which project up to 65 flights per year or more than one flight a week. Because this launch level represents a three-fold increase in space activity, the validity of NASA's models has been questioned by both the General Accounting Office (May 27, 1977 report "Space Transportation System: Past, Present, Future; PSAD-77-113) and the Congressional Budget Office.

Congressional Budget Office criticism of NASA's mission model prompted the space agency, in March 1977, to study reduced launch programs; the lowest program studied was 300 shuttle flights during 1980-92. NASA's study concluded that, even though three orbiters could support this level of activity, five orbiters would still be the most economical fleet size. Five orbiters are more economical than three, according to NASA, because a considerable number of expendable launch vehicles would be needed to backup and to supplement a three-orbiter fleet.

We believe three orbiters may be more than sufficient to provide a balanced and viable space program, and indeed, even a program which is a substantial increase over past activity. For instance, the capacity of two orbiters alone is enough to fly more payloads than have been launched over the past 10 years. In justifying development of the STS, NASA stated in 1972 that three orbiters were adequate to perform a 581-flight mission model but two additional orbiters were needed to provide flexibility.

Based on NASA estimates of average mission duration and on such performance goals as ground turnaround time between missions, three orbiters could conceivably sustain over 50 launches a year. However, recent NASA and DOD studies project that a three-orbiter fleet can accommodate about 40 launches annually. This is an increase over present and past levels of about 26 to 35 expendable launch vehicle flights per year. Furthermore, every shuttle flight will have a much greater payload and mission capability. To illustrate, the orbiter's large cargo bay (15 feet by 60 feet) offers the same payload-carrying capability as four Delta expendable launch vehicles. Assuming only two payloads per shuttle flight, three orbiters could launch 80 payloads a year, which is a doubling of the Nation's past activity. Furthermore, the payload-to-launch ratio will undoubtedly improve as new concepts evolve to exploit STS capabilities.

The shuttle provides a great deal of capability and capacity not yet fully understood; the study of cargo integration is only starting.

Cargo integration presents formidable technical and managerial problems but has the potential of high payoff in terms of optimizing Shuttle payloads operations.

The Shuttle's capabilities in comparison to present launch vehicles' can also be discussed in terms of mission modes. Two examples are the Spacelab and the Long Duration Exposure Facility. Both modes provide an opportunity to perform multiple experiments with a single flight. For example, the first Spacelab mission will carry up to 42 experiments—an activity level which might have required several expendable launch vehicles. Similarly, the Long Duration Exposure Facility can hold 76 experiment trays, with each tray having up to 6 experiments. The Facility is a 30-foot long, free-flying structure which is delivered by the Shuttle to Earth orbit, left for 6 months or more to perform experiments, and then retrieved.

FOUR-ORBITER FLEET

Considering the substantial capabilities of three orbiters, it is difficult to foresee needs beyond that fleet size. An additional orbiter obviously could provide an increased yearly launch rate—the total ranging from 53 to over 60 a year. The fourth orbiter would also provide a cushion for attrition—a subject difficult to precisely evaluate. Even though the technical design objectives call for each orbiter to perform 500 missions and have a minimum of 10 years' use, NASA officials have commented that the Shuttle program must endure the same development risks uncertainty during its early flights as face any technically complex program, no matter how carefully conceived.

The present Administration has decided to support a four-orbiter fleet, with consideration for a fifth orbiter in future years in the event that projected flight rates, or the accidental loss of an orbiter, warrant such an action. NASA's procurement strategy to achieve this fleet size position is not completely clear to us. In essence, four orbiters are already partially "in the stream"—101, 102, 103, and the structural test orbiter. Yet, NASA's fiscal year 1979 budget request includes funds for a completely new vehicle (orbiter 104), which NASA describes as the fourth orbiter. Under this plan, the optional or fifth orbiter will be either (a) orbiter 101, modified for orbital flight capability, or (b) another wholly new vehicle procured after orbiter 104.

CONCLUSIONS AND RECOMMENDATIONS

In summary, GAO's position is that three orbiters (102, 103, and the upgraded structural test orbiter) can accommodate a substantial increase in space activity during the next decade. If the Congress anticipates a more significant increase, or deems it necessary to provide for attrition in the three-orbiter fleet, then orbiter 101 could be upgraded to operational capability. We question the desirability of funding orbiter 104 at this time.

This concludes my statement, Mr. Chairman.

I would like to take a moment to introduce my colleagues, and as you requested earlier, to say a little bit about myself.

I joined the General Accounting Office in 1954. Since that time, my experience has ranged from responsibility for all of the activities in the Army—personnel, logistics, procurement, research, financial,

and accounting programs. Later I was given the responsibility for all supply management activities in the Department of Defense, including all three services.

After that, I spent a short period of time as Director of our European branch in Frankfurt, then came back to become Deputy Director of the Defense Division in 1968. In 1972, as a part of a reorganization in the office, I became Director of the Procurement and Systems Acquisition Division, and that is when I picked up the responsibility for NASA, in addition to all of the procurement by the Department of Defense, and a considerable portion of procurement by the General Services Administration. A more complete biographical sketch will be submitted for the record.

To my right is Mr. Donald Day, who is an Associate Director in my division. He heads the science and technology group under which this work on NASA has been done for the past several years.

John Toler, to his right, is a Supervisory Auditor from our Dallas Regional Office. He spends most of his time at Houston and he is one of our NASA experts. John has with him Dan Sprowls and Dan Burton.

We will be happy to answer any questions which you might have.

BIOGRAPHICAL SKETCHES OF GAO WITNESSES

Mr. BOLAND. We will insert at this point in the record the biographical sketches of the GAO witnesses

[The biographical sketches follow:]

RICHARD W. GUTMANN, DIRECTOR, PROCUREMENT AND SYSTEMS ACQUISITION DIVISION, U.S. GENERAL ACCOUNTING OFFICE

Mr. Gutmann is a graduate of the George Washington University in Washington, D.C. from which he received a degree in Business Administration. He also attended the Harvard University Advanced Management Program. His first service with the Government was as Naval Aviator during World War II. He is a Certified Public Accountant and practiced public accounting prior to joining the General Accounting Office in 1954.

During his first five years with the General Accounting Office, Mr. Gutmann worked primarily on the audits of Defense contracts. During that time, he assisted in initiating the pricing reviews that continue to be an important part of the GAO's contracts work. Later, as Director of the GAO's European Branch, he was responsible for directing the Office's work in Europe, Africa, the Middle East, Pakistan, and India.

In 1968, Mr. Gutmann was named Deputy Director of the GAO's Defense Division. In that capacity, he assisted in the overall direction of the accounting, auditing, and investigative work conducted by the General Accounting Office in the Department of Defense. Mr. Gutmann has been the Director of the Procurement and Systems Acquisition Division of the GAO since 1972 when that Division was established.

The Procurement and Systems Acquisition Division is the focal point in the GAO for either planning or conducting audits and investigations of all of the Federal Government's procurement and science and technology programs. In addition, Mr. Gutmann's Division is the GAO contact point for cooperation and coordination with the Office of Procurement Policy in the Office of Management and Budget.

DONALD E. DAY, ASSOCIATE DIRECTOR, PROCUREMENT AND SYSTEMS ACQUISITION DIVISION, U.S. GENERAL ACCOUNTING OFFICE

Mr. Day is a graduate of the University of Maryland and the National War College at Fort McNair. He served in the U.S. Marine Corps in Korea and is a certified public accountant in Maryland. He joined the General Accounting Office in 1958.

During his earlier years with the General Accounting Office, Mr. Day worked on various technical assignments relating to communications, procurement, supply management, and construction.

In 1972 Mr. Day was appointed Assistant Director in the Procurement and Systems Acquisition Division and assisted in the annual planning and managing of work related to investigations into the management and acquisition of major systems in the Department of Defense and civil agencies. The programs and activities were primarily those administered by the Department of Defense, Department of Energy, and the National Aeronautics and Space Administration.

In 1978, Mr. Day was appointed Associate Director and assists the Director with the overall management of the Division. He is primarily responsible for planning, executing, and reporting on management efficiency and program results in the government-wide program of science and technology. The Procurement and Systems Acquisition Division is the focal point in the General Accounting Office for either planning or conducting audits and investigations of all of the Federal Government's procurement and science and technology programs.

JOHN N. TOLER, JR., SUPERVISORY GAO AUDITOR, DALLAS REGIONAL OFFICE,
U.S. GENERAL ACCOUNTING OFFICE

Mr. Toler is a graduate of the University of Arkansas at Monticello from which he received a degree in Business Administration. He is a Certified Public Accountant in Texas and Arkansas.

Since joining the General Accounting Office in 1963, he has been assigned the responsibility for a variety of audits covering a wide range of Government activities, both civil and defense. Much of his time has been spent in reviewing major research and development programs. In addition to his field experience with the Dallas Regional Office, he has served four years in two Washington headquarter's divisions.

Mr. Toler has been responsible, in one capacity or another for the GAO reviews of NASA'S Space Transportation System since mid 1973. Since December 1975, he has served as an audit manager in the Dallas Regional Office. In this capacity, he has been responsible for concurrently directing procurement and systems acquisition reviews, including the space shuttle review, and in assisting the Washington staff plan science and technology reviews within the Dallas region. He also serves as the Executive Secretary of the Southwest Intergovernmental Audit Forum and as the GAO regional liaison for Cost Accounting Standard Board matters.

DANNY L. SPROWLS, GAO AUDITOR, DALLAS REGIONAL OFFICE, U.S. GENERAL
ACCOUNTING OFFICE

Mr. Sprowls is a graduate of Southwestern State University in Weatherford, Oklahoma, from which he received Bachelor of Science Degrees in Mathematics and Accounting. He is currently pursuing a Masters degree from the University of Houston in Houston, Texas. He is a certified public accountant in Texas and Oklahoma.

Mr. Sprowls has devoted much of his time, since joining GAO's Dallas Regional Office in 1970, to reviewing major research and development programs. Since mid-1976 he has been the site-senior in-charge of GAO's permanent audit site at Johnson Space Center. He has been involved in reviews of NASA's Space Transportation System for over three years and has been responsible for directing the day-to-day audit of the program for the past two years. His duties included coordination of audit efforts at Johnson Space Center, Kennedy Space Center, Marshall Space Flight Center, NASA Headquarters, contractor locations and the Air Force's Space and Missile Systems Organization.

DANNY R. BURTON, GAO MANAGEMENT ANALYST, DALLAS REGIONAL OFFICE,
U.S. GENERAL ACCOUNTING OFFICE

Mr. Burton holds a Bachelor of Science degree in Economics from Texas Tech University, Lubbock, Texas. He is also a graduate of the binationally-accredited University of the Americas, located in Puebla, Mexico, from which he received a Master of Business Administration degree, summa cum laude. Presently, outside of his work schedule, Mr. Burton is pursuing a Juris Doctor degree and has completed approximately one-half of the requirements.

Since joining GAO's Dallas Regional Office in 1972, Mr. Burton's field assignments have had considerable variety, ranging from analysis of Canal Zone problems and issues to the present study of space shuttle launch site and fleet size requirements. He was responsible for developing and coordinating major portions of the study.

SCOPE OF HEARING

Mr. BOLAND. I would like to open with a line of questioning that I hope will challenge some of the points made in each of your statements. It will also, I hope, shed some light on the issues raised by the General Accounting Office concerning the size of the orbiter fleet and the number of launch sites.

Before getting into the questions, however, I want to say a word or two about the answers to these questions.

It would seem to me that the Shuttle program is one that ought to be able to evoke basically factual answers from all interested parties, with little variance from one party to the next. For example, if we ask you how many flights a three-orbiter fleet can support, I would hope that I would get the same answer from everyone here, not 50 from GAO and not 35 from NASA, and if I ask you how many pounds the Shuttle flying north in the polar orbit from Kennedy can carry into low polar orbit, I would expect to get essentially the same answer from everyone here.

Basically the answer to that question I would assume is simply a factor of space mechanics.

I would also hope that the witnesses here would not succumb to the temptation of what I call scare tactics. I understand, for example, that the other day the staff was advised by an Air Force representative that we could never fly missions north out of Kennedy because we would have to build a new tracking station in Canada, and that came as a bit of a shock to us, since we are investing about \$700 million or \$800 million in a new tracking and data relay system which has been advertised by NASA all these years as having the capability of covering nearly every square foot of the earth for the purpose of tracking the Shuttle, so I would only hope that the answers to these questions are ones that we can count on.

SPACE SHUTTLE WEIGHT CAPABILITY FOR KSC POLAR ORBIT LAUNCH

With that brief introduction, let me ask the first question of all of you sitting at the table and it is one I referred to a minute ago. That is how much weight can a Shuttle flying north out of Kennedy into polar orbit, how much weight can it carry into orbit?

In a letter dated February 17 from Dr. William Perry to the GAO, he states:

We are now using a full 24,300-pound TITAN IIIC payload delivery capability for Vandenberg Air Force Base, and are fully depending on the 32,000-pound Shuttle delivery capability from Vandenberg Air Force Base by the mid-1980s.

Your report suggests that if range safety constraints are waived at the Kennedy Space Center, the Shuttle flying north over the Continental United States could deliver 25,000 pounds to low polar orbit. The report also states that this capability is adequate for DOD. In fact, the standard Shuttle payload capability is only 22,000 pounds under these conditions, 98 degrees inclination, 150 nautical miles.

We are aware that it may be possible to increase Shuttle performance by several hundred pounds for certain flights without risk by off-loading some items from

the Shuttle flight manifest. If the Shuttle is configured to deliver a payload but not retrieve an old satellite on the same flight, performance might be increased to perhaps 25,000 pounds. However, from these Shuttle performance figures we must deduct the weight of a cradle to properly support our payload in the Shuttle, about 2,500 pounds. The resulting performance is less than that of current boosters, and is totally unacceptable for the mid-1980 period.

So my first question is, can we all agree with Dr. Perry that when you deduct the 2,500-pound weight of the cradle, the maximum payload capability that the Shuttle can carry into a 98-degree inclination orbit from Kennedy is only 22,000 pounds? Does everybody agree with that?

Mr. TOLER. No, sir.

Mr. GUTMANN. No sir, we do not, Mr. Chairman. Based on the calculations which we have made from data provided by NASA and DOD, we find that the most demanding payload of the Department of Defense requires about a 32,000-pound payload launch. We show that a polar orbit can be managed out of Kennedy with more than a 34,000-pound payload.

Now there may be other problems with that polar orbit. Some of them we have discussed, land overflight as well as the necessity for developing an arrangement with the Soviet Union for advance notice.

John, do you want to add something?

Mr. TOLER. Not at this time.

Mr. BOLAND. Dr. Perry; Dr. Frosch?

Dr. FROSCH. We don't know how to get that result from the computations. We have seen a list of things which they believe can be removed from the Shuttle. Even that doesn't get us to a delivering weight of 34,000 pounds, and if one were to try to do what the GAO suggests, we would have to begin to worry about some safety considerations. We would certainly have to worry about the orderly flow of missions. It is not simply a matter of going in and removing things, flying a mission, and putting them back. You have to change the system in some very important ways. For example, on one of the lists I saw, and I don't know if it is the one that had to do with this mission, one went even so far as to down-load the manifest items that could impact crew and on orbiter safety. We do not believe that that is wise to do.

Mr. GUTMANN. Dr. Frosch, you may be referring when you mention one of the calculations—

Dr. FROSCH. I don't know which calculation.

Mr. GUTMANN. You might have been referring to ours.

Dr. FROSCH. Yes.

Mr. GUTMANN. I might address that briefly.

In working these figures out, of course, we used NASA data, and we arrayed this data on long worksheets and talked to NASA people about them to determine whether or not we had made the correct deductions and additions with respect to weight, depending upon the mode that the Shuttle is launched in.

The final position of over 34,000 is based upon data developed by our Houston staff, which I worked out personally with the Under Secretary of the Air Force.

Now we agree with what Dr. Frosch said, and I think these words appear in either his statement or Dr. Perry's, that it would not be "a fully capable Shuttle" for that particular flight. That particular

payload, does not require all of the capabilities in terms of cargo handling that would be on other kinds of flights. So we do have agreement from some elements in the Department of Defense that physically the Shuttle can carry that payload from Kennedy into a proper orbit.

Dr. FROSCHE. Mr. Chairman, might I comment on that?

Mr. BOLAND. Might I have Dr. Perry's comment on it? Apparently you are sticking to your assertion that 22,000 pounds is the weight which can be launched at 98-degree inclination from KSC.

Dr. PERRY. Yes, I am sticking to my assertion on that.

Mr. BOLAND. Would you like to respond to some of the information that he has given us now?

SOURCE OF GAO CALCULATIONS FOR KSC POLAR ORBIT LAUNCH

Dr. PERRY. I don't know where those figures come from. I have not been able to reproduce them in any of my calculations.

Mr. BOLAND. From whom did the figures come, Mr. Gutmann; from NASA, that you are quoting? You said you were in contact with NASA people or NASA officials and a lot of this information was developed as a result of conversation with people in NASA?

Mr. GUTMANN. I would amend that last part just a little bit, Mr. Chairman. More than conversation, we would get data, actual computations and analyses from NASA. Mr. Toler could respond more fully to that.

Mr. BOLAND. That is fine.

Mr. TOLER. We have been working very closely with the Johnson Space Center people who are charged with the responsibility for making these calculations. They have recently completed a series of computer runs analyzing this data, upon which we based our conclusion that the Space Shuttle could handle the DOD heavy payloads.

Mr. BOLAND. Obviously, we are not going to come to any agreement among the three with respect to this particular matter.

Dr. FROSCHE. Mr. Chairman, there are some more things to be said, if I may say them.

Mr. BOLAND. Yes.

Dr. FROSCHE. Among other things that have been removed in this computation is the ability abort to the mission, that is to say, to come back to a safe place, given certain failures in engines.

Mr. BOLAND. Do you agree with that?

Mr. TOLER. No, sir, that has not been deleted.

Dr. FROSCHE. Then we have no idea from what system of data or computation they extracted this information from, because we cannot duplicate their results.

LAUNCH AZIMUTH FROM KSC

Dr. PERRY. I might ask one question, Mr. Chairman, as to what launch angle that assumes, whether they are assuming a dog leg to avoid the populated areas or whether they are assuming a direct ascent. I don't know how to normalize my comments until I know what the references are.

Mr. TOLER. Yes, sir this assumes a 10-degree launch azimuth from Kennedy.

Dr. PERRY. It doesn't include a dog leg.

Mr. TOLER. It requires a dog leg to achieve the 98-degree, 150-nautical mile polar orbit.

Mr. BOLAND. Will you supply for the record the data that you have come up with, and in the record we will have NASA and DOD respond to those data on some of the questions that are being raised here.

[DOD information follows:]

The 22,000 pounds capability referenced in Dr. Perry's letter to GAO was based on the performance of an Orbiter with standard manifest into the mission orbit from a 13° launch azimuth dictated by sufficient water depth for solid rocket booster recovery. Tailoring the Orbiter for this particular mission orbit, but *without the capability to retrieve* a depleted payload on the same mission, results in a net payload increase of approximately 3,600 pounds or an overall performance of 25,600 pounds. (The 22,000 pounds capability has subsequently been revised to 22,455 pounds.)

In order to achieve the 34,000 pound performance referenced by GAO, a 10° launch azimuth was assumed (which implies no solid rocket booster recovery and sonic boom impingement on the coast, in addition to overflight of the continental U.S., Canada, and Soviet Union), and items critical to mission accomplishment were deleted.

As a result of an updated analysis in response to this issue, the current NASA position with respect to acceptable launch azimuth constraints is that 19° will now be necessary to keep potentially damaging sonic boom overpressures offshore and to avoid solid rocket booster impact in offshore oil fields. At this 19° launch azimuth, the resulting baseline performance for a standard Orbiter is 17,036 pounds. If a *deploy only mission* is considered and solid rocket boosters are not recovered, performance may be increased to 21,882 pounds when only mission essential equipment is retained.

[GAO information follows:]

A KSC-launched Space Shuttle can carry over 32,000 pounds to 98-degree inclination orbits. To accomplish northerly launches from KSC to polar and near-polar orbits, the Space Shuttle must change its launch trajectory in flight. (See Figure 1)

A KSC-based STS can accommodate all of the payloads, civil and military, projected for the 1980-91 period, including those projected for high inclination orbits.

Pursuant to the Chairman's directive that GAO, NASA, and DOD get together after the hearings and reconcile their differences on payload carrying capabilities, a meeting was held at Johnson Space Center on March 17, 1978. Headquarters' representatives from all agencies were present. At this meeting, tentative agreement was reached on the following performance figures:

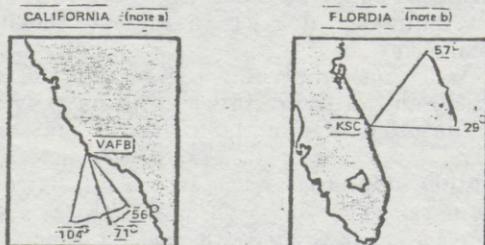
Shuttle performance capability for northerly launches from KSC (assuming initial launch ascent azimuths of 8, 10, 13, and 19 degrees, with a subsequent dog leg maneuver to obtain a 98 degrees—150 nautical miles orbit)

Initial launch ascent azimuth (degrees):	Weight-carrying capability (pounds)
8	34, 922
10	33, 512
13	31, 148
19	25, 729

Backup details and explanations of these figures are given in attached charts 1 through 4.

The figures shown above do not reflect the less severe wind conditions that exist at KSC as compared to Vandenburg which could result in additional performance capability, perhaps ranging from 750 to 2,100 pounds depending on actual winds at time of launch. Additionally, NASA has underway several studies involving ways to modify the Shuttle's design to give additional performance capability ranging from 2,000 to 20,000 pounds. One of the studies involves adding a catalyst to the SRB propellant, which could improve the Shuttle's capability by 5,000 pounds. The studies, are targeted for completion in June 1978.

PLANNED TWO-SITE OPERATIONS (KSC AND VAFB)



POSSIBLE ONE-SITE OPERATIONS (KSC-ONLY)

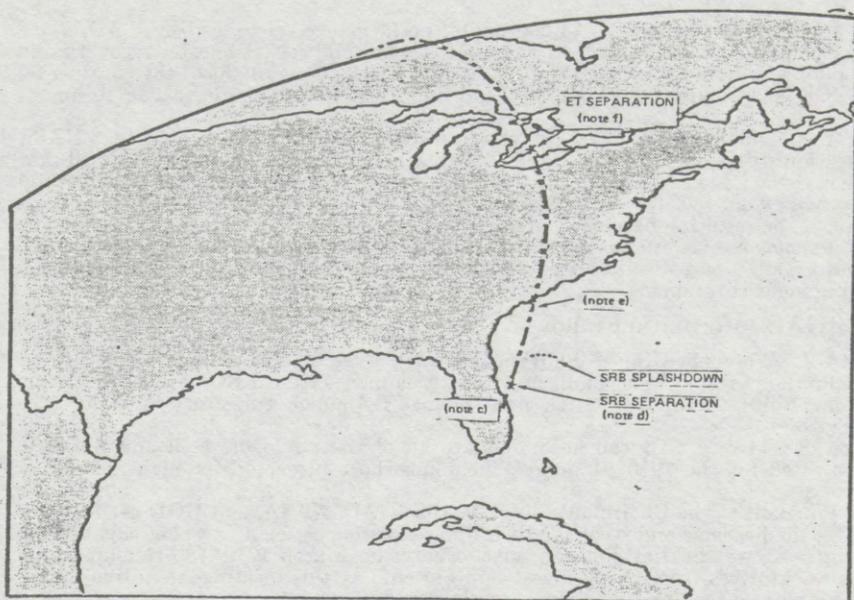


FIGURE 1.—Comparison of STS Launch Operations: Planned Two-site versus Possible One-Site

Notes to Figure 1:

^a Shuttle launches to high inclination orbits (56 to 104 degrees) are planned from Vandenberg Air Force Base, which is not scheduled for operations until June 1983. Polar (90 degrees) and sunsynchronous (about 98 degrees) orbits are popular high inclination orbits and are especially useful for Earth observation missions. Although present plans show that Vandenberg will be used to launch the Shuttle to inclinations ranging from 56 to 104 degrees, it is probable that sonic boom and external tank (ET) impact considerations will not permit direct Shuttle ascent into inclination of 56 to 71 degrees. If so, a dogleg maneuver (similar to that discussed in note c) will have to be used if these inclinations are to be achieved from Vandenberg.

^b The primary site, KSC, is expected to be operational in mid-1980 and will be used to launch the orbiter to low inclination orbits ranging from 28.5 to 57 degrees. According to NASA, inclinations above 57 degrees are not achievable from KSC due to land overflight considerations. However, KSC-only operations are

possible (see note c) and offer significant cost savings. For a number of reasons, we feel that an absolute constraint on Shuttle overflight of land may be unwarranted.

^c Southerly launches from KSC are not feasible due primarily to sonic boom considerations. Similarly, for the same reason plus solid rocket booster splashdown requirements, *direct* northerly launches from KSC to polar (90 degrees) and near-polar (98 degrees) orbits are not feasible. However, these orbits are obtainable from KSC by using an initial launch ascent azimuth which is less than true north and then subsequently using a dogleg (orbiter yaw steering) maneuver to change trajectory in flight. This maneuver is done immediately after SRB separation.

^d About 2 minutes after the integrated Shuttle vehicle ascends from the launch pad, the SRBs are jettisoned at an altitude of about 26 miles. The system is 31 miles downrange, over the ocean. At this point the most critical phase of a Shuttle launch, regardless of launch direction, has been completed.

^e After SRB separation, the orbiter and ET continue ascending and are about 70 miles high when they reach the coastline.

^f The orbiter separates from the ET about 845 miles downrange from the launch site. The orbiter continues into orbit while the ET, in a suborbital trajectory, falls into a remote part of the Indian Ocean.

As a point of understanding for the record, we note that the performance figures discussed at the March 17th meeting are *not* based on system changes which affect abort procedures or in any way compromise orbiter and crew safety. The figures do *not* include any deployment manifest deletions from the orbiter, that is, *no* items were off-loaded from the standard delivery configuration even though it was generally recognized that certain non-safety items (televisions, cameras, etc.) were not mission-essential. The participants agreed to discuss at a future meeting those items which could possibly be off-loaded, thus giving additional payload capability.

Two other issues were raised by NASA at the March 17th meeting as possible constraints against northerly launches from KSC—(1) potential sonic booms on Florida coastal areas and (2) oil and gas leases in possible SRB splashdown areas. These two issues are addressed following this discussion on performance capability.

Headquarters representatives of the three agencies met again on March 23-24, 1978, in Washington, D.C. There was no indication at that meeting that substantive changes would be made to the payload carrying capability tentatively agreed to a week earlier at Johnson Space Center. However, the DOD representative stated that the payload question was still being studied while we met.

We met again with NASA officials in Washington on March 29. DOD representatives were not present. We were informed that non-safety related manifest items totalling 359 pounds could be off-loaded. The NASA representatives also stated that the performance capability as previously discussed was in error; they said that capability gained by deploying but not retrieving on the same mission was over-stated by 1,050 pounds—that is, the figure should be 6,384 and not 7,434. We have not analyzed this new data.

At this meeting, the NASA representatives also stated that DOD had refigured its mission requirements (i.e., capability needed for its heaviest payloads) and, thus, several thousand pounds should be deducted from the figures tentatively agreed upon earlier. Stated in its simplest terms, it seems that what NASA was saying was that DOD's payload could be greater than the 32,000 pounds requirement previously cited.

During the March 29th meeting, NASA's Associate Administrator for Space Transportation Systems commented that the hazards of land overflight was the real issue regarding northerly launches from KSC. He said potential constraints due to sonic boom considerations or oil and gas leases could be overcome. Moreover, he added that if for some reason the total performance capability was now not enough for DOD's heavy payloads, sufficient system improvements could be made at an additional cost. The Associate Administrator indicated, that assuming land overflight was acceptable, it would be more cost-effective than building Shuttle facilities at Vandenberg.

CHART 1

SHUTTLE PERFORMANCE CAPABILITY FOR NORTHERLY LAUNCHES FROM KSC (ASSUMING INITIAL LAUNCH ASCENT AZIMUTHS OF 8°, 10°, 13°, AND 19°, WITH A SUBSEQUENT DOGLEG MANEUVER TO OBTAIN A 98°, 150-NAUTICAL-MILE ORBIT)

Mission/operating profile	Weight-carrying capability (pounds) at various launch azimuths ¹			
	8°	10°	13°	19°
Basic deployment and retrieval ²	27,499	26,089	23,725	18,306
Less management reserve ³	1,270	1,270	1,270	1,270
Subtotal.....	26,229	24,819	22,455	17,036
Add capability gained by—				
Offloading SRB recovery system ⁴	1,259	1,259	1,259	1,259
Deploying but not retrieving on same mission ⁵	7,434	7,434	7,434	7,434
Total ⁶	34,922	33,512	31,148	25,729

¹ Weight-carrying capability decreases as the various launch azimuths increase because the Shuttle requires a "dog-leg" maneuver to achieve a 98° inclination orbit (angle at which the orbit crosses the Earth's equator). For example, a 13° azimuth would place the Shuttle in a 74° inclination orbit. To achieve a more northerly inclination (such as 98°) from this same azimuth, an in-flight direction change maneuver (requiring additional energy) must be performed. Thus, the greater the direction change, more fuel is required and the payload carrying capability is decreased.

² This basic deployment/retrieval capability is based on ground rules established by NASA and DOD. (See chart 2.)

³ This management reserve is part of the Shuttle's overall payload carrying capability; however, NASA management holds 1,270 lb aside in reserve status to cushion the effects of unforeseen system weight anomalies.

⁴ The solid rocket boosters will separate from the Shuttle system at an altitude of about 150,000 ft. After separation, the boosters will parachute into the ocean some 150 nautical miles downrange for recovery and reuse. Deleting this recovery system (parachutes, etc.) reduces system weight by 1,259 lb and increases weight-carrying capability by the same amount. For further explanation, see chart 3.

⁵ Missions calling for satellite delivery and retrieval on 1 flight require more fuel, time, and crew than do delivery-only missions. The latter category of missions allows 7,434 lb of additional weight-carrying capability. For further explanation, see chart 4.

⁶ These totals, and the preceding figures, were agreed to during a reconciliation meeting on Mar. 17, 1978, attended by headquarters' representatives from NASA, DOD, and GAO.

CHART 2

EXPLANATION OF GROUNDRULES AND ASSUMPTIONS UNDERLYING THE "BASIC DEPLOYMENT AND RETRIEVAL" CAPABILITY SHOWN IN CHART 1

a. The basic deployment and retrieval capability is in reference to DOD's heaviest or most demanding mission. The mission calls for a 32,000 pounds delivery capability to a 98 degrees inclination-150 nautical miles orbit, plus a retrieval capability of 25,000 pounds from the same orbit. As presently planned, the deployment/retrieval mission will require a four-person crew, seven days in space, and full fuel for the Reaction Control System (RCS) and the Orbital Maneuvering System (OMS).

b. Under the groundrules discussed above, a KSC-launched Shuttle cannot meet the reference mission of 32,000 pounds delivery/25,000 pounds retrieval. For example, the performance at an 8 degrees launch azimuth is 27,499 pounds delivery/25,000 pounds retrieval. However, by adjusting the mission/operating profile (for example, as indicated on chart 1, notes 4, and 5), it is possible to achieve a 32,000 pounds delivery capability.

c. Achieving the 32,000 pounds delivery capability does result in not having same-flight retrieval capability for this mission. We feel this is an acceptable trade-off because DOD, as mentioned by Dr. Perry, plans only two missions per year involving delivery weights greater than 22,000 pounds.

CHART 3

EXPLANATION OF THE "CAPABILITY GAINED BY OFF-LOADING SRB RECOVERY SYSTEM" SHOWN IN CHART 1

a. SRB splashdown

If the SRBs are to be recovered and reused 19 times as planned, NASA estimates that 180 feet is the minimum ocean depth acceptable for parachute-splashdown of the 140 feet long boosters. Off-loading the SRB recovery system (parachutes, etc.) for DOD's two heavy missions per year means that the boosters will not be reusable after splashdown, regardless of ocean depth. For these missions, water depths in the estimated splashdown area range from about 100 to 180 feet, depending upon the Shuttle's launch azimuth. The splashdown water depth associated with a 13 degrees launch azimuth is about 180 feet. According to NASA, this depth is sufficient to preclude the free-fall boosters' impacting and

lodging on the ocean floor. However, more northerly launch azimuths (such as 10 or 8 degrees) may have splashdown depths below 120 feet, perhaps necessitating booster salvage operations instead of a normal tow recovery.

b. SRB costs

NASA has estimated that each SRB will have an average cost of \$7.4 million (FY 1979 dollars) over the 12-year Shuttle era (FY 1980-91). Off-loading the SRB recovery system should not be construed as advocating throw-away boosters. The growth versions of DOD's heavy payloads are not expected until after 1985. By that time, many recovered/reworked boosters should be available. With proper planning, those boosters having limited remaining launch lives could be used for the few missions under consideration.

CHART 4

EXPLANATION OF THE "CAPABILITY GAINED BY DEPLOYING BUT NOT RETRIEVING ON THE SAME MISSION" AS SHOWN ON CHART 1

a. Weights associated with satellite retrieval capability

Compared to a deployment/retrieval mission, a deployment-only mission has greater delivery capability because the latter requires:

	<i>Pounds</i>
2 less crew members and 3 fewer days in space.....	1, 179
1 less cryogenic tank set.....	1, 608
No rendezvous radar.....	337
Less OMS fuel.....	936
Less RCS fuel.....	3, 374
Total.....	7, 434

b. No increased risk

According to NASA, none of the adjustments above will adversely affect about procedures or compromise orbiter and crew safety.

SONIC BOOM CONSIDERATIONS-KSC

During the March 17, 1978, meeting at Johnson Space Center, NASA Headquarters⁷ and Johnson Space Center officials expressed the concern that a 13 degree launch azimuth could cause sonic boom overpressures in excess of 2.0 pounds per square foot (psf) on Florida land areas during launch. (For a delineation of the relative behavior effects caused by sonic boom overpressures, see table 1.)

IS THE RECENT DATA ACCURATE?

The data provided us on March 17th indicates that overpressures exceeding 2 psf may impact on Florida land areas during a KSC Shuttle launch to the 13 degree azimuth (see figure 2). This data differs significantly from sonic boom overpressure charts developed by NASA previously. For example, the October 1976 NASA/USAF report to OMB indicated that an 8 degree launch azimuth was sufficient to preclude overpressures of more than 0.5 psf from impacting on land areas (see figure 3). An earlier report prepared by NASA's Marshall Space Flight Center had reached this same conclusion. Although the Marshall Center's estimate was qualified as being preliminary and awaiting detailed definitions of flight control systems and other variable factors, it was recognized as being representative of the Shuttle system and deviations from the results predicted were expected to be minimal. Moreover, the Center's study was a relatively detailed effort and made use of a sonic boom computer program.

In contrast, the recently supplied data is only a generalized estimate—no detailed study was performed to support it. For example, the assumption was made that the trajectory for a 13 degree launch azimuth from KSC (northerly) would not be significantly different than the trajectory for a 70 degree orbit inclination from Vandenberg (southerly). The Vandenberg sonic boom footprint was thus merely overlaid on a Florida coastline map. Scientific reports, however, point out that there is sufficient difference between northerly and southerly launch trajectories to warrant separate analyses of the sonic boom overpressure footprints. We have therefore requested that NASA perform a detailed computer-supported study of the overpressure footprint for a 13 degree launch azimuth; NASA has estimated that this effort will require several weeks to complete. We suggest that similar studies should be considered for launches at 10 degrees and 8 degrees.

In addition, there are other factors which should be taken into consideration before a final estimate of sonic boom overpressure is made. These factors include wind effects, atmospheric conditions, payload variations, aerodynamic uncertainties, azimuth and inclination effect, etc. Some of these factors (e.g., wind effects) can be estimated and taken into consideration now, but some may require actual flight data before final sonic boom predictions can be made.

It should also be noted that, under presently planned reentry and landing profiles at KSC, the Shuttle will cause sonic boom overpressures ranging up to 2.1 psf. The land area impacted by sonic boom overpressures stretches across the entire peninsula from Tampa to KSC in a path approximately 27 miles wide and 75 miles long (see figure 4). About 500,000 people and such cities as Orlando, St. Petersburg, Lakeland, and Winter Haven will experience some degree of overpressures, ranging up to 2.0 psf. The region impacted by the maximum overpressures—those in the range of 2.0 to 2.1 psf—is, however, relatively small and sparsely populated.

SONIC BOOM CONSIDERATIONS—VANDENBERG

Sonic boom overpressures impacting on land during Shuttle launch are not limited to northerly launches from KSC. A 70 degree launch inclination now planned for a Vandenberg Shuttle could result in overpressures as high as 30psf impacting off the California coast on the Channel Islands (see figure 5). Some marine scientists have stated that the force of such severe sonic booms (up to 30 psf) could disrupt critical wildlife colonies on these islands. The Channel Islands serve as the habitat for several rare or endangered species, including the brown pelican, and also provide the most diverse seal and sea lion rookery in North America. At present, 16,000 to 17,000 sea lions use one of these islands as a breeding ground and the only other breeding area is an island off the Alaska coast. Marine scientists are concerned that severe sonic booms could startle adult birds and marine mammals into abandoning their breeding areas, thus leaving the young subject to predators or starvation. Also, it is believed that the sonic booms could crush delicate seabird eggs and damage the eardrums of a variety of animals.

USAF officials are not unaware of this potential problem. A series of studies to examine the possible harm from this degree of overpressure are planned, partly in response to the growing concern among marine scientists. To move the most intense booms away from these islands, changes in launch velocities and inclination are being considered.

The reentry boom at Vandenberg is expected to affect a few thousand people and subject the Channel Islands to overpressures up to 2.0 psf (see figure 6).

SUMMARY AND CONCLUSIONS

We believe that insufficient data has been developed to allow an accurate determination of what degree of sonic boom overpressure would impact Florida land areas with a northerly KSC launch. Detailed analysis of appropriate trajectory data and other variable factors may provide sufficient basis to make sound decisions.

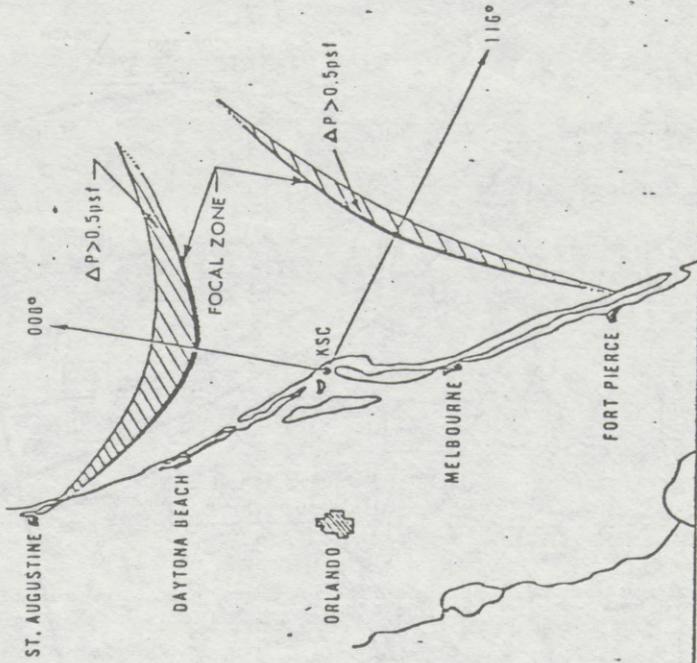
TABLE 1.—*Behavioral effects of sonic booms*

Sonic boom overpressures (psf) :	<i>Behavioral effects</i>
0.3-----	Orienting, but no startle response. Eyeblink response in 10 percent of subjects. No arm/hand movement.
0.6 to 2.3-----	Mixed pattern of orienting and startle responses. Eyeblink in about half of subjects. Arm/hand movements in about a quarter of subjects; no gross bodily movements.
2.7 to 6.5-----	Predominant pattern of startle responses. Eyeblink response in 90 percent of subjects. Arm/hand movements in more than half of subjects; gross body flexion in about a fourth of subjects.
7.1 to 13.4-----	Arm/hand movements in more than 90 percent of subjects.

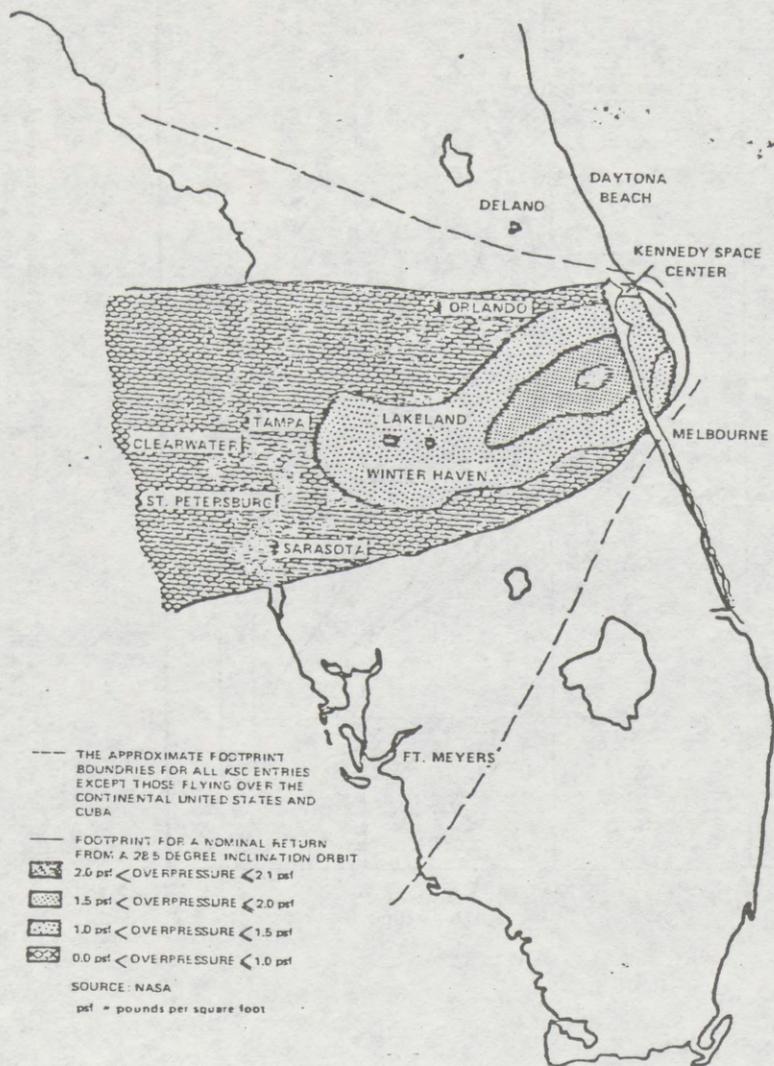
SOURCE.—“Environmental Impact Statement,” Space Shuttle Program, Draft, July 1977.

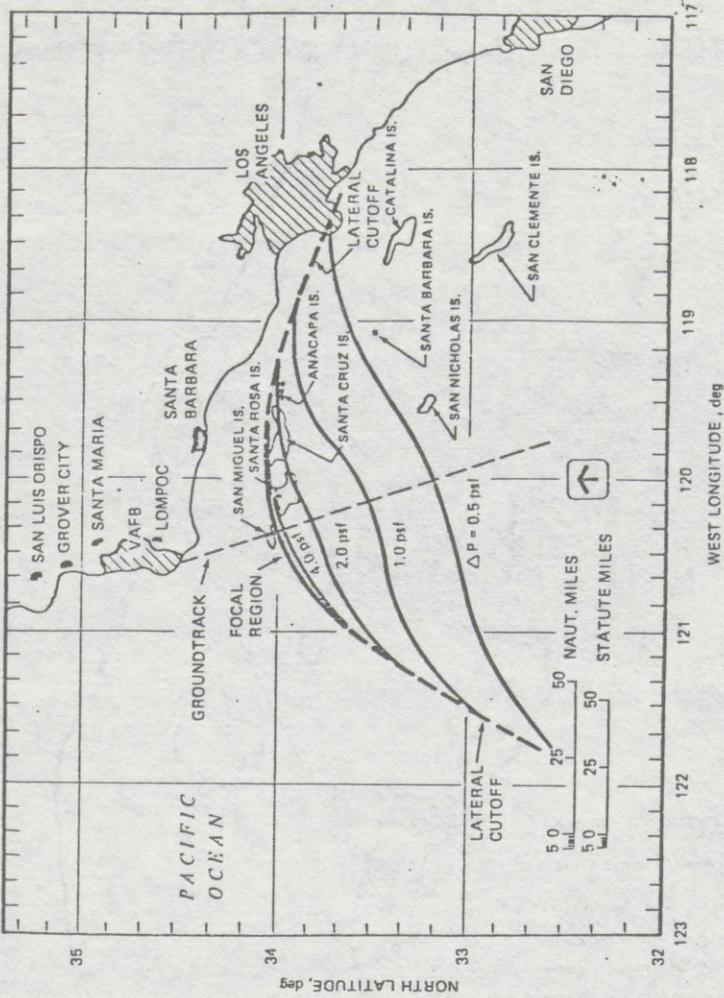
(Figures 2 through 6 follow:)

KSC LAUNCH AZIMUTH LIMITS WITH SONIC BOOM CONSTRAINT

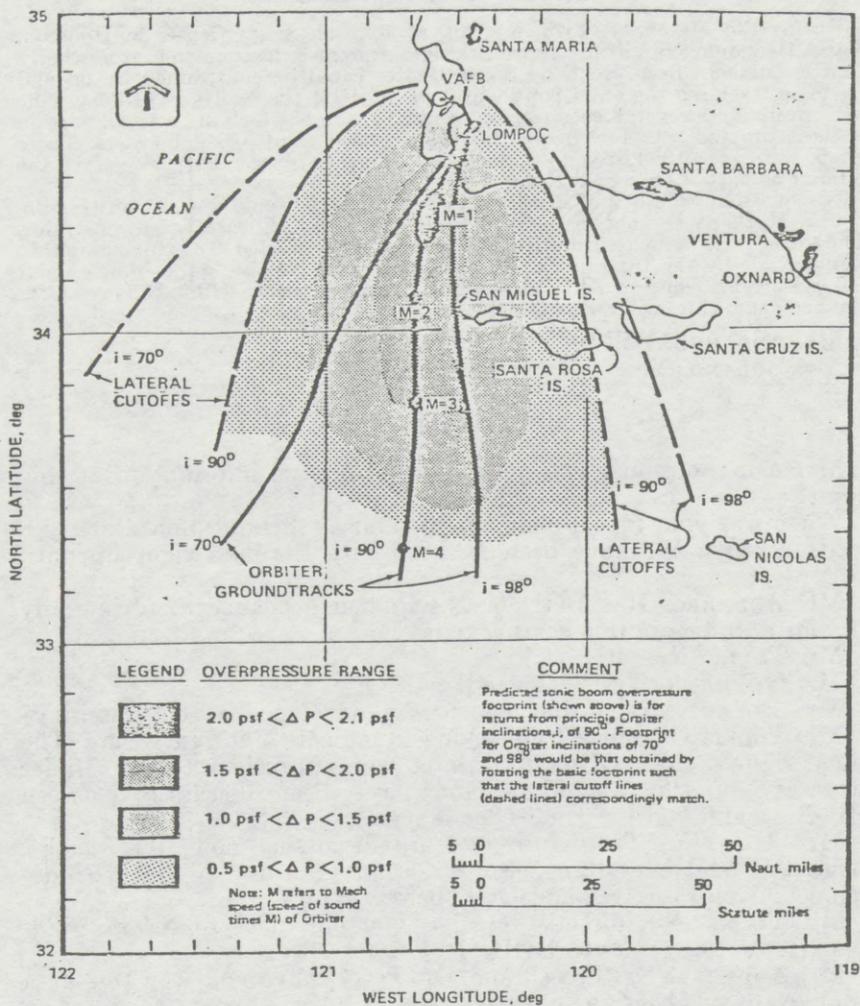


SPACE SHUTTLE SONIC BOOM OVERPRESSURES PREDICTED FOR KENNEDY SPACE CENTER APPROACHES





Predicted sea level footprint of sonic boom overpressures resulting from VAFB Shuttle launches on a 70° inclination.



Predicted footprint of sonic boom overpressures resulting from normal end-of-mission return of Orbiter to Vandenberg Air Force Base.

OIL AND GAS LEASE CONSIDERATIONS

During the March 17, 1978, meeting at Johnson Space Center in Houston, NASA Headquarters and JSC representatives expressed the concern that northerly Shuttle launches from Kennedy Space Center could be constrained by oil and gas lease tracts on the outer continental shelf (OCS). Basically, NASA's specific concern involves several lease tracts, located in waters which are a small portion of the estimated splashdown area for the Shuttle's solid rocket boosters. These tracts were recently leased to commercial interests by the Department of the Interior as part of OCS Sale Number 43.

We question whether offshore oil and gas leases would be as constraining against northerly launches as indicated by NASA. If such leases are a constraint, then all easterly launches from KSC will be similarly affected. To explain, another planned sale by the Interior Department, OCS Sale Number 54, contains about 160 lease tracts which could be affected by Shuttle launches within the presently-planned azimuth range. See figure 7.

Mr. ADDABBO. Will the chairman yield?

Mr. BOLAND. Yes.

DISCUSSION OF GAO REPORT

Mr. ADDABBO. Just one question for my own information at this point.

When was your report completed, as far as this question?

Mr. TOLER. We have been working with the data right up until yesterday.

Mr. ADDABBO. Has DOD or NASA had a chance to review any of your data before this hearing today?

Mr. TOLER. Yes sir.

Mr. GUTMANN. Yes sir, indeed.

Mr. BOLAND. Even that which was developed as of yesterday?

Mr. TOLER. Of course I am trying to indicate a currency here. The latest figures that we have I think were furnished to the Under Secretary of the Air Force and have been discussed between Mr. Gutmann and the Under Secretary.

Mr. ADDABBO. The figures we are discussing now, the weight, inclination and everything else, was that information that you developed given to NASA and DOD before today?

Mr. TOLER. Not directly by myself or our office to NASA headquarters, but certainly to DOD.

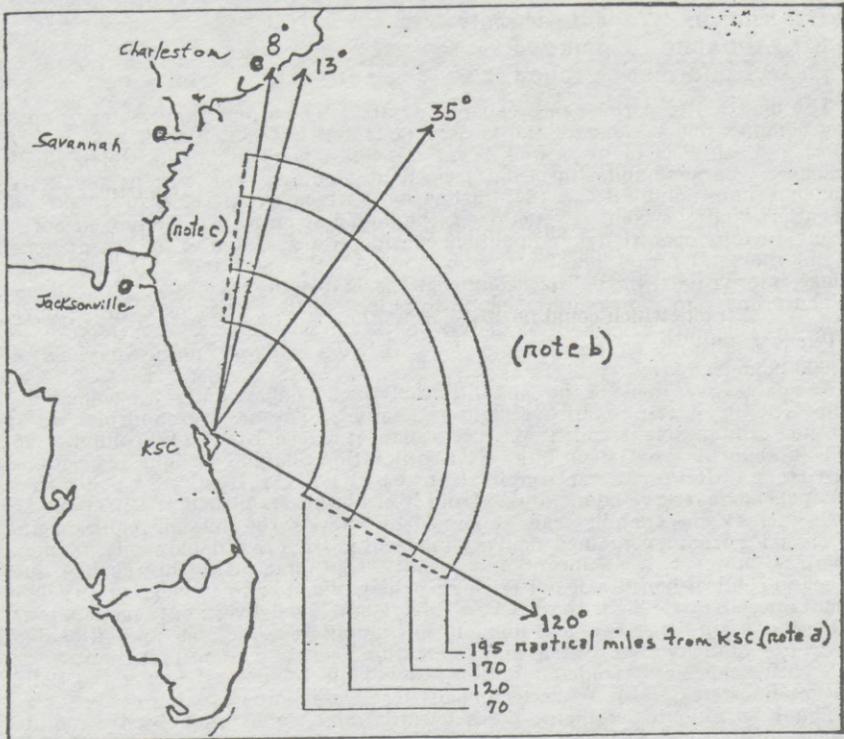
Mr. ADDABBO. Dr. Frosch and Dr. Perry, have you seen this data prior to today's hearings?

Dr. FROSCH. We have only seen an earlier draft report as of, I guess, a month or so ago. We have not seen any of these data.

Mr. ADDABBO. In this draft report, I imagine they made these findings.

Could you not have within that time been able to develop an answer to them, if there was a specific answer, where their computations were in error. So we wouldn't have this haze before us today. So that we could have seen a chart here by GAO this morning explaining how they computed their findings, and a direct answer by NASA and DOD as to where they thought GAO had made an error, or if there is an error?

Dr. FROSCH. That report didn't have enough computational detail in it to do that, and it did not have the 34,000 figure, as I recall.



Notes:

a/According to NASA, the area within a 195-nautical mile-radius of the launch site has potential hazards. For example sonic boom overpressures may focus in the range of 70-120 nautical miles. The solid rocket boosters will splashdown 120-170 nautical miles downrange. Also, for a return-to-launch-site abort maneuver, the external tank's fuel will be dispersed and the tank dropped downrange at about 170-195 nautical miles.

FIGURE 7.—Oil and Gas Lease Considerations

a According to NASA, the area within a 195-nautical mile-radius of the launch site has potential hazards. For example sonic boom overpressures may focus in the range of 70-120 nautical miles. The solid rocket boosters will splashdown 120-170 nautical miles downrange. Also, for a return-to-launch-site abort maneuver, the external tank's fuel will be dispersed and the tank dropped downrange at about 170-195 nautical miles.

b Under present plans, KSC will be used for easterly launches at azimuths ranging from 35 to 120 degrees. Located between these azimuths are approximately 160 potential lease tracts, which are part of the Interior Department's Proposed OCS Sale Number 54. Tract identification is continuing; sales are tentatively scheduled to begin in late 1979.

c Located within the azimuth range of 8 to 13 degrees are approximately 97 tracts, which are part of OCS Sale Number 43. Tract identification has been completed and several lease bids have been made. For example, along the 13 degrees azimuth, ten lease bids have been submitted—five of the tracts under bid are located in waters which are a very small portion of the estimated SRB splashdown area.

Mr. ADDABBO. If GAO within the next 2 hours gives you their computations, how soon can you give to this committee and GAO an analysis of where GAO has made an error in their computation?

Dr. FROSCHE. Probably in a couple of days, Mr. Addabbo.

Mr. ADDABBO. Before we mark up the appropriation bill, I hope.

Dr. FROSC. We will certainly try.
Mr. ADDABBO. Thank you.
[NASA information follows:]

The question of performance capability outside of current range safety limits is a complex one because of the variety of factors associated with risk, intact abort and safety of flight as well as the mission dependent factors which affect timeliness, cargo manifesting, and propellant loadings. The current northerly launch azimuth limit is 35° (57° inclination), which avoids land overflight on ascent. If land overflight is sanctioned, the launch azimuth can be moved north as governed by operational and political considerations related to the ascent sonic boom, the solid rocket booster reentry and impact, abort requirements, range safety, international and political complications, and environmental considerations.

The primary mission requirement in question is called Mission 4, to be flown from Vandenberg AFB, requiring delivery of 32,000 pounds to a 98° inclination in a 150 NM altitude circular orbit and return from orbit of another payload of 25,000 pounds.

An analysis was made of the capability to fly such a deploy and retrieve missions from KSC by waiving land overflight restrictions. The basic groundrules were: baseline orbiter weight and SSME performance; external tank (ET) number 26 and subsequent; yaw steer after SRB separation; land overflight restrictions waived; and SRB performance equivalent to a 70° F SRM. It is NASA policy that a management reserve be maintained and it has been established at 1270 pounds.

An increase in capability can be gained by altering the mission requirements by changing from a combined delivery/retrieval mission to a deploy only mission. There is, however, a significant cost penalty associated with this change due either to the lost benefits of not retrieving the payload or to the cost of an additional Space Shuttle flight to retrieve the payload. The delivery only mode allows reduction of crew members and mission time, manifest reductions, and offloading of Orbiter Maneuvering System and Recreation Control System propellants.

A performance/cost trade-off option is available by not retrieving the Solid Rocket Boosters (SRB). While technically feasible, it imposes a net cost penalty of about \$8 million per flight, poses hazards, and would undoubtedly require salvage operations. Deletion of the SRB recovery capability removes 14,858 pounds of weight and gains 1259 pounds of payload capability.

A summary of the capabilities at various azimuths is given below. The payload requirement is 32,000 pounds.

Launch azimuth	Deploy/retrieve		Deploy only without SRB recovery
	With SRB recovery	Without SRB recovery	
8°	26,229	27,488	31,075
10°	24,819	26,078	29,665
13°	22,455	23,714	27,301
19°	17,037	18,295	21,882

Launch azimuths of 8°, 10°, and 13° impose severe sonic boom impingements on land north of the launch site. The 19° launch azimuth limits the impingement to a maximum of two pounds per square foot overpressure under *nominal* conditions, which do not include effects of trajectory dispersions, winds, and temperature inversions. Since the maximum overpressures at the focal zone could be between 20 and 30 pounds per square foot, movement of the sonic boom footprint due to off nominal conditions poses a risk of land impingement of damaging overpressures much greater than 2 pounds per square foot. Additionally, for 8° and 10° launch azimuths, the SRB impact area includes water depths below minimum, thus endangering the ocean bottom environment and posing a hazard to shipping if not recovered or salvaged. Also, for the 8°, 10°, and 13° launch azimuths, the SRB impact area, and the ET impact area for some aborts, as well as their reentry sonic booms, impact among oil and gas lease parcels opened for sale on March 28, 1978.

Fundamentally, the Congress is being asked to approve a national policy that overflight is acceptable. The NASA, DOD, the Department of State, and the Office of Management and Budget consider that overflight of the Eastern United

States, Canada, and the Soviet Union is unacceptable. Moreover, the performance analyses show that even with overflight the critical DOD payload program cannot be accommodated. Finally in the long term, a four or five orbiter fleet/two-site operation is in the best interests of the United States, both from the cost effectiveness standpoint and because decisions made now will establish the future level of this nation's space capability for many years. The issues and alternatives are complex and the stakes are high—scientific and technological leadership, national security, and international prestige. Moving forward now with an adequate orbiter fleet/two-site operation will enhance this nation's posture in space and provide a means for taking full advantage of new opportunities in the future exploitation of space.

[GAO information follows:]

A KSC-launched Space Shuttle can carry over 32,000 pounds to 98-degree inclination orbits. GAO met with NASA and DOD on several occasions and reached agreement that payload requirements of 32,000 pounds could be launched out of Kennedy by making changes to the launch trajectory and mission configuration. There are remaining differences of opinion concerning safety considerations.

Shuttle experts agree that the most critical phase of a Shuttle launch is between lift-off and solid rocket booster (SRB) separation. This phase will have been completed long before land overflight occurs on a northerly launch from Kennedy. SRB separation takes place over the ocean 31 miles from the launch site. The orbiter and external tank continue ascending over 314 miles of open ocean and will be about 70 miles high when land overflight begins.

With regard to safety considerations, we believe that if NASA meets its reliability goals there will be relatively minor risk to the U.S. and Canadian population. Actual Space Shuttle reliability, of course, must be demonstrated. The exact number of Shuttle launches required to gain confidence in the Shuttle's performance reliability has not been determined. By June 1983, however, when polar Shuttle launches are scheduled to begin, the STS will have had over 3-years experience, entailing over 50 Shuttle flights. This would constitute a strong basis for assuming that these flights will provide a sufficient "shake down" period in which any problems will be identified and corrected. If uncertainties and problems still exist after 3 or 4 years of operations, there would be a serious question concerning the viability of the entire Shuttle program.

Mr. BOLAND. Let me ask the next question of course which is related to the one with respect to weight.

DOD PAYLOAD CAPABILITY REQUIREMENTS

How many defense-related missions currently planned will require a payload capability or do require a payload capability in excess of 22,000 pounds for polar orbit?

Dr. PERRY. Two per year, Mr. Boland.

Mr. BOLAND. Can these two or three missions be launched by TITAN III?

Dr. PERRY. For the period between now and 1985 roughly, they can be launched by the TITAN III. The programs that we would expect to launch in the post-1985 period on the Shuttle would have a weight and volume that is not accommodated by the current TITANs, so we would have to redesign. We would have to have less capable payloads than we are now planning to have post-1985 if we were limited to the current TITANs.

MAINTAINING TITAN-III LAUNCH CAPABILITY

Mr. BOLAND. What would be the cost-benefit trade off of maintaining a launch capability at Vandenberg for the two or three annual TITAN III launches required for these satellites and in building only one Shuttle launch site at Kennedy against the cost of building and operating two Shuttle launch sites?

It is my understanding that one side of the cost-benefit argument is that the GAO indicates that it will cost approximately \$2.6 billion for manpower to operate those facilities over the 12-year Shuttle period, so the question really is, would it be cheaper than \$3.5 billion to maintain an extremely low level launch capability of TITAN III's at Vandenberg during the Shuttle period?

Dr. PERRY. First of all, Mr. Chairman, I can't reconstruct the \$3.5 billion figure. Our current estimates of the costs of the construction at Vandenberg is \$900 million.

To that, to get any other number you have to add the yearly operations and maintenance costs, and how big that number becomes depends on how many years you want to add it up. If you add it up to 10 years, you get one number, 20 years another number. In any event, a significant portion of the operation and maintenance costs are going to accrue at whatever facility you launch it.

Mr. BOLAND. We are addressing the natural dollar comparisons relative to the questions I ask. If you cannot provide it now, will you do so for the record?

Dr. PERRY. Yes, we can, Mr. Chairman.

[DOD information follows:]

The cost of retaining an ELV capability at VAFB for launch of only the heavy DOD payloads while transitioning all other payloads to KSC is about \$100 million more than the current two site baseline.

[GAO information follows:]

GAO's position is that maintaining expendables at Vandenberg is not required since the Shuttle capability from Kennedy appears adequate to accommodate DOD's heaviest payloads. However, our analysis of the cost of this alternative of not building and operating Vandenberg shuttle facilities, but launching heavy DOD payloads on expendables from Vandenberg is as follows.

COST ADVANTAGES OF NOT BUILDING AND OPERATING VANDENBERG, BUT LAUNCHING HEAVY DOD PAYLOADS ON EXPENDABLES FROM VANDENBERG

[In billions of real year dollars]

Launch rate from KSC	Cost savings of not building and operating Vandenberg	Cost of 2 expendable launches per year from Vandenberg for heavy DOD payloads	Net cost advantages of reduced Vandenberg Shuttle facilities
40.....	3.5	2.3	1.2
60.....	2.3	2.3

Details and sources for the \$2.3 billion cost figure launching the heavy DOD payloads on expendables from Vandenberg are given in the following table:

COST COMPUTATION OF LAUNCHING HEAVY
DOD PAYLOADS ON EXPENDABLE LAUNCH VEHICLES
FROM VANDENBERG AFB
(MILLIONS)

Nature of Costs (in FY 1979 dollars) <u>Incurred</u>	<u>1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Research and Development, Upgrade Titan Launch Vehicle (note a)	\$198.00						
Titan 34D Launch Vehicle (2 per year at \$58 million each) (note b)					\$116.00	\$116.00	\$116.00
Titan III 7 Launch Vehicle (2 per year at \$59 million each) (note c)							
Launch Operations Support (for 2 flights per year) (note d)							
Totals (in FY 1979 Dollars)	<u>\$198.00</u>				<u>\$116.00</u>	<u>\$116.00</u>	<u>\$116.00</u>
Conversion Factors (at 7 percent)	1.0000	1.0700	1.1449	1.2250	1.3108	1.4026	1.5007
Totals (in Real Year Dollars)	<u>\$198.00</u>				<u>\$152.05</u>	<u>\$162.70</u>	<u>\$174.08</u>

<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>Totals</u>
						\$ 198.00
						348.00
\$118.00	\$118.00	\$118.00	\$118.00	\$118.00	\$118.00	708.00
<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>156.00</u>
<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$1,410.00</u>
1.6058	1.7182	1.8385	1.9672	2.1049	2.2522	
<u>\$231.24</u>	<u>247.42</u>	<u>\$264.74</u>	<u>\$283.28</u>	<u>\$303.11</u>	<u>\$324.32</u>	<u>\$2,340.94</u>
						or
						<u>\$2.3-billion</u>

Notes:

- a/This cost, provided by Headquarters USAF/RDS, is the estimated cost required to upgrade the Titan launch vehicle from its present 5-1/2 segments to 7 segments. A 7-segment vehicle would be required if the payload weight growth projected after 1985 materializes.
- b/The unit cost of this 5-1/2 segment launch vehicle (\$58 million in FY 1979 dollars) was provided by Headquarters USAF/RDS and is based on a production rate of two per year. The Titan 34D costs shown here may be somewhat overstated in terms of the option under study. For example, even under current planning DOD will procure several of these vehicles, in varying stages of completion, to provide a Shuttle backup posture for defense payloads at Vandenberg through 1985. Thus, part of these costs will be incurred in either alternative-- Shuttle at Vandenberg or expendables at Vandenberg; the option under study should exclude common costs and analyze only additional costs.
- c/The unit cost of the Titan III (\$59 million in FY 1979 dollars) was provided by Headquarters USAF/RDS and is based on a production rate of two per year. If DOD's payloads do not experience the projected weight growth, this 7-segment launch vehicle would not be required.
- d/The \$26 million (FY 1979 dollars) cost for launching 2 expendable vehicles per year from Vandenberg was provided by Headquarters USAF/RDS. Under the proposed 2 Shuttle sites/5 orbiter fleet scenario, expendable launch vehicle support costs will be incurred at Vandenberg through 1985. Our analysis here included only those additional costs which would be incurred to fly the heavy DOD payloads on expendables from Vandenberg if Shuttle facilities were not built; thus, the additional launch support costs begin in 1986.

Mr. BOLAND. Now a weight question for you to answer, Dr. Frosch.

SPACE LAB WEIGHT REQUIREMENTS

What is the maximum weight requirement for currently planned Spacelab flights in a 98-degree inclination orbit?

Mr. YARDLEY. Mr. Chairman, I don't know if we have got that precise number, but our Spacelabs are usually limited by the down weight of 32,000 pounds. Now when you add consumables to that, we would like to have a launch capability of something like 38,000 to 40,000 pounds. But into a 98-degree orbit from Vandenberg Air Force Base, we would be limited to about 32,000 pounds.

SPACE LAB FLIGHTS PLANNED FOR 487 MISSION MODEL

Mr. BOLAND. How many of those Spacelab flights are also currently planned in the 487 mission model?

Mr. YARDLEY. We will have to furnish it to you.

[NASA information follows:]

There are approximately 39 Spacelab flights to be launched into a polar orbit from VAFB and their weight ranges from about 22,000 up to 35,600 lbs. Twenty-eight of these are dedicated Spacelab flights whose total weight exceeds the capability of the Shuttle when launched with a "dog leg" maneuver into the required inclination. The remaining eleven Spacelab flights are flown with other cargo which could be reconfigured into alternate payload groupings to reduce the total weight of the flights to acceptable limits. The reconfiguration would result in the addition of several Shuttle flights to accommodate the restructured Spacelab flight cargo on the Shuttle.

EFFECT OF WEIGHT LIMITATION ON SPACELAB FLIGHTS FROM KSC

Mr. BOLAND. What we are trying to get at here is how would the 22,000-pound weight limitation affect Spacelab flights flown out of Kennedy at a 98-degree incline orbit.

Mr. YARDLEY. I don't think you could fly them at all. I think with just 22,000 pounds of payload you just don't have enough weight margin left over for experiments or consumables.

[GAO Information follows:]

A KSC-launched Space Shuttle can carry over 32,000 pounds to 98-degrees inclination orbits. To accomplish northerly launches from KSC to polar and near-polar orbits, the Space Shuttle must change its launch trajectory in flight.

A KSC-based STS can accommodate all of the payloads, civil (including space-lab) and military, projected for the 1980-91 period, including those projected for high inclination orbits.

Pursuant to the Chairman's directive that GAO, NASA, and DOD get together after the hearings and reconcile their differences on payload carrying capabilities, a meeting was held at Johnson Space Center on March 17, 1978. Headquarters representatives from all agencies were present. At this meeting, tentative agreement was reached on the following performance figures:

Shuttle performance capability for northerly launches from KSC (assuming initial launch ascent azimuths of 8, 10, 13, and 19 degrees, with a subsequent dog leg maneuver to obtain a 98 degrees—150 nautical miles orbit

Initial launch ascent azimuth (degrees) :	Weight-carrying capability (pounds)
8.....	34,922
10.....	33,512
13.....	31,148
19.....	25,729

The figures shown above do not reflect the less severe wind conditions that exist at KSC as compared to Vandenberg which could result in additional performance capability, perhaps ranging from 750 to 2,100 pounds depending on actual winds at time of launch. Additionally, NASA has underway several studies involving ways to modify the Shuttle's design to give additional performance capability ranging from 2,000 to 20,000 pounds. One of the studies involves adding a catalyst to the SRB propellant, which could improve the Shuttle's capability by 5,000 pounds. The studies, are targeted for completion in June 1978.

As a point of understanding for the record, we note that the performance figures discussed at the March 17th meeting are not based on system changes which affect abort procedures or in any way compromise orbiter and crew safety. The figures do not include any deployment manifest deletions from the orbiter, that is, no items were off-loaded from the standard delivery configuration even though it was generally recognized that certain non-safety items (televisions, cameras, etc.) were not mission-essential.

ONE LAUNCH SITE VS. TWO LAUNCH SITES

Mr. BOLAND. Let me get back to the question on one site versus two sites, and again concerning the economic implications of that decision.

Does everyone here agree, including the GAO, that we would have to maintain a low level expendable booster capability of TITAN III's at Vandenberg in order to meet all of the currently planned defense requirements if we build only one site at Kennedy? Does everyone agree with that?

Mr. GUTMANN. No, sir.

Mr. BOLAND. GAO does not agree with that.

Mr. GUTMANN. No sir, we do not. We think that Kennedy can handle all civilian and defense payloads, including spacelab flights.

Mr. BOLAND. In a question at a recent HUD Subcommittee on NASA hearings I said, "In addition everything NASA has ever told this committee about the key to the success of the Shuttle rests on the economic assumption that expendable launch vehicles will be priced out of the market. That is a fair statement, isn't it?"

Dr. Frosch's response is "Yes".

Then I asked, "Clearly the Shuttle has no economic advantage if we have to operate both the Shuttle system and the conventional booster system. In fact, that kind of situation would be much more expensive and not less. I don't think we could disagree with that."

Your response was "No, sir."

Now let me ask the GAO essentially what you are asking the Congress to consider is to build one Shuttle launch site and maintain a conventional booster capability at Vandenberg for a very few super heavy defense payloads.

Are you absolutely convinced that by doing that, by operating both a Shuttle system and the conventional booster system, that it would not be more expensive than completely closing down all conventional booster operations?

Mr. GUTMANN. Sir, I think that our position is slightly different than that. We think that Kennedy can handle the most demanding payloads that are presently coming out of Vandenberg together with those payloads planned for the future.

Now the expendable vehicles might be usable from a cost-benefit standpoint. It might well be cheaper for some of DOD's launches to continue to be handled with expendables, rather than build Vandenberg.

Mr. TOLER. But we are not advocating that expendables be retained since we believe KSC can handle all of the projected payloads, both civil and defense.

Mr. BOLAND. Do you have a response to this?

NORTHERLY LAUNCH ACCEPTABILITY

Dr. FROSCH. There is another aspect, Mr. Chairman, and that is the acceptability of a northerly launch.

In an easterly launch, there is a period of some seconds towards the end of the launch phase in which, if something went drastically wrong, the pieces would impact on land in Africa. In a northerly launch out of KSC, for any major catastrophe which occurs in the period from about 2½ minutes into flight until about 7 minutes of flight, the pieces would land in the Eastern U.S. and/or Canada. This difference I believe is tremendous. I have worried about it considerably since hearing of this proposal, and I can simply tell you where I come out.

RELIABILITY FACTORS OF NORTHERLY LAUNCH

I am unwilling to accept the responsibility of either making such launches or recommending them to the President, and I do not believe that they can be considered to be acceptable. [Administrator's note: An exception might be in case of severe national emergency.] The safety figures, the probability of impact figures that Mr. Gutmann gave, are purely theoretical figures. As related to the assumed reliability of the Apollo, particular figures that he quoted from the report, as far as we can tell, are equal to those figures multiplied by a factor of 30.

We have no statistics to know whether we are that good. There is no question that we will build the Space Shuttle as reliably as we possibly can for the obvious reason of the safety of the crew. It is one thing to talk about reliability for safety of the crew, a small number of people who are volunteers and want to fly that mission, and it is quite another to talk about the safety of overflight with potential impact in case of a catastrophe over a populated area with 50 million people in it.

Secondly, with regard to the numbers that were quoted for reliability, we are familiar, we believe, with the report from which they were taken. Those are the most optimistic numbers possible to be obtained from that report, and they assume that most of the people in the area will be inside protected areas, that is, inside buildings. They also used the case where a system was on the Space Transportation System for the dispersal of the external tank propellants.

If you take, for example, the numbers that don't have everybody in shelter, and don't have dispersal of the fuel, the theoretical estimates—and I emphasize again that they are estimates—are different from the numbers presented by a factor of 1,000. As a result, we are not talking about even a theoretical number of one part in 166,000, and it is meaningless to quote it to seven significant figures. We are talking about a possibility of damage, of danger in case of catastrophe, which we will, of course, try to avoid, of 1 in 166 I am afraid that I must characterize the suggestion as irresponsible. I would not care to assume that responsibility.

[GAO information follows:]

The probability of impact figures used by GAO were based on a vehicle reliability goal suggested by Aerospace in a 1969 study. The numbers came directly from a 1976 Aerospace Study which used the same reliability goal but also included additional data on the Saturn V and Titan IIIC vehicles. The GAO did not evolve the Shuttle reliability by factoring the Saturn V vehicle reliability but rather quoted from Aerospace studies.

The assumption for sheltering and fuel dispersion used in the 1976 Aerospace study of Shuttle were mutually agreed to by GAO, Aerospace, and SAMSO as the most reasonable assumptions to use for northerly KSC launches. The sheltering aspect placed a portion of the affected population under some sort of structure as would be reasonable and consistent with lifestyle in the U.S. This does not preclude injury to a sheltered individual but does afford that person a certain degree of protection. The fuel dispersion system assumption is based on the range safety package which is included on all test and developmental flights of the Shuttle. If the external tank has to be destroyed, the fuel remaining in the tank would be consumed in an explosion or dispersed into the atmosphere.

STS MISSION MODEL

Mr. BOLAND. Let me come back to another question we asked at the NASA hearings, with which you are familiar.

The original mission model for the 12-year Shuttle period was pegged at about 500 missions; that is correct, is it not?

With the proposed four-orbiter fleet, NASA now pegs the mission model at 487 missions.

Dr. FROSCHE. That is the top of the mission model capability with four orbiters.

THREE-ORBITER FLEET CAPABILITY

Mr. BOLAND. Do I understand the GAO correctly in that they maintain that a three-orbiter fleet could fly the full 487 mission model with the exception of a few superheavy payloads? Is that correct?

Mr. DAY. Getting back to the earlier point, for just a moment, we could still fly the superheavy payloads. That point I think is one we would stick with, at least for the present.

Mr. Toler could better answer the 487 flight question.

Mr. TOLER. The three orbiters which we speak of could handle approximately, and this is based on NASA and DOD calculations, 40 flights per year, which is less than 487 during 1980-91. So you could not do it with three orbiters.

[GAO information follows:]

The total number of launches proposed for the Space Shuttle from both Kennedy and Vandenberg through 1992 depends upon which mission model is referenced. NASA officials have stated that the mission models are not to be considered firm space requirements. The models are only planning estimates and have been revised almost annually since 1971. The 1977 or current model shows 552 Shuttle flights.

The basic question, however, is not how many launches have been proposed by NASA or anyone else. The size of future space programs is a matter for the national political leadership to decide. The basic issue is how many orbiters are needed to provide a balanced and viable space program. We believe three orbiters can support space programs which represent a substantial increase over past activity, whether measured in terms of launch rates, payload levels, or mission modes. For example, the Aerospace Corporation of California has done a number of orbiter fleetsizing studies in support of joint NASA/Air Force planning activities. The studies placed particular emphasis on repeatability of test conditions to establish confidence in specific fleet-sizing options. A KSC-only, three orbiter configuration was examined using a wide range of inputs representing 210 con-

secutive years—that is, 21 scenarios over consecutive 10-year periods. The studies concluded that three orbiters operating from KSC could support about 40 flights per year. At this annual launch rate, given the large cargo bay, and assuming only two payloads per flight, three orbiters could support 80 payloads a year—nearly double the nation's past payload activity. For instance, during 1967–76 the U.S. launched about 43 payloads a year.

We emphasize that the 40 flights/80 payloads a year are conservative figures. NASA describes the orbiter's large cargo bay as having a payload-carrying capability equivalent to that of two Atlas-Centaur or four Delta expendable launch vehicles. Also, using the Spacelab and the Long Duration Exposure Facility (LDEF), multiple experiments are possible with a single Shuttle launch; almost one-half of the payloads in the mission models involve the Spacelab.

It is obvious that the duration of Spacelab flights affects orbiter availability for other missions, most of which require only 2 or 3 days from lift-off to return. However, the Aerospace corporation studies, which show that 3 orbiters can support 40 flights per year, used an average mission duration of 8.0 days; this average represents a distribution derived from a NASA model which included Spacelab missions. The fairly long average mission duration, 8.0 days, limited the flight rate to 40 launches per year. An earlier series of studies using shorter missions (with an average duration of 4.6 days) allowed a three-orbiter fleet to support up to 48 flights per year. The model, presented by Dr. Frosch in these hearings, has an average mission duration of 5.4 days. Here again, this is another indicator of the conservativeness of the 40 launches a year.

Additional indicators are the test conditions used in the Aerospace studies. Groundrules in the studies include the following assumptions:

- a two-week (205 hours) turnaround time, using two shifts per day. (The two-week period included a one-day contingency hold to absorb ground support anomalies.);
- 45 percent of all launches encounter ground support delays ranging from one to eight days;
- a priority subset of nine launches, representing critical DOD and launch-window constrained NASA flights; and
- each orbiter was down 90 days every third year for extensive refurbishment and overhaul.

FOUR-ORBITER FLEET CAPABILITY

Mr. BOLAND. Do I understand correctly that the GAO suggestion is that a fourth orbiter should be purchased to provide insurance against the attrition of one of the three orbiters?

Mr. TOLER. GAO feels that attrition should certainly be a consideration of this committee in deciding on the number of orbiters.

Mr. BOLAND. The GAO's analysis is simply one orbiter less than what we had been discussing with NASA in our 1979 hearings. Our discussion centered around the question of whether or not you needed a fifth orbiter as insurance for a four-orbiter fleet in case of the attrition of one of the four orbiters.

Let me quote you from our hearings. Mr. Traxler asked a question; you are responding to him:

Mr. TRAXLER. Moving on to the orbiter, talking about your flight traffic requirements, in the event an orbiter were damaged or destroyed say during the year 1984, you will have four orbiters operational. During that calendar year you currently have scheduled 43 flights. Of those flights, part of the reduced payload model of 487 missions, we understand that the maximum that the three orbiters at two sites can handle in a calendar year is approximately 30 to 35 flights. That is what you told us last week.

Now the question is, if you lose or damage an orbiter during calendar year 1985, how can you possibly meet the flight traffic requirement of 34 launches from Kennedy and the nine from Vandenberg?

Mr. Yardley responded: "We cannot make it." Dr. Lovelace agreed "We cannot do it."

Now I want to ask the GAO, after reading that exchange between Mr. Traxler and Mr. Yardley and Dr. Lovelace, how in 1984 you

could fly the current schedule of 43 flights with only three orbiters when NASA testified only six weeks ago that it could not be done?

Mr. TOLER. I can only presume that NASA's figures are based on a five-day, two shift schedule—

Mr. BOLAND. Mr. Yardley is shaking his head.

Mr. YARDLEY. Our figures which are published in the report prepared by the DOD and NASA for the OMB, which GAO has had for some months, show that 30 flights per year can be launched on a five-day work week; 35 on a seven-day work week, if you have two sites. If you have only one site, which is the GAO recommendation, then you can launch 32 flights with three orbiters during a five-day work week and 39 flights during a seven-day work week.

So you see, in that case, on a seven-day week we are almost up to his forty.

Mr. TOLER. Our 40 flights per year though, in clarification, is based on the NASA data.

Mr. YARDLEY. This is the only data that NASA has published.

Mr. SPROWLS. The 40 flights that we are quoting is the computer simulation model that Aerospace has been running for NASA and DOD. It is a conservative figure of what could be sustained with three orbiters. It is 39 plus or minus two flights a year.

We use an average of 40 flights a year. Based on the assumptions that NASA has always had in the program such as turn-around time and mission duration, three orbiters should be able to sustain over 50 flights a year.

Mr. BOLAND. Do you want to respond to that?

Mr. YARDLEY. I would like to make just one comment. A number of the figures in Mr. Gutmann's statement regarding how many flights you could accomplish appear to be based on a much more simplistic way of computing flights, rather than on a more realistic one which did account for weather, payload requirements to reconfigure the orbiter, and many other factors. As Dr. Frosch showed you, we are assuming 252-hour turnaround at KSC to begin with, getting down to 200 hours at KSC in about five or six years. If you assume 160 hours for turn-around, that makes quite a difference on how many flights you can fly.

Mr. TOLER. Our statistics, which are again based on the Aerospace study, did take into account the types of things that he is speaking to here.

ONE LAUNCH SITE VS. TWO LAUNCH SITES

Mr. BOLAND. Let me ask one more question about the two-site issue.

Part of the argument in favor of the two sites is based on redundancy. For example, if you had a catastrophic accident on the launch at one site, you could switch launches to the other site. There may be some holes in that argument, however, and I want to explore this with you for a moment.

First let's assume that you had a catastrophic event at Vandenberg pad where, incidentally, you only have one pad for launching under the current plan. For the sake of argument let's say that the accident at Vandenberg rendered that launch site as useless for about six weeks. Now let's assume that in three weeks you had to launch a sensitive defense requirement satellite into a polar orbit, the question is, could

the back-up conventional TITAN IIIC boosters being held in reserve by the Air Force be prepared for launch in three weeks? Or will you have to use Kennedy and launch north over the continental United States?

General Coy. Until the backup capability is phased out at VAFB in FY 85 it will require four to six weeks to prepare a Titan III for launch. After FY 85, no backup capability is planned. However, I think the only time you would resort to northerly shuttle launches from KSC would be when the risk to national security posed by not flying the mission is considered to be greater than the risk to the population posed by overflight. That judgment would have to be made at the highest government levels.

Mr. BOLAND. Asked another way, if you had a catastrophic event at Kennedy that shut down the launch capability for six weeks, let's say three months, how would you launch payloads into orbit that require east-west launches? Could they be handled out of Vandenberg? If so, would you have to fly over land?

Dr. FROSCHE. I do not think we visualize any NASA payloads that would be so sensitive in a national security sense. We do not have any payloads like that which we could not wait the time. I cannot speak to the Defense payloads. But to launch them into equatorial orbit from Vandenberg, if they are heavy payloads so that you cannot afford extra fuel, one would certainly have to launch east over the United States.

Mr. BOLAND. We will recess until 2:00 o'clock.

AFTERNOON SESSION

SPACE SHUTTLE COSTS AND SCHEDULES

Mr. SIKES. The committee will come to order.

Projections provided the committee show that through fiscal 1983 DOD and NASA will spend about \$12.7 billion on the Space Shuttle. There have been cost increases in past years and schedule slippages. Given this past experience of underestimating costs and schedules, the committee would like to know how confident are the various witnesses that the current costs and schedules you are projecting are realistic?

Dr. FROSCHE. Shall I begin, Mr. Chairman?

Mr. SIKES. Yes, if you please.

Dr. FROSCHE. I think we would assess ourselves as having reasonably good confidence that the cost and schedule can be met. The cost changes in noninflated dollars, from the beginning of the program in 1972, are about 5 percent as I recall.

I do not know the full history of the schedule slippage, but I believe that any schedule slippage for the date of the first manned orbital flight was due to funding cutbacks in the past.

Mr. YARDLEY. In the early years there were some slips because of funding cutbacks by OMB, but the schedule for the first orbital flight has been constant for almost 5 years.

Dr. FROSCHE. I would add to my assessment that we are now in the crucial development test phase of the engines and the orbiter system, leading to the first orbital flight. It is over the period of the next 6 or 8 months that we will be finding out key issues. We know no reason

now why our estimates are not reasonable, but this is the period in which we are obtaining the most important data.

Mr. SIKES. Are there comments from the other witnesses?

Mr. GUTMAN. We really do not have a basis for evaluating the accuracy of that estimate, Mr. Sikes.

Mr. SIKES. Any others?

SPACE SHUTTLE COST RELATED TO DOD

Dr. PERRY. Mr. Chairman, relative to the DOD expenditures, estimating the total program cost to DOD through 1983, we have estimated that as \$1.5 billion and we think that estimate is accurate to within 20 percent.

SPACE SHUTTLE FULL OPERATIONAL CAPABILITY

Mr. SIKES. If the Shuttle were brought to full operational capability, would the cost be considerably more than the currently projected \$12.7 billion?

Dr. FROSCHE. I am not sure I understand the question, Mr. Chairman.

Mr. SIKES. Do you expect to operate the Shuttle at full capability?

Dr. FROSCHE. The various orbiters, as they are being built in the development and production program, will have slightly different capabilities. Orbiters 3 and 4 will have the full capability; the one that we have numbered 099 and 102 will have somewhat less than full capability. Mr. Yardley I think could estimate the differences.

Mr. YARDLEY. The 099 orbiter will be about 2,000 pounds under full capability and 102 will be about 3,000 pounds under.

Mr. SIKES. You are not anticipating full operational capability?

Dr. FROSCHE. Not with those two orbiters.

Mr. SIKES. I am trying to establish whether this is the cost or whether, if you were to increase the operational capability, the costs would be greater.

Mr. YARDLEY. That estimate includes the full costs of all 4 orbiters and launch facilities. Mr. Lilly points out there is no way you can increase the capability unless you buy more orbiters, more launch pads.

SCHEDULE SLIPPAGES RELATED TO EXPENDABLE LAUNCH VEHICLES

Mr. SIKES. Would the schedule slippages require additional expenditures for expendable launch vehicles?

Dr. FROSCHE. Depending on the length of slippage, if there were a significant delay we would have to purchase additional expendable launch vehicles to carry through the period of transition.

Mr. SIKES. At this reading are you apprehensive about additional slippages?

Dr. FROSCHE. I am concerned that there may be a possibility of slippages, if we have difficulty in our testing, but I know of no reason now to really anticipate that.

COST RELATED TO SCHEDULE SLIPPAGE

Mr. SIKES. What other costs would increase if slippages were to occur?

Dr. FROSCH. There would be additional time required in the development phase that would need to be budgeted for and there may be some other costs in the transition.

Mr. YARDLEY. I think mainly it would just be carrying on longer with the expendable launch vehicles.

VANDENBERG OPERATIONAL CAPABILITY

Mr. SIKES. The Fiscal 1979 budget shows the initial operating capability to date for the Vandenberg site has been delayed by 6 months. What was the reason for the delay?

General COY. The reason for delay, Mr. Chairman, was to rephase the program to make it compatible with the delivery of the orbiters from NASA.

IMPACT ON SHUTTLE LAUNCHES RELATED TO VANDENBERG OPERATIONAL CAPABILITY

Mr. SIKES. Will that delay have any impact on planned Shuttle launches or on the number of expendable launch vehicles required?

General COY. No, sir.

Mr. SIKES. Mr. Chairman, I have some additional questions I would like answered for the record.

[Clerk's note: The questions submitted by Mr. Sikes and the answers thereto follow.]

TITAN IIID BACKUP VEHICLES

Question: Last year a total of \$61.9 million was appropriated for the procurement of two Titan IIID/IUS launch vehicles as a backup capability to the Shuttle. The FY 1978 budget explained that one additional launch vehicle would be procured in FY 1979. The FY 1979 budget requests \$11.5 million for the Space Booster program, but apparently does not include funds for the third backup Titan/IUS. What program changes have caused these revised estimates?

DOD Answer: Subsequent to the appropriation approval last year, two existing Defense Support Program satellites were designated for retrofit from a Titan III launch configuration to a Space Shuttle launch configuration. This decision assures an early Defense Support Program transition to the Space Shuttle. This decision also eliminated the Air Force need for two expendable boosters: one for a pre-Shuttle launch and the backup booster previously planned for FY 1979.

Question: The \$11.5 million requested for the Space Booster program will provide for hot/fire demonstrations of the solid rocket motor and for launch vehicle fairing and hardware support. Would you describe the planned hot/fire demonstrations and explain why procurement funding is being used?

DOD Answer: The Titan III solid rocket motor hot/fire demonstrations will re-confirm the producibility of the motor's ablatative nozzle. The producer of the rayon fiber used to fabricate the ablatative nozzles is no longer in business. Prior to committing to flight the Titan III solid rocket motor nozzles that are built using a replacement material, a producibility demonstration is planned using

two production motors. This is somewhat analogous to production lot sampling tests.

Question: Dr. Perry's statement explains that the backup inventory of expendable launch vehicles consists of three complete Titan III's, four partially assembled vehicles, and four complete sets of parts. Provide a schedule for the record showing the cost by year, by program, to buy this inventory.

DOD Answer: The cost (in millions) for procurement, production engineering, hardware support, and propellants is as follows:

Program	Fiscal year 1978	Fiscal year 1979	Fiscal years 1980-82	Total
PE 35119F	\$59.0	\$5.2	\$12.0	\$76.2
[Deleted]	[Deleted]	[Deleted]	[Deleted]	[Deleted]

Question. What do you mean by "four partially assembled vehicles?" Why are they needed?

DOD Answer. The four partially assembled vehicles consist of Titan III(34)D subassemblies and details that require about 12 additional months of effort for delivery of fully assembled vehicles. These backup assets provide the ability to assemble additional completed vehicles if some of the fully assembled backup vehicles are launched to support mission requirements. The quantity, which is reviewed annually, provides a limited ability to support [deleted] missions.

Question. Why do you need four complete sets of parts?

DOD Answer. The four sets of Titan III(34)D long lead material can be assembled into completed vehicles in about 24 months. If the Shuttle backup capability is used, these materials could be processed into subassemblies and details or, in a worst case scenario, into completed vehicles. The total DOD backup program is structured to minimize investments consistent with an assured launch capability for missions critical to national security and provides for measured investment in backup vehicles as we monitor the progress of the Shuttle program.

SHOULD SHUTTLE COSTS BE BUDGETED "ABOVE THE LINE"?

Question. Some officials have indicated that Shuttle transition costs should be "above the line." That is, these transition costs should be in addition to the normal baseline budgets for space activities. These officials justify this position on the grounds that during the transition period there will be little or no advantage to the Shuttle, just extra costs. Do NASA and DOD consider Shuttle costs as "above the line?"

DOD Answer. The DOD budget includes Shuttle transition related costs within the various payload Program Elements. While there will be investment costs associated with transition, we view the Shuttle as an economical program because of lower transportation costs and because of the unique capabilities the Shuttle offers to perform DOD missions more efficiently.

[NASA information follows:]

NASA does not require any additional funding for transition operations. All the NASA payloads in the Shuttle era are being designed for Shuttle accommodation and, therefore, require neither funding to

make the payloads dual compatible (capable of launch with Shuttle and expendable launch vehicles) nor funding for backup expendable launch vehicles in case of Shuttle delay or shutdown.

The question of "above the line" or "below the line" is not relevant.

OMB RECOMMENDATIONS ON FLEET SIZE

Mr. SIKES. Did the Office of Management and Budget in its review of the fiscal 1979 budget consider lowering the number of orbiters or recommending against construction of Vandenberg?

Dr. FROSCH. I cannot speak to all of the factors they considered. At one point in the discussions they certainly recommended a 3-orbiter program and I do not recall whether that was to include one site or two. I think at the point at which it went to the President, it was a recommendation for 3 orbiters and 2 launch sites; but what they considered previously probably included all possibilities. Certainly there were discussions of all possibilities.

Mr. SNODGRASS. Dr. Frosch, did NASA make an appeal to the President to overturn an OMB recommendation in essence or did OMB unilaterally withdraw the recommendation?

Dr. FROSCH. Neither, really. Early in the budget discussions we agreed with OMB that the issue of the structure of the Shuttle program would have to be a Presidential issue and that OMB and the Department of Defense and NASA would take that issue to the President. That issue was then considered separately, argued separately, and taken to the President separately.

Mr. SNODGRASS. OMB argued for 3 and you argued for 4?

Dr. FROSCH. We argued for 5.

Mr. SNODGRASS. OMB argued for 3?

Dr. FROSCH. 3.

Mr. SNODGRASS. And the President chose 4, decided on 4 orbiters and 2 launch sites and the maintenance of the capability for an option for a fifth orbiter.

Mr. SIKES. Mr. Chairman, place the following two questions in the record under my name.

[Clerk's note: The questions submitted by Mr. Sikes and the answers thereto follow.]

IUS COST CHANGES

Question. The fiscal year 1978 budget justification data showed that \$63.1 million would be required in FY 1979 for continued development of the Inertial Upper Stage. The actual FY 1979 budget request is for \$87.6 million. What caused the increase?

DOD Answer. The following factors account for the increase in funding identified in FY 1979 for the Inertial Upper Stage (IUS) development.

The Fiscal Year 1978 budget submittal identified \$63.1 million in FY 1979 for continued development of the basic two stage IUS. Funding for integration of the IUS to the Shuttle and development of an IUS third motor configuration was identified under the Kennedy Space Center (KSC) program category. Funding of the IUS/Shuttle integration and the evolutionary twin stage IUS configuration are now identified under the IUS program category. This transfer added

\$11.4 million to the \$63.1 million identified last year for IUS development in FY 1979.

A new program requirement for assembly and checkout of the IUS in the existing Solid Motor Assembly Building (SMAB) at Cape Canaveral Air Force Station caused an additional \$3.3 million increase in FY 1979 for design of the SMAB modifications.

The remaining \$9.8 million increase is the result of better requirements definition and cost data determined during the IUS Validation Phase (Sep 1976-Mar 1978). Included was the identification of additional payload requirements and the addition of COMSEC to the IUS design to protect classified payload data.

VANDENBERG COST CHANGE

Question. The FY 1978 budget also showed that \$157 million would be required in FY 1979 for procurement of equipment for Vandenberg Air Force Base. The actual FY 1979 request is for \$75.6 million. What caused the decrease.?

DOD Answer. Procurements for acquisition of a Shuttle capability at Vandenberg Air Force Base (VAFB) were rephased last year in accordance with later site activation need dates. This was primarily the result of a six month delay in the VAFB initial operational capability date, commensurate with the revised NASA delivery schedule for Orbiter 103 required to support VAFB activation, revised co-procurement dates with NASA, and better definition of requirements from the nearly complete Ground Support Systems definition contract (July 1976-June 1978).

COSTS FOR VANDENBERG FACILITY

Mr. SIKES. The GAO statement indicates it will cost \$1.2 billion to build Vandenberg and \$2.6 billion in manpower costs to operate the Vandenberg through 1992. Does the Department of Defense agree it will cost a total of \$3.8 billion to build and man Vandenberg through 1992?

General COY. The \$1.2 billion is our estimate of the investment cost and \$2.6 billion for the operating and maintenance cost through the 1991 time period.

Mr. SIKES. You said \$2.6 billion for operation?

General COY. Yes, sir.

Mr. SIKES. Did you concur in the \$1.2 billion to build?

General COY. That is the upper bound of our estimate.

Mr. SIKES. I shall have to suspend the hearings for a few moments because there is a rollcall in progress. We will be back just as quickly as we can.

Off the record.

[Discussion off the record.]

Mr. BOLAND. The committee will come to order.

As I understand it, Mr. Sikes asked DOD does DOD agree it will cost a total of \$3.8 billion to build and man Vandenberg through 1992. What was the answer to that?

General COY. The answer to the question was yes, we agree that \$1.2 billion is the upper bound of our estimate.

The other \$2.6 billion is operating and maintenance costs for Vandenberg over the period through 1991.

Mr. BOLAND. 1991. What is the response of GAO to that?

Mr. DAY. I am sorry, sir, was that with regard to the \$3.8 billion?

Mr. BOLAND. Yes. That is your figure, the \$3.8 billion, through 1992, am I correct?

Mr. DAY. It is based on the Department of Defense estimates.

Mr. BOLAND. You apparently agree with that figure.

Mr. DAY. Yes, sir.

Mr. BOLAND. Let me ask you whether or not these estimates include all costs?

For example, do the cost estimates include all mission-related equipment and facilities at Vandenberg, base support, down-range support, and similar expenditures? Is that correct?

[GAO information follows:]

GAO's estimated cost savings of \$3.5 billion consist of facilities investment (\$1.0 billion) and manpower costs (\$2.5 billion). The manpower figure is for both direct and indirect manpower for Shuttle operations at Vandenberg during fiscal years 1983-92. The figure does *not* include other direct and indirect costs at Vandenberg, such as those shown in the following chart.

OTHER VANDENBERG COSTS
(Millions of Fiscal Year 1975 Dollars)

	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	Totals
Cost Category											
Other Direct:											
Support equipment	\$31.1	\$13.2	\$ 6.3	\$ 3.8	\$ 3.8	\$ 3.8	\$ 3.8	\$ 3.8	\$ 3.8	\$ 1.0	\$ 74.4
spares	0.8	1.8	2.1	2.4	2.1	2.9	2.1	2.4	2.3	0.6	19.5
pad refurbishment	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.1	3.6
Subolies	3.9	9.3	10.9	12.4	10.9	14.7	10.9	12.4	11.6	3.1	100.1
Propellant											
Other Indirect:											
Utilities	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.1	2.8
Facilities											
maintenance	2.3	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.8	0.7	25.4
Totals	\$38.7	\$27.8	\$22.8	\$22.1	\$20.3	\$24.9	\$20.3	\$22.1	\$21.2	\$5.6	\$225.8

Notes: These costs, as shown here, are all in the Space Shuttle Preliminary Cost Data Base, dated June 1977, prepared by the Operations Resources Analysis Office, Johnson Space Center. We have converted these costs to real year amounts in the following chart.

OTHER VANDENBERG COSTS
(Millions of Real Year Dollars)

FY 1975 Amounts (See preceding chart)	Conversion Factor	Real Year Amounts
1983 \$38.7	x 1.785	= \$ 69.0795
1984 27.8	x 1.91	= 53.098
1985 22.8	x 2.0437	= 46.59636
1986 22.1	x 2.1868	= 48.32828
1987 20.3	x 2.3399	= 47.49997
1988 24.9	x 2.5037	= 62.34213
1989 20.3	x 2.679	= 54.3837
1990 22.1	x 2.8665	= 63.34965
1991 21.2	x 3.0672	= 65.02464
1992 5.6	x 3.2819	= 18.37864
		\$528.08087

Dr. PERRY. I am sorry, I did not hear the question.

Mr. BOLAND. I want to know whether or not this estimate includes all costs, costs which would include all mission-related equipment in the various facilities at Vandenberg, base support, down-range support, and similar expenditures?

General COY, what about that?

General COY. Yes, sir, it does include base support. I am not quite positive on down-range support.

Mr. BOLAND. Do you want to supply that?

General COY. Yes, sir, it does.

Mr. BOLAND. It does?

General COY. Down-range support peculiar to Shuttle.

Mr. BOLAND. How about the additional expenditures beyond those two, does it include all expenditures?

General COY. Yes, sir.

Mr. BOLAND. All right. Let me ask you whether or not, can additional steps be taken to reduce the cost of building and manning Vandenberg? For example, could fewer pads and less elaborate support facilities and single-shift operations be considered as ways to reduce Vandenberg costs?

General COY. Sir, we are currently investigating just such alternatives. Our facility definition contract will be complete in the June 1978 time period. Recognizing that we have less money in our presently approved program than is our top estimate, we are looking at ways of staying well below the top estimate, to include things such as less equipage, at least in the initial phase of the Vandenberg activity, where the launch schedule has not reached its peak at that time.

Mr. BOLAND. Let me ask you, what would be the effects of using Vandenberg only for polar launches and other flight profiles which will require land overflight if flown from Kennedy?

Dr. FROSCHE. That is all it is used for.

Mr. BOLAND. Do you want to proceed, Mr. Edwards?

UPGRADING STRUCTURAL TEST ORBITER

Mr. EDWARDS. The GAO statement proposes a total of 3 orbiters, 102, 103 and the upgraded structural test orbiter. If a fourth orbiter is required for increased reliability, GAO would recommend upgrading orbiter 101.

The President's budget, on the other hand, proposes what is described as a 4-orbiter fleet with provision to keep the option open for a fifth orbiter.

Is it feasible to upgrade the structural test orbiter as proposed by GAO to provide a 3-orbiter fleet?

Mr. YARDLEY. Our plan, Mr. Chairman, is to have orbiters 102, 103 and the upgraded structural test article as our first three orbiters. The fourth orbiter in the President's budget plan is a new orbiter, 104.

The question is, why are we not using the 101 airframe which was flown in the Approach and Landing (ALT) tests? That airframe is now about 6,000 pounds heavier than it should be. There would be a

lot of special engineering costs to convert that vehicle to a production article. We could do that instead of buying a fifth orbiter, and save about \$50 million, but it would be less than a full capability orbiter.

Mr. BOLAND. Are you talking about upgrading 101 into the fifth orbiter?

Mr. YARDLEY. Yes, sir.

Mr. TOLER. Could we comment on that briefly? I would like to have Dan Sprowls make a comment.

Mr. SPROWLS. Mr. Chairman, we are not exactly sure how much overweight 101 would be. We tried to look into the issue. We understood 101 was overweight. The nearest we have been able to tell from looking at the figures, 101 would be roughly the same weight as 102 and the structural test article.

Mr. BOLAND. That is not so apparently.

Mr. YARDLEY. My technical people tell me it is not so. I do not know what GAO is doing.

SOURCE OF GAO INFORMATION

Mr. TOLER. We are talking with your technical people who keep the books.

Dr. FROSCHE. But you did your own addition.

Mr. TOLER. No, sir. This is in discussion with your people.

Dr. LOVELACE. Would you give us a copy of the document that you received from those technical people with their addition on it, that causes you to say 101 is equal in weight to 102?

Mr. GUTMANN. We could provide it.

Dr. LOVELACE. I think we need it for the record. That is the only way we can resolve this particular problem. You provide it for the record.

[GAO information follows:]

The following orbiter weights were given to GAO in February 1978 and reconfirmed by the Shuttle Program Manager at Johnson Space Center on March 22, 1978. As shown, the status weight of Orbiter 101 is approximately the same as Orbiter 102 and the Structural Test Article (Orbiter 099). Furthermore, the planning weights show that if Orbiter 101 were made an operational vehicle, it would be lighter than Orbiters 102 or 099.

	ORBITER WEIGHTS				
	[In pounds]				
	101A ¹	102	099/STA	103	104
Status weight ²	146, 110	145, 577	145, 675	144, 821	144, 821
Available modifications ³	3, 500	1, 600	2, 800	4, 000	4, 000
Planning weight (expected operational weight).....	142, 610	143, 977	142, 875	140, 821	140, 821
Overweight ⁴	1, 789	3, 156	2, 054	0	0

¹ The weights of Orbiter 101A are currently not being tracked since the vehicle is not officially in the program. The weights presented are the most recent information GAO has.

² Status weight is reported by the prime contractor each month.

³ The Orbiter Project Office at Johnson Space Center estimated that making these changes to all 5 orbiters would cost approximately \$58,000,000. We do not know if the estimate has been revised since Orbiter 101 was deleted from planning.

⁴ The weight of Orbiters 103 and 104 are used to determine the overweight status of the other orbiters. As stated in Mr. Yardley's testimony, Orbiters 099 and 102 will be about 2,000 and 3,000 lb. overweight, respectively. A comparable estimate for Orbiter 101 shows it would be about 1,800 lb. overweight.

Mr. BOLAND. My understanding is that you have been in constant communication with the people at Johnson Space Center and that you obtained your information and statistics from the JSC.

Mr. TOLER. This is correct, plus we supplement our information through contact with NASA headquarters personnel.

Mr. BOLAND. You can identify the people who gave you that information; that would be no problem.

Mr. TOLER. That is no problem at all.

[GAO information follows:]

We have discussed this matter with the subcommittee and have agreed that placing these names on the public record would not be necessary.

COST OF GAO PROPOSAL VS. COST OF FOUR—ORBITER FLEET

Mr. EDWARDS. What would be the cost of the GAO proposal as compared to the cost of a 4-orbiter fleet as proposed in the President's budget?

[NASA information follows:]

The cost of the four Orbiter fleet using the GAO methodology consisting of orbiter vehicles 102, STA, 103, and 101 modified would be approximately \$2,472 million in FY 1979 budget dollars.

The cost of the four Orbiter fleet in the NASA recommended budget, consisting of vehicles 102, STA, 103, 104, is \$2,522 million in FY 1979 budget dollars.

The results of using the 101 modified orbiter vehicle in place of a new 104 vehicle is a savings of approximately \$50 million and penalty of about 5,500 pounds in payload capability.

[GAO information follows:]

During February 1978 we obtained the following procurement and modification cost estimates from NASA Headquarters officials.

Production/modification (real year dollars in millions) ¹

Orbiter:		
101	-----	\$500
104	-----	852

¹ These costs assumed Orbiter 104 would be the fourth vehicle and Orbiter 101 the fifth vehicle.

Based on these estimates GAO stated that approximately \$350 million (\$852-\$500) could be saved by modifying orbiter 101 instead of procuring Orbiter 104. Subsequent to the March 9th Hearings NASA Headquarters officials stated the \$500 million estimate should be adjusted to be comparable with the \$852 million. Increases to the \$500 million include an allowance for main engines and additional support costs. Also, if orbiter 104 were not produced, an allocation of production penalty would be added to Orbiter 101 cost. A production penalty is being incurred because during 1977 the overall production effort was slipped one year.

After making the appropriate adjustments, NASA officials state Orbiter 101 modification costs would be \$766 million if Orbiter 104 were not produced and a net savings of \$86 million (\$852-\$766) would result. We concur that adjustments should be made to the \$500 million. We have not reviewed the detail supporting the \$766 million.

The following orbiter weights were also given to GAO in February 1978 and reconfirmed by the Shuttle Program Manager at Johnson Space Center on March 22, 1978. As shown, the status weight of Orbiter 101 is approximately the same as Orbiter 102 and the Structural Test Article (Orbiter 099). Furthermore, the planning weights show that if Orbiter 101 were made an operational vehicle, it would be lighter than Orbiters 102 or 099.

ORBITER WEIGHTS

[In pounds]

	101A ¹	102	099/STA	103	104
Status weight ²	146, 110	145, 577	145, 675	144, 821	144, 821
Available modifications ³	3, 500	1, 600	2, 800	4, 000	4, 000
Planning weight (expected operational weight).....	142, 610	143, 977	142, 875	140, 821	140, 821
Overweight ⁴	1, 789	3, 156	2, 054	0	0

¹ The weights of Orbiter 101A are currently not being tracked since the vehicle is not officially in the program. The weights presented are the most recent information GAO has.

² Status weight is reported by the prime contractor each month.

³ The Orbiter Project Office at Johnson Space Center estimated that making these changes to all 5 orbiters would cost approximately \$56,000,000. We do not know if the estimate has been revised since Orbiter 101 was deleted from planning.

⁴ The weight of Orbiters 103 and 104 are used to determine the overweight status of the other orbiters. As stated in Mr. Yardley's testimony Orbiters 099 and 102 will be about 2,000 and 3,000 lb overweight, respectively. A comparable estimate for Orbiter 101 shows it would be about 1,800 lb overweight.

Mr. YARDLEY. I think he is asking for a cost of a 3-orbiter fleet instead of 4.

Mr. EDWARDS. That is what I understood GAO to be proposing.

Dr. FROSCHE. Is this just for the orbiters or the system, including the launch site?

Mr. EDWARDS. I am talking about the orbiters.

Mr. TOLER. One thing I would like to clarify is, GAO is not necessarily recommending no more than 3 orbiters.

Mr. EDWARDS. I understood you to recommend 3. You said, in effect, you could go along with the fourth one, if the fourth one could be justified, but I never understood you to say you were recommending 4.

Mr. TOLER. No, sir. We recommended 3, you are correct in that respect, but we say that if you need to provide for attrition, and that was a decision that we were not in a position to make, then you should have a fourth orbiter. But as to the cost of the orbiters, the total cost of the 3 basic orbiters, would be the cost of 102, 103 and the STA.

I think NASA could probably provide those costs for you.

Dr. FROSCHE. We can provide those costs.

Mr. YARDLEY. Surely. Roughly, it is around \$700 million in 1979 dollars for the fourth orbiter. Of course that takes a little detailed analysis to see. When you take out the fourth orbiter, the first 3 cost more because of the overhead, which has to be redistributed. I would like to add one other fact. In the very thorough, exhaustive study that NASA and DOD put together in September of last year for OMB on the matter of orbiters and launch sites, which I am sure the committee has, the number attributed to costs to the United States Government, was \$6.377 billion in additional cost if you use 3 orbiters and 1 site instead of 5 orbiters and 2 sites.

FEASIBILITY OF UPGRADING STRUCTURAL TEST ORBITER

Mr. EDWARDS. Is the GAO proposal to upgrade orbiter 101 to provide a 4-orbiter fleet a feasible proposal?

Dr. FROSCHE. Yes, it is feasible, it can be done within the restrictions of accepting the weight penalty.

Mr. YARDLEY. It would save \$50 million.

Mr. TOLER. The \$50 million is a new figure to us. We understood the contractor would not come in and estimate the cost to upgrade that until 3 or 4 months from now. The best available information from NASA that we were able to obtain is, there is a potential of a \$300 million to \$350 million savings in real year dollars by upgrading orbiter 101.

[GAO information follows:]

During February 1978 we obtained the following procurement and modification cost estimates from NASA Headquarters officials.

	<i>Production/modification (real year dollars in millions)¹</i>
Orbiter:	
101 -----	\$500
104 -----	852

¹ These cost assumed Orbiter 104 would be the fourth vehicle and Orbiter 101 the fifth vehicle.

Based on these estimates GAO stated that approximately \$350 million (\$852-\$500) could be saved by modifying orbiter 101 instead of procuring Orbiter 104. Subsequent to the March 9th Hearings NASA Headquarters officials stated the \$500 million estimate should be adjusted to be comparable with the \$852 million. Increases to the \$500 million include an allowance for main engines and additional support costs. Also, if orbiter 104 were not produced, an allocation of production penalty would be added to Orbiter 101 costs. A production penalty is being incurred because during 1977 the overall production effort was slipped one year.

After making the appropriate adjustments, NASA officials state Orbiter 101 modification costs would be \$755 million if Orbiter 104 were not produced and a net savings of \$86 million (\$852-\$766) would result. We concur that adjustments should be made to the \$500 million. We have not reviewed the detail supporting the \$766 million.

Mr. YARDLEY. That is totally wrong.

Dr. FROSCHE. Mr. Chairman, I think we have to clarify who it is the GAO thinks NASA is when they ask a question like that. Apparently they assert that it is NASA if they ask someone in NASA for numbers or get some document that was produced somewhere in NASA with numbers on it and that, to them, is NASA. That seems to me to be a very curious idea. We are a very large organization. We do continual studies on costs and on engineering, and they can come out of all kinds of levels, all kinds of documentation, all kinds of verification. I do not know who they mean by NASA. They apparently do not mean me.

Mr. BOLAND. I think we established they would detail that and identify who would be NASA and the particular individuals.

SCOPE OF HEARING

Incidentally, this is not an adversary proceeding. We are just trying to get answers to some of the questions, some of the serious questions. There are a number of members who serve on these 3 committees who are concerned about whether or not we need 2 sites, whether or not we need 4 orbiters, 3, 4, or 5 orbiters; the only way we can establish that fact is by people who have the expertise and the knowledge to come here and tell us about it. That is exactly why we are doing it.

We have great faith in the GAO. You know it is an arm of the Congress and it is used frequently by the Congress, incessantly by the Congress, as a matter of fact, and comes up with some awfully good reports.

Now this may be a lemon. I do not know, what they have come up with here, but we are going to find out whether or not it is; precisely, the figures they give us and whether or not the figures DOD and the figures given us by NASA are the correct ones.

We can establish that for the record and compare the testimony of the witnesses who are here today, plus the documentation that both sides will supply to us before we actually mark this bill up.

Mr. EDWARDS. Mr. Chairman I agree it is not an adversary proceeding. I sit here having this niggling feeling, however, that we are a little premature. It seems to me there is an awful lot of getting together that should have been done between GAO and these agencies before we had this hearing, but nevertheless here we are.

COST OF FOUR-ORBITER FLEET VS. FIVE ORBITER FLEET

What would be the cost of a 4-orbiter fleet using the GAO method as compared to the cost of a 5-orbiter fleet option using the methodology proposed in the President's budget?

Dr. FROSCH. I do not know.

Mr. EDWARDS. Can you do that for the record?

Dr. FROSCH. I am afraid we may have to ask what the GAO methodology is.

Mr. YARDLEY. We do not understand the question.

Mr. EDWARDS. Well, I am trying to get at the cost comparison between the 4-orbiter fleet and a 5-orbiter fleet, using the GAO methodology, whatever that is, by upgrading orbiter 101, compared to the method by which you fellows arrived at a cost for 5 orbiters in the President's budget, without upgrading 101.

I do not know whether you can now give me an answer.

Dr. FROSCH. I think we would have to do that for the record.

[NASA information follows:]

The NASA cost estimate of a four orbiter fleet comprised of Orbiters 102, STA, 103, and 104 is \$2,522 million in FY 1979 budget dollars. This includes \$100 million to provide for the light weight modification to the STA.

The estimated cost of a five orbiter fleet comprised of Orbiters 102, STA, 103, 104, and 105 is \$2,787 million in FY 1979 budget dollars.

The cost of a five orbiter fleet comprised of Orbiters 102, STA, 103, 104, and 101 modified is estimated at \$2,737 million in FY 1979 budget dollars.

In the five orbiter fleet estimates, it has been assumed that the light weight modification to the STA is not required.

[GAO information follows]

The present Administration has decided to support a four-Orbiter fleet, with consideration for a fifth in future years in the event that projected flight rates, or the accidental loss of an Orbiter, warrant such an action. Present NASA plans do not include Orbiter 101 as part of this "Four-orbiter Shuttle Fleet"; however, it might be used as a fifth orbiter. The following charts show (1) NASA's procurement strategy for a five-orbiter fleet and (2) procurement costs of a four-orbiter fleet if Orbiter 101 instead of 104 is used as a fourth orbiter.

CHART 1

CHART 1

NASA'S PROCUREMENT STRATEGY FOR
A FIVE-ORBITER FLEET (note a)

<u>Orbiter Designation</u>	<u>Estimated Costs Procurement/Modification (Dollars in Millions) (note b)</u>	<u>Status/Comments</u>
101	(note a)	This development vehicle (the Enterprise) was used for approach and landing tests in 1977; however, it is not fully engineered for operations. NASA does not plan for Orbiter 101 to be part of the "four-orbiter shuttle fleet" referred to in the President's fiscal year 1979 budget request.
102	\$28.0	This development vehicle will be used for the First Manned Orbital Flight in mid-1979. After six orbital test flights, the vehicle will require only minor modifications to become fully operational.
Structural Test Article (Orbiter 099)	\$596.6	Originally intended to be used for structural tests only, the test article will be upgraded to operational capability. Some equipment from Orbiter 101, such as crew module and avionics, will be used to help minimize the cost of upgrading. This vehicle is planned to be operational in February 1981.
103	\$801.7	This will be the first vehicle built entirely with production funds. Fabrication and assembly of primary structures will continue in fiscal year 1979 and detail parts fabrication for secondary structures will start. The planned delivery date for this vehicle is September 1982.
104	\$851.6	Essentially no funds have been expended for this vehicle. The fiscal year 1979 budget request includes about \$20 million which will be used to procure long-lead materials and begin fabrication. Orbiter 104's scheduled delivery date is September 1984.

Notes:

a/NASA has not decided whether the optional or future Orbiter will be (a) Orbiter 101, modified for orbital flight capability or (b) a wholly new vehicle, to be procured after Orbiter 104. Modification of Orbiter 101 would cost about \$651 million.

b/To operate four Orbiters, ground support equipment costing about \$230 million will be required. The cost of this equipment is not allocated to individual Orbiters.

CHART 2

CHART 2

FOUR ORBITER FLEET PROCUREMENT COSTS
USING ORBITER 101 INSTEAD OF 104

<u>Orbiter Designation</u>	<u>Estimated Costs Procurement/Modification (Dollars in Millions) (Note a)</u>
102	\$ 28.0
099	596.6
103	801.7
101	766.0 (Note b)

Notes:

a/To operate four orbiters, ground support equipment costing about \$230 million will be required. The cost of this equipment is not allocated to individual orbiters.

b/This estimate is derived by combining modification costs of \$651 million (see chart 1) and production penalty costs of \$115 million. The production penalty currently included in Orbiter 104's cost estimate would be allocated to Orbiter 101. This penalty will be incurred because the program has experienced a one-year slippage in the overall production effort.

SAVINGS IN REDUCING UNIT COST OF EACH ORBITER

Mr. EDWARDS. If savings could not be made by reducing the number of orbiters, are there steps that could be taken to reduce the unit cost of each orbiter?

Mr. YARDLEY. Yes, buy more of them.

Mr. EDWARDS. That is the only way?

Mr. YARDLEY. Just as an example, deleting the fifth orbiter saved, as I recall, \$365 million, whereas the fourth one costs \$700 million in FY 1979 budget dollars. In other words, the price of the other four orbiters increases because of the deletion of the fifth one.

Dr. FROSC. I think one comment to be made is that, if I interpret your question correctly to mean we build each of the orbiters cheaper, I do not think we know how to do that without compromising either the payload characteristics or the safety or some other characteristics of the orbiter. This is after all, in spite of being called in part production, nothing like a production run.

In essence each one of these orbiters is hand-built, one at a time. There is relatively little one can do in the usual production sense of cost reduction.

Mr. EDWARDS. You are saying there is no gold-plating in these orbiters?

Dr. FROSC. I never know what gold-plating means. I presume it means something that is not necessary to do the job. I think we have been pretty careful not to put things in that we do not think are required either to do the job or for the safety of the job.

EXPENDABLE LAUNCH VEHICLES

Mr. EDWARDS. Let's turn to the expendable launch vehicles now.

How many different types of expendable launch vehicles are currently produced in the United States?

Mr. YARDLEY. It is 7. It depends on how you count the types. They have several different configurations.

Dr. FROSC. NASA uses 2 basic classes of major launch vehicles, a Centaur and a Delta class, which comes in 2 principal sub-classes. That is, we use Atlas-Centaur and the two types of Delta. We also use Scout, a smaller all solid vehicle, for some orbital insertions. Then there are various sounding rockets that are used for sub-orbital research. It is partly a classification problem because there are variations of these depending upon the particular job to be done.

Mr. EDWARDS. How about putting a chart in the record setting those out?

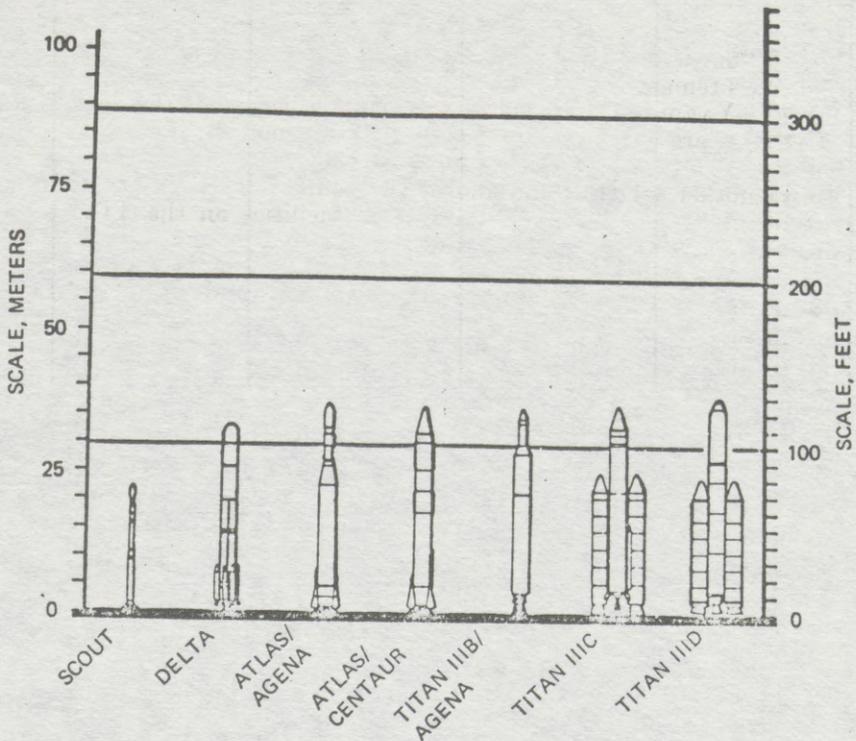
[DOD information follows:]

U. S. EXPENDABLE LAUNCH VEHICLES

LAUNCH VEHICLE	CURRENT PRODUCTION AND LAUNCHES	FY 79 AND SUBSEQUENT NEW PRODUCTION	FY 79 AND SUBSEQUENT REFURBISHMENTS
SCOUT	X		
ATLAS CENTAUR	X		
ATLAS SLV-3A	X		
ATLAS E/F ICBM'S	X		X
DELTA 2914	X		
DELTA 3914	X		
THOR IRBM	X		
TITAN III(24)B	X		
TITAN III(34)B	X		
TITAN III(23)C	X		
TITAN III(23)D	X		
TITAN III(34)D		X	
TITAN III(34)D/IUS	X	X	

[NASA information follows:]

A chart of current U.S. launch vehicles follows:



CURRENT UNITED STATES LAUNCH VEHICLES

EXPENDABLE LAUNCH VEHICLE UTILIZATION DURING SHUTTLE TRANSITION

Mr. EDWARDS. How many different kinds of expendable launch vehicles will be maintained during the Shuttle transition period?

Mr. YARDLEY. The Air Force plans to have some Titan back-ups.

General COY. From a DOD standpoint, we will be maintaining the TITAN III family of launch vehicles, as well as continuing to use the old ATLAS E/Fs that have been converted into the space boosters for use from Vandenberg, as well as THORs, until that inventory is depleted.

Mr. YARDLEY. NASA will not use any expendable launch vehicle of its own after 1980 except for Vandenberg. We will have to use the Delta and the Atlas-F until the Shuttle is available out at Vandenberg.

Mr. EDWARDS. I take it DOD and NASA have different requirements for expendable launch vehicles during the transition period and to that extent will use those suitable for those requirements.

General COY. Yes, sir.

Dr. FROSCH. Essentially we are each continuing what we are currently doing, until we phase out the expendable launch vehicles.

EXPENDABLE LAUNCH VEHICLE PHASE-OUT

Mr. EDWARDS. How long will expendable launch vehicle production facilities remain open?

Mr. YARDLEY. For our NASA launch vehicles, the last Atlas-Centaurs are in the factory right now. As soon as they are finished that will be closed out. We are currently debating whether we will buy another 4 Deltas and another 5 Scouts.

General COY. As far as production facilities on the TITAN III, Mr. Edwards, we plan that until April of 1982.

EXPENDABLE LAUNCH VEHICLE PROCUREMENT AND COST

Mr. EDWARDS. Will you set out for the record, both of you, how many expendable vehicles will be procured, and what will be the total cost of procuring these vehicles?

[DOD information follows:]

The DOD's future plans include the procurement of three Titan III(34)D's, two Titan III(34)D/IUS's, and refurbishment of ten deactivated Atlas E/F Intercontinental Ballistic Missiles. In addition, four sets of Titan III subassemblies and details and four sets of Titan III long lead are planned. The DOD procurement cost for these FY 1979 and subsequent procurements and the phase out of the Titan III production capability is \$546.4 million.

[NASA information follows:]

During FY 1978, NASA plans to procure the following vehicles:

Vehicle	Number to be procured	Estimated unit hardware cost	Total Estimated cost	Remarks
Scout.....	5	\$3,400,000	\$17,000,000	To be procured for the DOD on a reimbursable basis in support of transit missions; decision to procure will be made by end of April 1978.
Delta.....	3	\$9,000,000	\$27,000,000	These units are currently under contract to support NASA missions; consideration is being given to procurement of 4 more vehicles to provide backup capability during transition to the Shuttle.

PROJECT MILESTONES TO BE OBTAINED BEFORE PHASING OUT EXPENDABLE LAUNCH VEHICLE PRODUCTION

Mr. EDWARDS. What milestones will have to be reached in the Shuttle program to justify closing expendable launch vehicle production lines?

Dr. FROSCH. I think we will have to complete the orbital flight test phase before we would have sufficient confidence that we would be through with the expendable launch vehicles.

Mr. EDWARDS. Can anything be done to accelerate the closing of expendable launch vehicle production lines and what are the possible savings from accelerated closings?

Dr. FROSCH. We do not think that we could accelerate them without bringing in new facilities which would cost more and probably would not be completed in time.

Mr. EDWARDS. How about the Air Force?

General COY. We do not see a savings, sir, unless the program could be accelerated, and we think that the program is going at the proper speed at the present time.

Mr. EDWARDS. One part of my question was this: could it be accelerated in your case?

General COY. Well, the DOD's getting on to the Shuttle of course is dependent upon the progress made by NASA as well as our own rate of activation at Vandenberg.

I do not see at present funding levels how we can accelerate the activation of Vandenberg.

Mr. BOLAND. Mr. McKAY.

Mr. MCKAY. Gentlemen, I will ask a number of questions to be answered now, and I will submit an additional number of questions for the record.

CONSTRUCTION OF VANDENBERG FACILITY

My first question is, why is it necessary to begin construction of the Vandenberg site at this time?

General GILBERT. Mr. Chairman, when we look at the requirement for facilities there, this year is about the last year we could have come to the Congress in order to provide facilities by the IOC date required. When you consider we will go on contract for the actual construction phase early next year as things are going now, and 24 to 26 months to construct these facilities—assuming everything goes well with weather, labor and so forth—it does not give us a lot of time beyond that absolutely and essentially needed.

Mr. MCKAY. You are saying that you have to start now to meet the timetable of the demise of the existing missiles you are working with?

General GILBERT. June 1983, yes, sir.

Mr. MCKAY. During that time you will expend the ones Mr. Edwards was talking about?

General COY. No, sir.

General GILBERT. No, sir.

General COY. The plan is to maintain the expendable launch vehicles as a back-up until we completely transition onto Shuttle. We expect that transition of existing payloads, redesigned as necessary to be complete by the fiscal 1985 time period.

Mr. MCKAY. You are arguing that in order to get ready for the first Space Shuttle operation, you have to start now, not next year?

General COY. Yes, sir. In fact, we have already started working on payloads, redesigning payloads in order to make the transition to Shuttle.

ESTIMATED DOD COST PER LAUNCH

Mr. MCKAY. What is the total estimated cost per launch for each DOD launch through 1992?

General COY. Our pricing policy with NASA is a \$12.2 million price per launch in fiscal year 1975 dollars.

Mr. MCKAY. What is that in current or then-year dollars? Can you provide that?

General COY. It will vary from year to year.

Mr. McKAY. What is your estimate of what it will cost by 1983?
General Coy. In the 1983 time period?

Mr. McKAY. Yes.

General Coy. We will provide that for the record.
[DOD information follows:]

The NASA/DOD pricing policy stipulates a fixed price for the first six full years of STS operations and a price fixed at the NASA estimated cost of materials and services for each of the succeeding years. Further, since DOD must operate Vandenberg for all users, each of the 111 DOD flights has an additional cost equal to its pro-rata share of the Vandenberg operations cost. Note that the eight DOD flights which fly prior to the Vandenberg IOC will, by this method, have a "share" of the Vandenberg operations costs assigned to them. Finally, the DOD will pay an additional operations cost for secure mission operations at Johnson Space Center. Each DOD flight has been allocated a share of this cost. Our estimate of the cost per flight follows:

DOD COST PER FLIGHT ESTIMATE FOR DEDICATED FLIGHTS

[In millions of dollars]

	Fiscal year										
	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
Cost in fiscal year 1975 dollars:											
Material and services.....	12.2	12.2	12.2	12.2	12.2	12.2	6.4	6.4	6.4	6.4	6.4
VAFB.....	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4	9.4
Mission operations.....	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7	.7
Total.....	22.3	22.3	22.3	22.3	22.3	22.3	16.5	16.5	16.5	16.5	16.5
Cost in then-year dollars (total).....	31.4	32.6	33.9	35.3	36.6	38.1	29.3	30.5	31.7	32.9	34.3

Mr. McKAY. What factors are included in that estimate, such as capital, O&M costs, and so forth, so we get the total costs of what you are doing there?

[DOD information follows:]

The Memorandum of Agreement between NASA and DOD; subject, Basic Principles of NASA/DOD Space Transportation System Launch Reimbursement, dtd 17 March 1977 defines the factors included in the estimates. Specifically, NASA and DOD have agreed that the DOD will reimburse NASA for "Materials and Services." Materials and Services costs are defined as the total of all costs incurred by the government (NASA) for the procurement of all expended hardware, refurbishment hardware, and flight spares and provisions (excluding external tank propellants). Materials and Services does not include the launch and flight support personnel costs at Kennedy Space Center, Vandenberg Air Force Base, and Johnson Space Center. The Memorandum of Agreement stipulates that the DOD will provide launch support at Vandenberg for all non-DOD users in return for which NASA will provide Kennedy launch support for all DOD launches at Kennedy and flight operations for all DOD launches (from both sites). The DOD cost to support non-DOD users and the NASA cost to support DOD are projected to be approximately equal.

LAUNCHES FROM KENNEDY AND VANDENBERG

Mr. McKAY. How many NASA and DOD or other launches are made now from Kennedy or Vandenberg that cross over a land mass shortly after launch?

Dr. FROSCHE. As far as I know, none.

General Coy. None that I am aware of.

Mr. McKAY. None at all?

Dr. FROSCHE. No.

Mr. McKAY. How many and of what types of launches are made now that cross in polar orbit over the Soviet Union?

Dr. FROSCHE. All polar orbit satellites, when in orbit, pass over the Soviet Union.

Mr. YARDLEY. No launch vehicles during ascent.

Dr. FROSCHE. I do not think any launch vehicles pass over the Soviet Union during ascent because, in fact, from Vandenberg they are all launched south over the South Pacific Ocean.

Mr. McKAY. Provide a list of those launches for the last 3 years and identify the type of nature of each, if you will.

Dr. FROSCHE. There are not any.

Mr. TOLER. May I make a comment here?

Mr. McKAY. Sure.

Mr. TOLER. The TITAN III second stage will pass over the Soviet Union since it goes on into orbit—

Dr. FROSCHE. In orbit it will. Once it is in orbit it will, yes.

General COY. Transtage is used only for geosynchronous missions and does not pass over the Soviet Union. The Titan III second stage after it is orbital will in some applications pass over the Soviet Union.

Dr. FROSCHE. But not in that part of its boost phase where it could conceivably come down.

Mr. TOLER. These are the type of statistics we had mentioned earlier about the 1 in 6,250 chance of the second stage of the TITAN injuring or endangering someone on the ground during reentry. So there is still a risk involved.

Mr. McKAY. All right.

TITAN-III-D-IUS

The DOD testimony in the Air Force justification books indicate that the Air Force is continuing development, procurement and construction of facilities for the TITAN III-D missile and launch complex as a back-up system. Does this reflect a lack of confidence in the Shuttle program?

Dr. PERRY. This is simply the contingency plan we have, Mr. McKAY. We will provide you the exact number of those but there are 3 complete TITANs and a number of partly assembled TITANs which we are procuring as a contingency.

General GILBERT. Insofar as the construction in this program is concerned, Mr. McKAY, that is for the TITAN 34D, IUS facility. The IUS, of course, will also be used, as explained this morning, in the Space Shuttle itself.

Mr. McKAY. Yes, but you are talking about this as a back-up system?

General GILBERT. As I understand it—

General COY. Sir, the TITAN III-D-IUS system is required in order to increase the reliability of our present expendables.

As I mentioned in my briefing, we expect the expendable reliability to go up from .90 to about .97. In order to ease the transition of our payloads into the Shuttle era we are transitioning onto the IUS and the IUS will also be used on the Shuttle. The construction that I believe you are alluding to is associated with accommodating the IUS at the Kennedy Space Center and will be required with a TITAN III-D-TITAN 34D/IUS.

EXPENDABLE LAUNCH VEHICLES

Mr. McKAY. You said part of your system would go into the Space Shuttle as part of that operation, but the implication here is that you are going to keep the expendables as a "back-up system," which means that you are not quite sure whether the Shuttle is going to make it, so you have to have another system to be sure.

General Cox. No, sir. I am sorry. We are trying to transition onto Shuttle in an orderly fashion.

Mr. McKAY. So that you do not intend to keep 2 systems, one for back-up in case the Shuttle fails?

General Cox. We intend to provide for contingencies only during the transition period.

As Dr. Perry mentioned this morning, we plan to phase out all expendables by the end of fiscal 1985.

Mr. McKAY. Maybe we ought to get down to what back-up system means. Let's get those definitions.

[DOD information follows:]

The DOD is planning to provide expendable vehicle launch capability during the period of transition to the Space Transportation System. This backup capability is intended to protect high priority DOD missions from the following:

- A delay in the operational availability of the STS
- A delay in the availability of an Orbiter capable of launching DOD heavy-lift missions
- A delay in the availability of a Shuttle compatible payload
- A short term (less than six months) grounding of the entire Shuttle fleet early in the operations era

This backup ELV capability will be phased out at the end of FY 85. It is not intended to supplement the Shuttle fleet capacity in the event that the traffic grows beyond the fleet capacity (DOD priority will obtain all the flights required from a limited fleet resource). In FY 85 a disposition determination will be made concerning any residual backup ELVs. If it is economically advantageous, we will use them to launch existing dual compatible payloads but this is not currently planned.

Mr. McKAY. You will excuse me, gentlemen. I will have to go make this vote.

[Discussion off the record.]

Mr. BOLAND. Mr. Coughlin, as all of you know, serves on the subcommittee that deals with NASA funding. We are pleased to have you.

Mr. COUGHLIN. Thank you, Mr. Chairman.

KSC POLAR ORBIT LAUNCHES

Just so I am clear, it is possible, is it not, to launch polar orbit missions from Kennedy Space Center without overflying the territory of the United States, using an orbit launching vehicle and a booster; am I correct on that?

Dr. FROSCHE. It is possible if you carry enough fuel so you can launch in one direction and then change the orbital direction.

Mr. YARDLEY. If you go all the way into orbit and then change, yes. But the capability of the Shuttle is such that you can put about 6 to 8,000 pounds into a polar orbit with the IUS.

Mr. COUGHLIN. So that the maximum that you could put into a polar orbit launching from Kennedy without overflying the United States would be 6 to 8,000 pounds, is that correct?

Mr. YARDLEY. Yes.

Mr. COUGHLIN. About what percentage of orbital launches are under 8,000 pounds?

Dr. FROSCH. None of them.

Mr. COUGHLIN. Am I correct that all but 18 missions could be launched from Kennedy Space Center in that fashion?

[DOD information follows:]

The current DOD mission model, Revision 6 (modified), shows 44 total launches from FY 80 through 1st Quarter FY 92 which are projected for high inclination launches from Vandenberg. Of that total, 27 can be flown as suggested (KSC launch without CONUS overflights, IUS or smaller upper stage for plane change to the required orbit). Seventeen launches cannot be so accommodated.

[NASA information follows:]

In the current mission model, there are 17 high priority DOD missions which cannot be accommodated from KSC because of Shuttle performance limitations. In addition, 39 Spacelab missions projected for VAFB cannot be launched into high inclination orbit from KSC using an IUS. The Spacelab must stay attached to the orbiter.

[GAO information follows:]

A KSC-launched Space Shuttle can carry over 32,000 pounds to 98-degree inclination orbits. GAO met with NASA and DOD on several occasions and reached agreement that payload requirements of 32,000 pounds could be launched out of Kennedy by making changes to the launch trajectory and mission configuration. There are remaining differences of opinion concerning safety considerations and the disadvantages of having only one Shuttle launch site.

Shuttle experts agree that the most critical phase of a Shuttle launch is between lift-off and solid rocket booster (SRB) separation. This phase will have been completed long before land overflight occurs on a northerly launch from Kennedy. SRB separation takes place over the ocean 31 miles from the launch site. The orbiter and external tank continue ascending over 314 miles of open ocean and will be about 70 miles high when land overflight begins.

With regard to safety considerations, we believe that if NASA meets its reliability goals there will be relatively minor risk to the U.S. and Canadian population. Actual Space Shuttle reliability, of course, must be demonstrated. The exact number of Shuttle launches required to gain confidence in the Shuttle's performance reliability has not been determined. By June 1983, however, when polar Shuttle launches are scheduled to begin, the STS will have had over 3-years experience, entailing over 50 Shuttle flights. This would constitute a strong basis for assuming that these flights will provide a sufficient "shake down" period in which any problems will be identified and corrected. If uncertainties and problems still exist after 3 or 4 years of operations, there would be a serious question concerning the viability of the entire Shuttle program.

Dr. FROSCH. No.

Mr. YARDLEY. I do not know.

Dr. FROSCH. Two points. We do not think so, we will have to check the numbers, but I have to add that to do so removes any efficiency of the Shuttle system, because it means that your total payload to orbit for that flight is —

Mr. COUGHLIN. This is polar orbit.

Dr. FROSCH. The only thing you can do on that flight is carry that one spacecraft and enough fuel to get it into its proper final orbit.

Mr. COUGHLIN. You cannot have a multiple mission launch?

Dr. FROSCH. You cannot have a multiple mission, and you have to use an IUS or some other orbital transfer vehicle in order to do it so that you have the additional cost to launch the spacecraft.

USE OF TELEOPERATOR RETRIEVAL SYSTEM

Mr. COUGHLIN. Is it possible to retrieve polar orbiting payloads from a Kennedy-launched Shuttle using the planned teleoperator retrieval system or the orbital transfer vehicle?

Mr. YARDLEY. Not without the Shuttle having to overfly the United States on launch. You see, what you were talking about a minute ago, the Shuttle would be launched at a 35 degree launch azimuth (57 degrees inclination). It would then put out the IUS, say it is a Landsat mission, the Landsat and IUS would put a big dog-leg in and go polar. To retrieve that Landsat satellite is impossible by any means known to man, unless the Shuttle itself can get in to that orbit.

COST COMPARISONS OF GAO STUDY

Mr. COUGHLIN. When Chairman Boland was talking about cost comparisons, this involved cost comparisons between the GAO study of launches from Kennedy direct into a polar orbit, and the figures that I am trying to get involve a cost comparison having polar orbital launches from Kennedy Space Center that do not overfly the United States, and the balance of the polar launches being done from Vandenberg with expendable vehicles.

Let me ask two very precise questions on that. I tried to get this last time, but the figures that came out I do not think reflected that exactly.

COST COMPARISON FOR THE THREE ORBITER FLEET

Could you for the record provide a cost comparison showing a 3-orbiter fleet only out of Kennedy, with continued use of expendables at Vandenberg?

[NASA information follows:]

The cost comparison requested for the record was addressed in the joint NASA/DOD OMB Study Update in 1977 (a copy has been provided as per request).

This analysis made allowance for orbiter attrition in all cases and compared the cost of operations with four and three orbiters at one and two launch sites versus five orbiters operating at two launch sites. The baseline for all cases was 487 Shuttle flights between mid-CY 1980 and the end of CY 1991. All costs were considered in three principal categories—non-recurring investment, operations, and payloads.

The results are summarized in the three tables shown below. Three orbiters operating only at KSC incur about a \$6.4 billion increase above that required for five orbiters operating at two sites.

The capability of the three orbiters with attrition considerations is about 250 total flights. This level of capability requires augmentation of the Shuttle at KSC with 193 expendable launch vehicles in addition to the expendable launch vehicles required at VAFB.

NATIONAL TOTAL PROGRAM COST COMPARISON

(MILLIONS OF FY 79 DOLLARS)

COST CATEGORY	KSC AND VAFB OPERATIONS			KSC OPERATIONS ONLY	
	COST 5 ORBITERS	DELTA COSTS		DELTA COSTS	
		4 ORBITERS	3 ORBITERS	4 ORBITERS	3 ORBITERS
CIVIL PROGRAM	(21,469)	(+4,257)	(+6,200)	(+4,099)	(+6,853)
NON-RECURRING	11,815	- 395	-1,016	-380	-1,016
OPERATIONS	9,654	+2,510	+3,885	+1,754	+3,833
PAYLOADS	NOT INCL	+2,142	+3,331	+2,725	+4,036
DOD PROGRAM	(8,297)	(+ 39)	(+ 847)	(- 227)	(- 476)
NON-RECURRING	2,964	+ 69	-806	-1,086	-1,731
OPERATIONS	5,333	-30	+1,453	+ 659	+1,055
PAYLOADS	NOT INCL	0	+ 200	+ 200	+ 200
MISSION MODEL TOTAL	29,766	+4,296	+7,047	+3,872	+6,377

CIVIL PROGRAM COST COMPARISON

(MILLIONS '79 DOLLARS)

COST CATEGORY	BASELINE 5/2	DELTA COSTS (TO 5/2 CASE)			
		CASE 4/2	CASE 3/2	CASE 4/1	CASE 3/1
STS NON-RECURRING INVEST.	(11,815)	(-395)	(-1016)	(-380)	(-1016)
SHUTTLE DDT&E	7,391				
ORBITER PROCUREMENT	2,787	-585	-1261	-585	-1261
PRODUCTION PENALTY		+220	+ 275	+220	+ 275
SPACELAB/SSUS/IUS	1,029	- 30	- 30	- 15	- 30
FACILITIES	460				
OPS CAPABILITY	148	-	-	-	-
OPERATIONS	(9,654)	(+2,510)	(+3,885)	(+1,754)	(+3,833)
SHUTTLE	8,262	-1,857	-1,899	-1,336	-2,086
SSUS/IUS	674	- 445	- 503	- 167	- 362
SPACELAB	503	- 42	- 40	- 20	- 50
ELV	215	+4,854	+6,327	+3,277	+6,331
PAYLOADS	(27,275)	(+2,142)	(+3,331)	(+2,725)	(+4,036)
NASA	12,944	+1,163	+1,772	+ 771	+1,380
OTHER CIVIL	14,331	+ 979	+1,559	+1,954	+2,656
MISSION MODEL TOTAL	48,744	+4,257	+6,200	+4,099	+6,853

DOD TOTAL PROGRAM COST COMPARISON
(MILLIONS OF FY 79 DOLLARS)

COST CATEGORY	KSC AND VAFB			KSC ONLY	
	5 ORBITERS	DELTA COST		DELTA COST	
		4 ORBITERS	3 ORBITERS	4 ORBITERS	3 ORBITERS
INVESTMENT	(2964)	(+ 69)	(-806)	(-1086)	(-1731)
SHUTTLE RDT&E	140	0	0	- 18	7 18
GROUND SUPPORT SYSTEM	993	0	- 64	- 890	- 921
IUS DEVELOPMENT	235	0	0	0	0
MOS ACQUISITION	67	0	- 27	0	- 27
PAYLOAD TRANSITION	936	0	-548	- 249	- 598
ELV MODIFICATION	187	0	+239	+ 226	+ 239
BACKUP ELV	406	+ 69	-406	- 155	- 406
OPERATIONS	(5333)	(- 30)	(+1653)	(+ 859)	(+1255)
STS	-3363	- 34	-1546	-1055	-2206
ELV	1486	0	+3056	+1672	+3298
RELIABILITY (LOSSES)	242	+ 4	+ 25	+ 56	+ 51
OTHER	242	0	- 82	- 14	- 88
PAYLOAD	NOT INCL	0	+ 200	+ 200	+ 200
TOTAL	8297	+ 39	+ 847	- 227	- 476

[GAO information follows:]

We think that the cost figure of \$6.4 billion is overstated and misleading. The figures comes from studies prepared for OMB by NASA and DOD. The basic study, "Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues," is dated October 15, 1976, and was intended to provide OMB the comprehensive data and analyses necessary to determine the number of orbiters needed for the national operational fleet.

These specific figures are included in the October 1977 update of the above study. Here again, the update was prepared by NASA and DOD for OMB's use in evaluating the agencies' budget requests, particularly as concerned the five-orbiter position. The study shows the costs of 3-Orbiter/1 site and 4-Orbiter/1 site programs essentially as follows:

COST INCREASES (DECREASES) WITH LESS THAN 5 ORBITERS/2 SITES

[In billions of fiscal year 1979 dollars]

Cost-category	3-orbiters/ 1-site	4-orbiters/ 1-site
Nonrecurring.....	(\$2.747)	(\$1.466)
Operations.....	4.888	2.413
Payload benefits lost.....	4.236	2.925
Net cost increase.....	6.377	3.872

According to the NASA/DOD analysis, a Shuttle program with less than 5 orbiters/2 sites is not cost-effective due to increased operations cost and lost payload benefits. The increased operations costs are for the extensive use of ELVs. In turn, use of these ELVs, says NASA, will not generate payload cost savings offered by the Shuttle (in other words, the cost category called "Payload benefits lost" represents opportunity costs).

We disagree with the approach used in the 1976 and 1977 studies for several reasons, as discussed below.

CONSTANT MISSION MODEL

Even though the NASA/DOD study examined various fleet size cases (three, four and five Orbiters, operating from one and two sites), each of the cases was analyzed in relation to a constant mission model for the 1980-91 timeframe. The constant mission model, however, was developed largely to complement the capabilities of a five-orbiter Shuttle fleet. Any analysis which retains the maximum program developed for 5 Orbiters would obviously show that a smaller fleet size would not be cost effective. If, however, a varying program level had been used to reflect a more reasonable increase in space activity, the costs assigned for additional ELVs and payload benefits lost would have been greatly reduced.

In addition, it should be noted that most of the payloads in the mission model will require Government appropriations, even though no specific space objectives for the 1980s have been set forth by either the executive branch or the Congress. We therefore question the appropriateness of using the mission model as a constant in evaluating alternative fleet sizes.

ORBITS ACHIEVABLE WITH 1-SITE OPERATIONS

Neither of the joint studies considered that a KSC-based Shuttle could be launched to polar and near-polar orbits. These studies thus assumed that (1) ELVs would be required to launch most of the payloads destined for these orbits; and (2) these payloads would not be accessible to the Shuttle for retrieval. A northerly-launched KSC Shuttle could, however, achieve these orbits and be capable of launching and retrieving (where appropriate) all payloads presently planned for Vandenberg launch.

BACKUP POSTURE

Both joint studies assumed that an extensive ELV backup posture would be required if fewer than 5 Orbiters were procured. Considering turnaround times, however, any size Orbiter fleet may provide more responsive backup than the Nation is currently experiencing with ELVs. For instance, the planned two-weeks turnaround time for the Shuttle is much faster than for ELVs. At KSC, 17 weeks (without overtime work) are needed to ready a replacement Titan III. At Vandenberg, ELVs are assembled on the pad, and turnaround time for a replacement ELV is about 4 to 6 months (without overtime). These turnaround times are lengthy because under current operations, ELV launches are not "backed-up" with a standby ELV; the production pipelines must provide replacements.

RECOVERY AND REUSE OF PAYLOADS

NASA expects that the Shuttle's capability to return however, bulkier payloads would allow payload cost saving techniques such as modular design, less sophisticated components, and more rugged hardware. However, in a recent report ("Space Transportation System: Past, Present, Future"; PSAD-77-113; May 27, 1977), we cautioned that:

"* * * evidence indicates * * * extensive use of these techniques is unlikely during the 1980s."

"Although NASA and DOD, the major users, plan some recovery and reuse, Battelle [Columbus Laboratories] surveyed potential non-Government users and found they do not believe these techniques will be widely used during this period. These users believed the demonstrated reliability of current satellites is quite satisfactory and the return of a 7- or 10-year-old satellite having antiquated technology would not be particularly useful. In addition, many satellites, such as those in geostationary orbits, cannot be reached by the orbiter, and its limited ability to maneuver in space may not allow satellites to be routinely and economically recovered."

* * * * *

"In 1973 the Federation of American Scientists stated that, while savings are possible, low-cost design is inconsistent with the trend in the American aerospace industry which emphasized high reliability, microminiaturization, and ruggedness. Furthermore, NASA's proposed user charge policy for flight sharing may encourage the continued design of compact, lightweight satellites because NASA bases charges on weight or length, whichever is greater."

For these reasons we think it inappropriate for NASA to count "payload benefits lost" so heavily when evaluating alternative programs and that the \$6.4 billion cost figure is overstated and misleading.

COST COMPARISON FOR THREE-ORBITER VS. FIVE-ORBITER FLEET

For the record provide a cost comparison showing a 3-orbiter fleet only out of Kennedy with continued use of expendables for only the essential missions out of Vandenberg versus a 5-orbiter fleet with 2 launch sites and expendables phased out. That means the Kennedy launches would not overfly the United States under those circumstances.

[DOD information follows:]

This cost comparison was performed in support of the 1977 OMB study update and is identified as the three Orbiter/single site alternative. This comparison resulted in an increase of \$6.4 billion over the baseline five Orbiter/two site case.

[NASA information follows:]

As noted in the previous response to Mr. Coughlin, a three orbiter flight at KSC cannot accommodate all of the KSC traffic projected in the 487 model. Consequently no capability would exist to support high inclination missions by overflying the U.S.; therefore, the cost comparison of this three orbiter KSC only case vs. a five orbiter two site case is as described above, i.e. a \$6.4 billion increase.

[GAO information follows:]

The total number of launches proposed for the Space Shuttle from both Kennedy and Vandenberg through 1992 depends upon which mission model is referenced. NASA officials have stated that the mission models are not to be considered firm space requirements. The models are only planning estimates and have been revised almost annually since 1971. The 1977 or current model shows 552 Shuttle flights.

The basic question, however, is not how many launches have been proposed by NASA or anyone else. The size of future space programs is a matter for the national political leadership to decide. The basic issue is how many orbiters are needed to provide a balanced and viable space program. We believe three orbiters can support space programs which represent a substantial increase over past activity, whether measured in terms of launch rates, payload levels, or mission modes. For example, the Aerospace Corporation of California has done a number of orbiter fleetsizing studies in support of joint NASA/Air Force planning activities. The studies placed particular emphasis on repeatability of test conditions to establish confidence in specific fleet-sizing options. A KSC-only, three orbiter configuration was examined using a wide range of inputs representing 210 consecutive years—that is, 21 scenarios over consecutive 10-year periods. The studies concluded that three orbiters operating from KSC could support about 40 flights per year. At this annual launch rate, given the large cargo bay, and assuming only two payloads per flight, three orbiters could support 80 payloads a year—nearly double the nation's past payload activity. For instance, during 1967-76 the U.S. launched about 43 payloads a year.

We emphasize that the 40 flights/80 payloads a year are conservative figures. NASA describes the orbiter's large cargo bay as having a payload-carrying capability equivalent to that of two Atlas-Centaur or four Delta expendable launch vehicles. Also, using the Spacelab and the Long Duration Exposure Facility (LDEF), multiple experiments are possible with a single Shuttle launch; almost one-half of the payloads in the mission models involve the Spacelab.

It is obvious that the duration of Spacelab flights affects orbiter availability for other missions, most of which require only 2 or 3 days from lift-off to return. However, the Aerospace corporation studies, which show that 3 orbiters can support 40 flights per year, used an average mission duration of 8.0 days; this average represents a distribution derived from a NASA model which included Spacelab missions. The fairly long average mission duration, 8.0 days, limited the flight rate to 40 launches per year. An earlier series of studies using shorter missions (with an average duration of 4.6 days) allowed a three-orbiter fleet to support up to 48 flights per year. The model, presented by Dr. Frosch in these hearings, has an average mission duration of 5.4 days (see p. 8a-13). Here again, this is another indicator of the conservativeness of the 40 launches a year.

Additional indicators are the test conditions used in the Aerospace studies. Groundrules in the studies include the following assumptions:

- a two-week (205 hours) turnaround time, using two shifts per day. (The two-week period included a one-day contingency hold to absorb ground support anomalies.);
- 45 percent of all launches encounter ground support delays ranging from one to eight days;
- a priority subset of nine launches, representing critical DOD and launch-window constrained NASA flights; and
- each orbiter was down 90 days every third year for extensive refurbishment and overhaul.

Dr. FROSCHE. So we would fly polar missions out of Kennedy for only those payloads light enough to go out over the water, be inserted into the orbit and then have an orbital transfer for the payload, everything else that was polar and heavier than that, would require expendable vehicles out of Vandenberg.

Mr. COUGHLIN. Or be launched from Kennedy without overflying the United States?

Mr. YARDLEY. That is almost exactly one of the cases we worked for the OMB report. In this case it was 3 orbiters at Kennedy only, with expendables at Vandenberg. We took the least expensive way if we had a choice between an expendable at Vandenberg or a Shuttle flight out of Kennedy with a dog-leg. So this is the cheapest. I do not know how many are dog-legs and how many are expendables, but it shows over \$6 billion extra cost over having 5 orbiters and 2 sites.

Mr. COUGHLIN. I am talking about 3 orbiters.

Mr. YARDLEY. Three orbiters plus expendables, using one site is \$6 billion more expensive than five orbiters and two launch sites.

Mr. COUGHLIN. This is a figure that I have not seen yet.

Mr. YARDLEY. This is in the report to OMB.

Mr. BOLAND. Will you supply us with the OMB report, too?

[NASA information follows:]

SUMMARY BRIEFING

JOINT NASA/USAF STUDY
ON
SPACE SHUTTLE ORBITER PROCUREMENT
AND
RELATED ISSUES

1977 UPDATE

* * * *

BACKGROUND

- PRESIDENTIAL DECISION - JAN 1972
 - NATIONAL STS PROGRAM TO SERVE ALL USERS -- CIVIL AND DEFENSE
- DEVELOPMENT PROGRAM INITIATED - MAR 1972
 - R&D PROGRAM PROVIDES TWO ORBITERS
 - SIX ORBITAL TEST FLIGHTS PLANNED - FIRST FLIGHT MAR/JUN 1979
 - INITIAL OPERATIONAL CAPABILITY PLANNED FOR MID-1980
- DOD/NASA JOINT STUDIES OF ORBITER PROCUREMENT ISSUES
 - STS COMMITTEE/AACB ACTIVITIES - JAN/MAY 1976
- OMB LETTER TO DOD/NASA - 8 JUN 1976
 - REQUEST JOINT STUDY
 - JOINT NASA/USAF STUDY ON SPACE SHUTTLE ORBITER PROCUREMENT AND RELATED ISSUES SUBMITTED 15 OCT 1976
- OMB LETTER TO NASA - 12 JULY 1977
 - REQUESTS UPDATE OF 1976 STUDY
- OMB LETTER TO DOD/DCI - 19 SEP 1977

OBJECTIVE

TO PROVIDE THE COMPREHENSIVE DATA AND ANALYSES WHICH COMPRISE
THE BASIS FOR DECISION ON THE PROCUREMENT OF AN ADEQUATE SPACE
SHUTTLE ORBITER FLEET TO SUPPORT THE NATIONAL SPACE ACTIVITY

KEY AREAS

- NATIONAL REQUIREMENT FOR SPACE SHUTTLE ORBITERS BASED ON REALISTIC PROJECTIONS
 - APPROPRIATE FLEET SIZE
 - CONSIDERATION OF ATTRITION
 - COST EFFECTIVENESS
- PROGRAMMATIC IMPACT OF FLEET SIZES LESS THAN 5 ORBITERS
- NEAR-TERM "MISSION MODEL"
- IMPLICATIONS OF REDUCED LEVELS OF NATIONAL SPACE ACTIVITY
- NEW & UNIQUE USES OF SPACE SHUTTLE CAPABILITIES

SCOPE

- 0 TASK I - SPACE SHUTTLE PROGRAM STATUS
- 0 TASK II - LAUNCH/LANDING SITE CONSIDERATIONS
- 0 TASK III - FLEET SIZE CAPABILITY ANALYSIS
- 0 TASK IV - MISSION MODEL/PAYLOAD CONSIDERATIONS
- 0 TASK V - COST EFFECTIVENESS ANALYSES
- 0 TASK VI - ANALYSIS OF REDUCED LEVELS OF SPACE ACTIVITY
- 0 TASK VII - SPACE BENEFITS & SPIN-OFFS/FORECAST FOR THE FUTURE

FRAME OF REFERENCE

- SIX R&D FLIGHTS - MID-1979 TO MID-1980
- OPERATIONAL PERIOD - MID-1980 THROUGH CY 1991
- RESOURCES AVAILABILITY

<u>AGENCY</u>	<u>RESOURCE</u>	<u>OPERATIONAL AVAILABILITY</u>
NASA	KSC LAUNCH & LANDING SITE	JUN 1980
NASA	JSC MISSION CONTROL CENTER	JUN 1980
DOD	INTERIM UPPER STAGE (IUS)	JUL 1980
NASA	ORBITER 2	JUN 1980
NASA	ORBITER 1	JUL 1981
DOD	VAFB LAUNCH & LANDING SITE	JUN 1983
NASA	ORBITER 3	JUN 1983
NASA	ORBITER 4	NOV 1983
NASA	ORBITER 5	DEC 1984

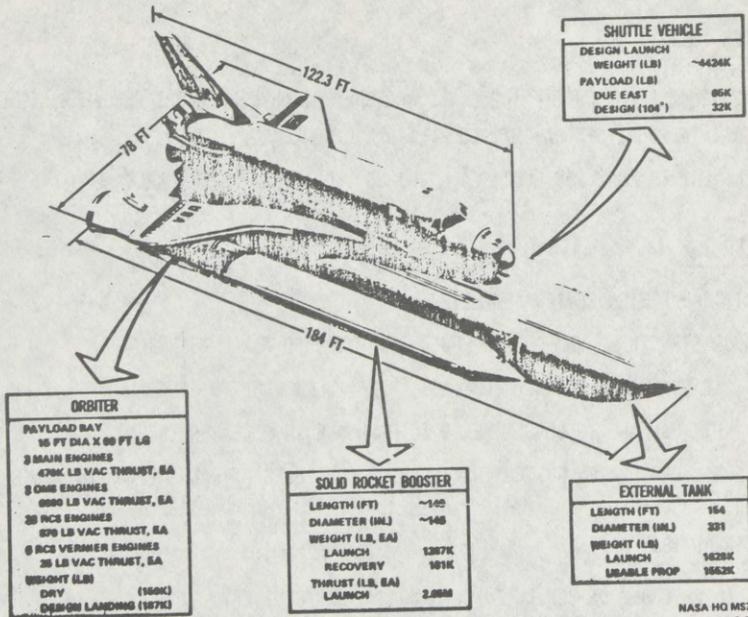
TASK I

SPACE SHUTTLE PROGRAM STATUS

**Space Shuttle
RECENT MAJOR ACCOMPLISHMENTS**

- **SUCCESSFUL COMPLETION OF FOUR MANNED FREE FLIGHTS**
- **SUCCESSFUL COMPLETION OF
FIRST SOLID ROCKET MOTOR FIRING**
- **300 SECOND SSME FIRING AT RATED POWER LEVEL
-OVER 9700 SECONDS TEST TIME ACCUMULATED**
- **FIRST EXTERNAL TANK DELIVERED**

SPACE SHUTTLE VEHICLE



NASA HO M576-1111(3)
11-3-75

ORBITER PROJECT STATUS● ORBITER 101

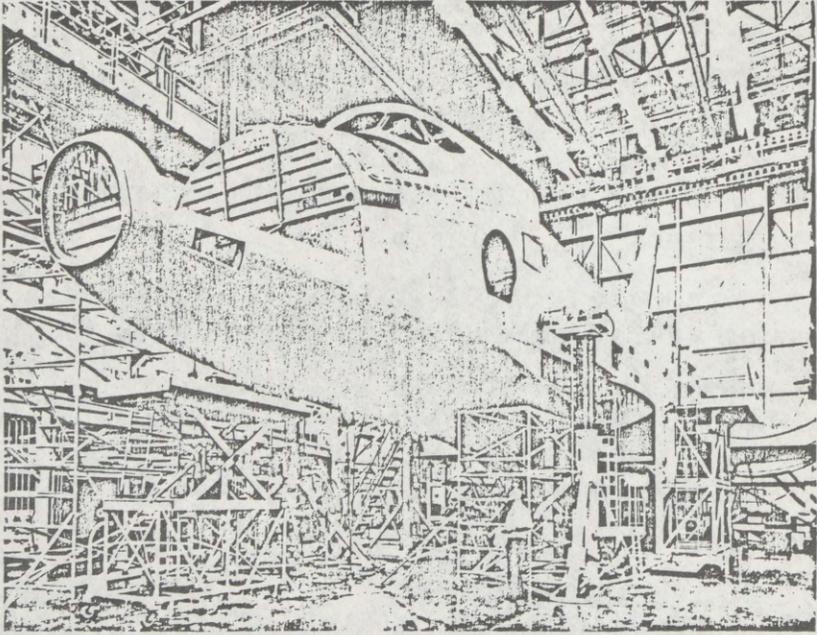
- FOUR SUCCESSFUL FREE FLIGHTS ACCOMPLISHED AT DRYDEN FLIGHT RESEARCH CENTER
- FIRST TAILCONE OFF FLIGHT ACCOMPLISHED OCTOBER 12, 1977
- DELIVERY TO MSFC FOR FULL SCALE GROUND VIBRATION TEST - MARCH 1978

● ORBITER 102

- CRITICAL DESIGN REVIEW COMPLETED
- MAJOR STRUCTURAL COMPONENTS PROGRESSING TOWARD FINAL ASSEMBLY
 - MID FUSELAGE, FORWARD FUSELAGE, WING, DELIVERED TO PALMDALE
 - AFT FUSELAGE TO BE DELIVERED TO PALMDALE IN DECEMBER 1977
- THERMAL PROTECTION SYSTEM INSTALLATION CONTINUES AT PALMDALE ON MID-FUSELAGE

● STRUCTURAL TEST ARTICLE

- FINAL ASSEMBLY ON SCHEDULE FOR JANUARY 1978 DELIVERY



APPROACH AND LANDING TEST PROJECT (ALT)

- FIVE CAPTIVE/INERT UNMANNED FLIGHT TESTS FOR CARRIER AIRCRAFT SUITABILITY
(COMPLETED)

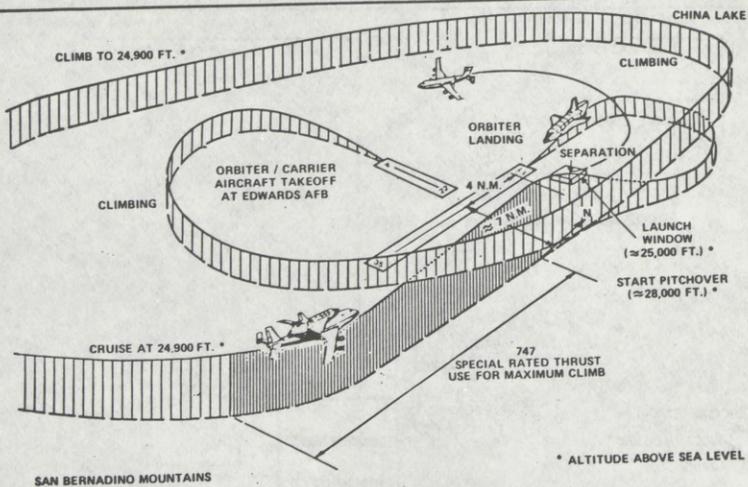
- THREE CAPTIVE/ACTIVE MANNED FLIGHT TESTS FOR FREE FLIGHT SYSTEMS AND
PROCEDURES CHECKS (COMPLETED)

- FIVE FREE FLIGHTS FOR AERODYNAMIC, GN&C, AND PILOT CONTROL TESTING (UNDERWAY)
 - THREE WITH TAILCONE ON (COMPLETED)
 - TWO WITH TAILCONE OFF (ONE COMPLETED)

- TWO FERRY FLIGHT PERFORMANCE CHECKS (DECEMBER)

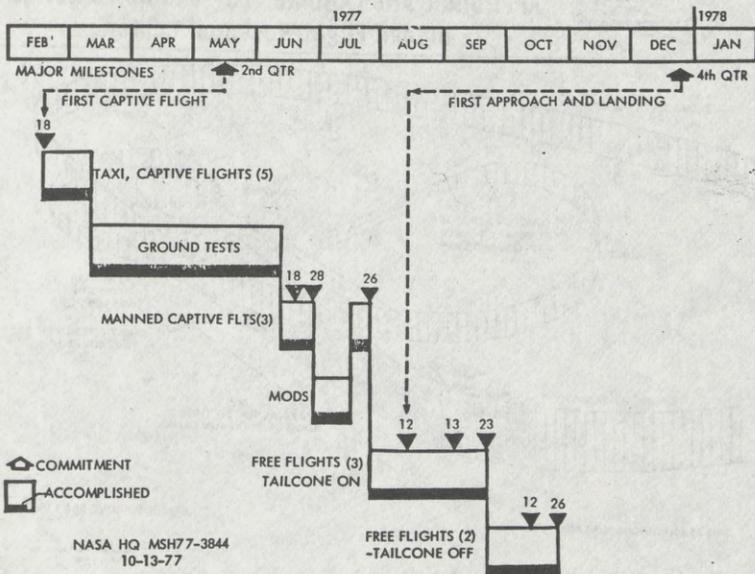


APPROACH AND LANDING TEST MISSION PROFILE Dryden Flight Research Center

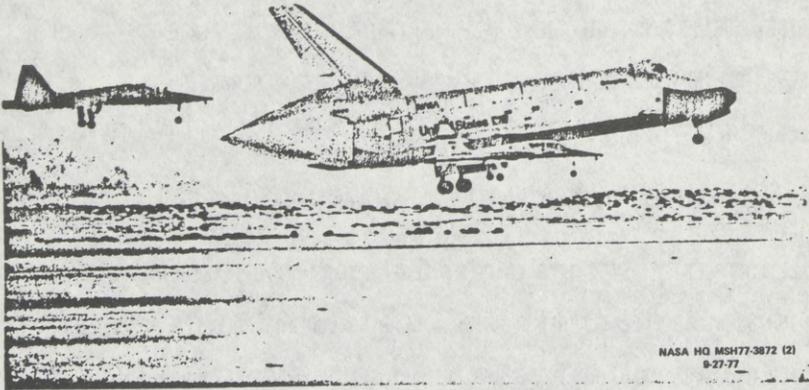


NASA HO M57-1038 (11)
REV. 6-6-77

APPROACH & LANDING TEST SCHEDULE



Space Shuttle Approach and Landing Tests – ENTERPRISE LANDING



MAIN ENGINE STATUS

- FIRST ENGINE THROTTLING TEST MPL-RPL ACHIEVED - JANUARY 7, 1977
- FIRST 60-SECOND FIRING AT RPL ACHIEVED - MARCH 12, 1977
- FIRST ENGINE THROTTLING TEST MPL-RPL WITH FLIGHT NOZZLE ACHIEVED - MARCH 16, 1977
- SEVEN ENGINES DELIVERED TO DATE (4 R&D, 2 FLIGHT, 1 REBURBISHED)
- ENGINE TESTS TO DATE
 - MORE THAN 215 TESTS WITH OVER 9700 SECONDS
- ALL COMPONENTS TESTED TO FULL POWER LEVEL EXCEPT 77.5:1 FLIGHT NOZZLE
- HIGH PRESSURE FUEL TURBOPUMP WHIRL & BEARING COOLING PROBLEMS RESOLVED
- HIGH PRESSURE OXIDIZER TURBOPUMP PRIMARY SEAL PROBLEM RESOLVED
- CURRENT ENGINE PROBLEM - OXIDIZER TURBOPUMP FIRE
 - UNDER INVESTIGATION

SPACE SHUTTLE MAIN ENGINE

- THRUST

VACUUM—470,000
POUNDS

- CHAMBER PRESSURE

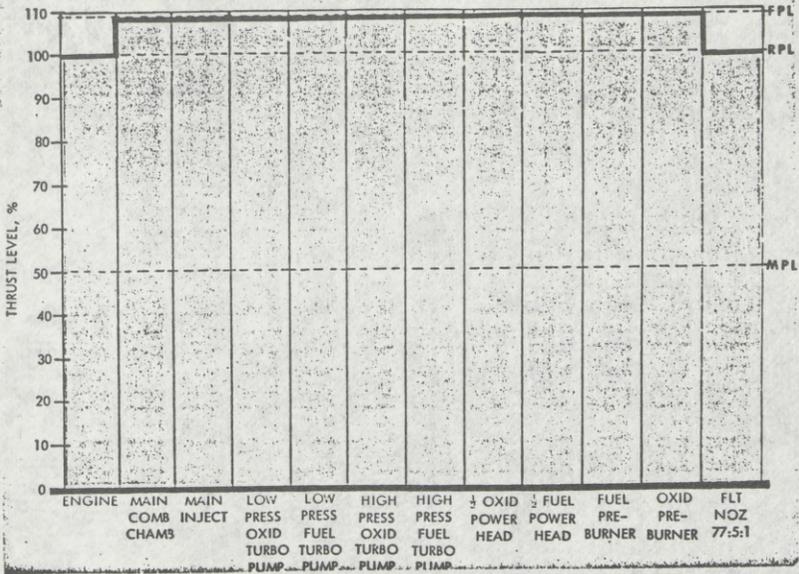
2970 POUNDS
PER SQ. INCH.

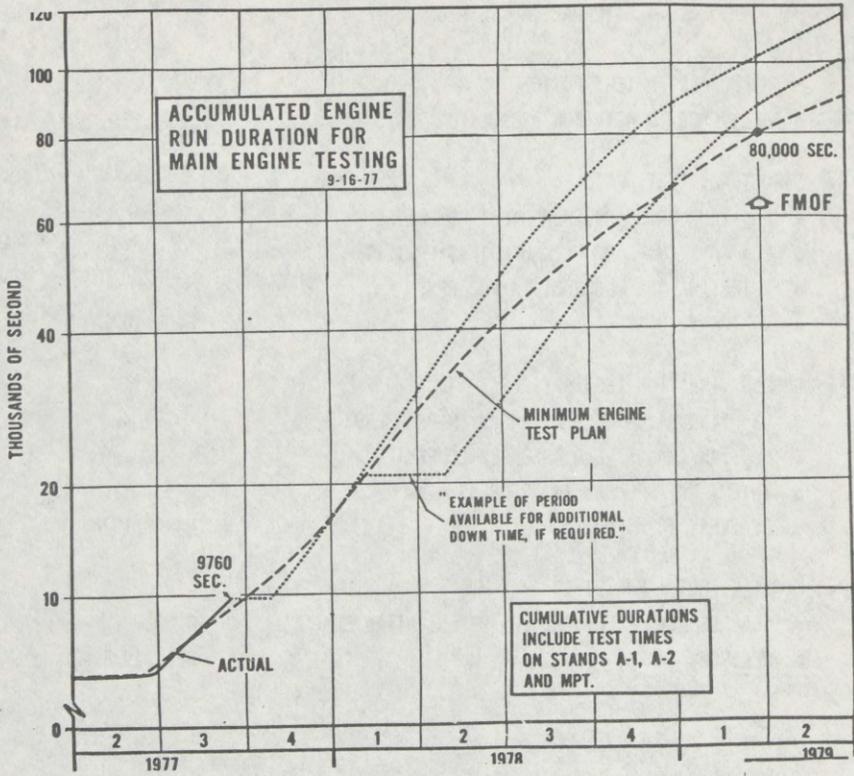
- LIFE

7.5 HOURS
—55 STARTS



SSME DEVELOPMENT TEST SUMMARY





EXTERNAL TANK STATUS

- MAIN PROPULSION TEST ARTICLE
 - DELIVERED TO NSTL FOR PROPULSION TESTS SEPT. 10, 1977

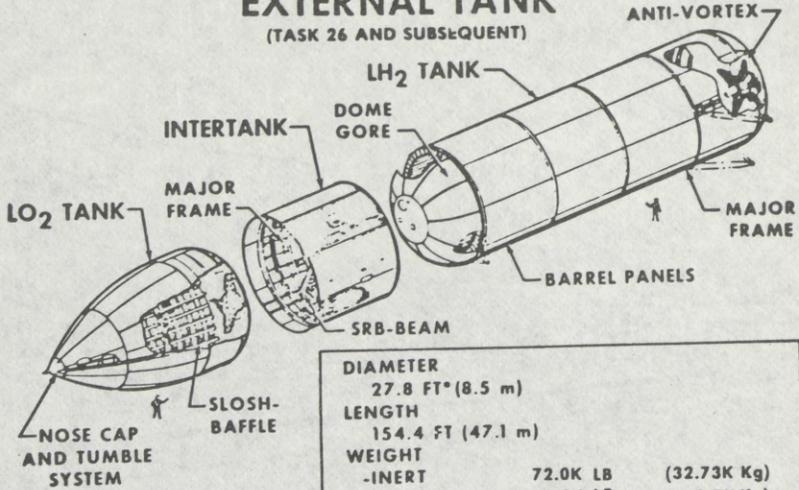
- STRUCTURAL TEST ARTICLE
 - LH₂ TANK PROOF PRESSURE TEST COMPLETED
 - LO₂ TANK IN PROOF PRESSURE TEST FACILITY
 - INTERTANK TPS CLOSEOUT IN PROGRESS
 - DELIVERY TO MSFC DEC. 1977

- GROUND VIBRATION TEST ARTICLE
 - LH₂ TANK MAJOR WELD ASSEMBLY IN PROGRESS
 - LO₂ TANK MAJOR WELD ASSEMBLY COMPLETED
 - INTERTANK ASSEMBLY IN PROGRESS
 - DELIVERY TO MSFC MARCH 1978

- FIRST FLIGHT TANK (ET-1)
 - SUBASSEMBLY OF LO₂ AND LH₂ DOMES INITIATED
 - DELIVERY TO KSC DEC. 1978

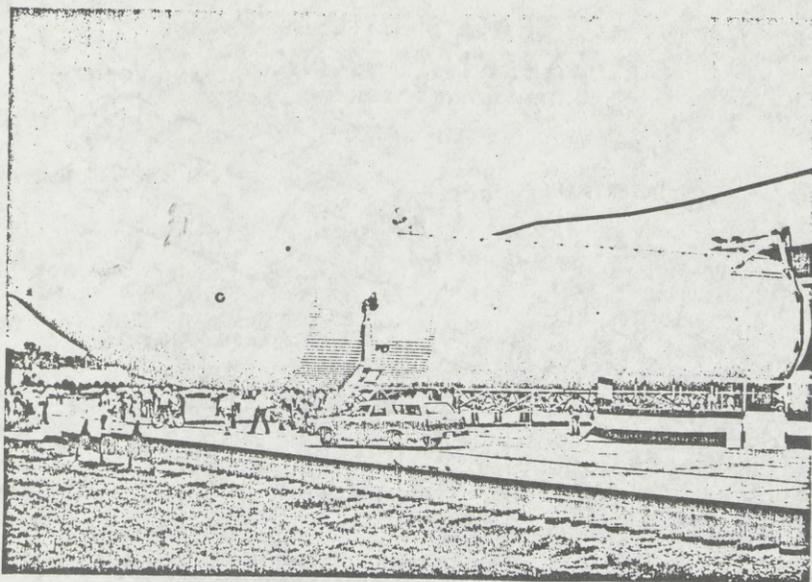
SPACE SHUTTLE EXTERNAL TANK

(TASK 26 AND SUBSEQUENT)



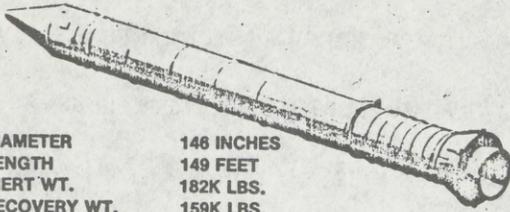
DIAMETER		
27.8 FT* (8.5 m)		
LENGTH		
154.4 FT (47.1 m)		
WEIGHT		
-INERT	72.0K LB	(32.73K Kg)
-LAUNCH	1649.3K LB	(749.7K Kg)

*INCLUDES SOFI (SPRAY ON FOAM INSULATION)

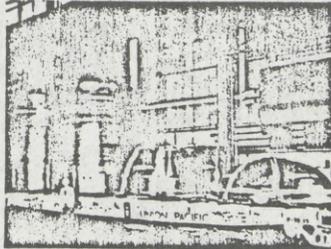
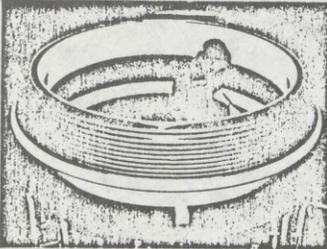


SOLID ROCKET BOOSTER PROJECT STATUS

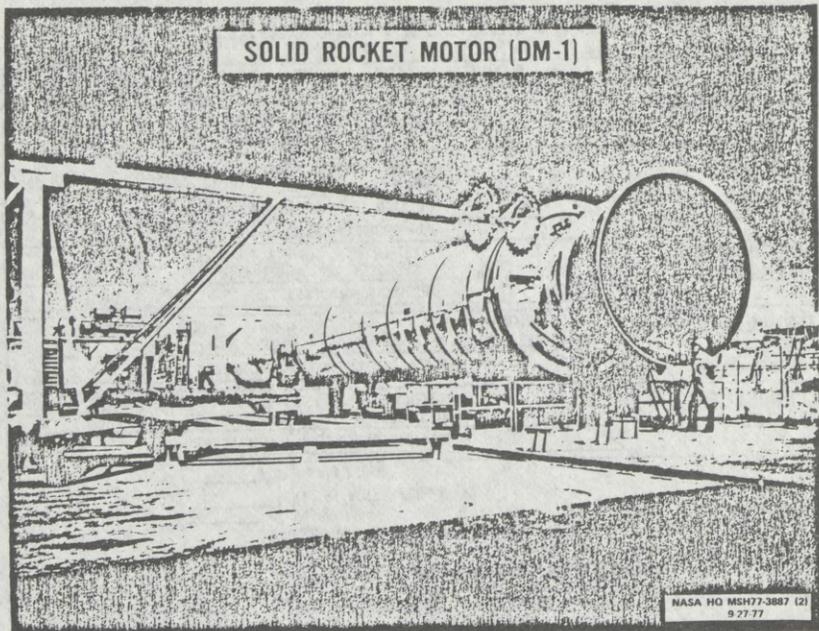
- COMPLETED BOOSTER SEPARATION MOTOR DEVELOPMENT FIRINGS MAY 1977
- SUCCESSFULLY COMPLETED FIRST DEVELOPMENT MOTOR FIRING JULY 1977
- SUCCESSFUL COMPLETION OF TWO PARACHUTE DROP TESTS JUNE, AUGUST 1977
- TESTING IN PROGRESS ON SRB ACTUATOR AT MSFC
- HYDRAULIC POWER UNIT SYSTEMS TEST IN PROGRESS
- ELECTRICAL AND INSTRUMENTATION VERIFICATION TESTING IN PROGRESS

SOLID ROCKET BOOSTER

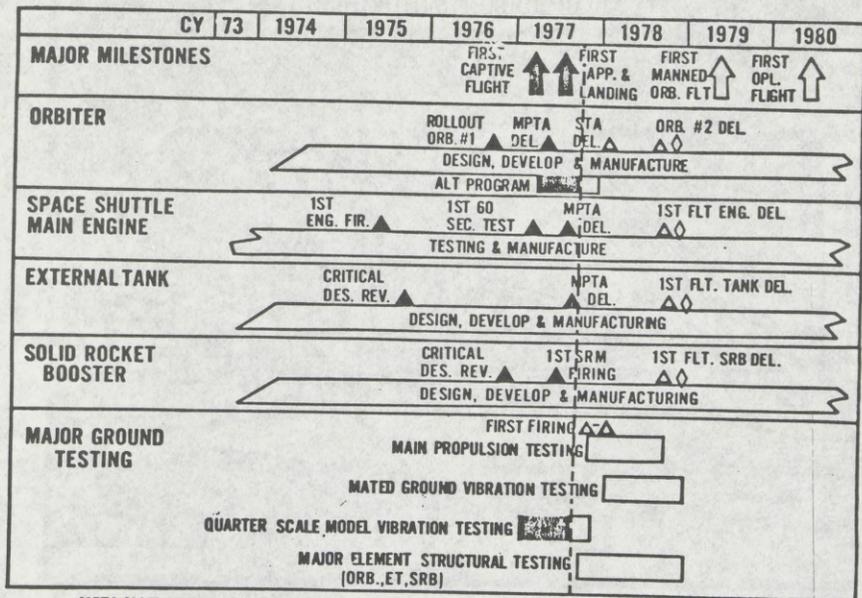
DIAMETER	146 INCHES
LENGTH	149 FEET
INERT WT.	182K LBS.
RECOVERY WT.	159K LBS.
PROPELLANT WT.	1,110K LBS.
THRUST (SEA LEVEL)	2.7M LBS.



NASA HQ ME 76-40213
6-11-76



SPACE SHUTTLE DEVELOPMENT PLAN



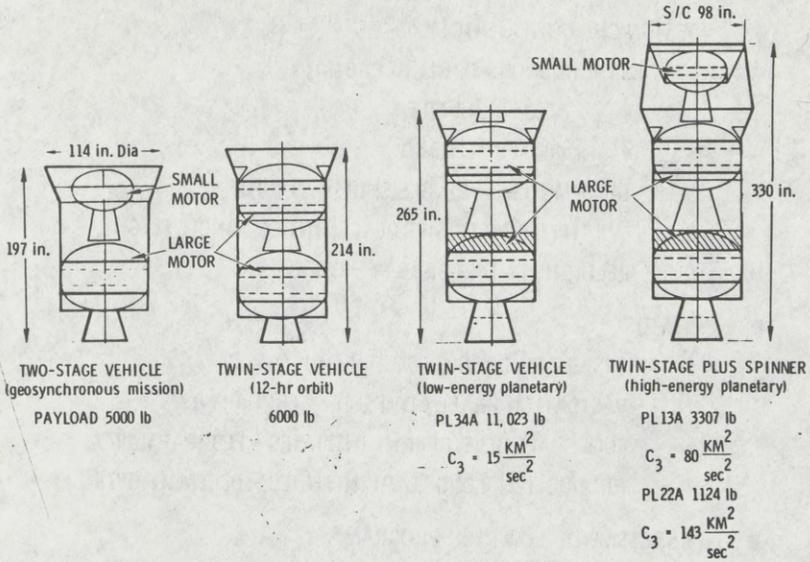
MPTA-MAIN PROPULSION TEST ARTICLE
SRM-SOLID ROCKET MOTOR

ALT-APPROACH AND LANDING TESTS
STA-STRUCTURAL TEST ARTICLE

INTERIM UPPER STAGE (IUS)

- DESIGN CHARACTERISTICS
 - / SYNCHRONOUS ORBIT CAPABILITY
 - 5000 LB SHUTTLE
 - 4000 LB T111(34)D
 - / TANDEM IUS ON SINGLE SHUTTLE FLIGHT
 - / MULTIPLE SPACECRAFT PLACEMENT ON SINGLE FLIGHT
 - / RELIABILITY TARGET: 0.96 - 0.98
- STATUS
 - / AFSARC OR DSARC - DECEMBER 1977
 - / VALIDATION PHASE COMPLETE - FEBRUARY 1978
 - / FULL SCALE DEVELOPMENT INITIATED - FEBRUARY 1978
 - / PRODUCTION (LONG LEAD) INITIATED - DECEMBER 1978
- ASSESSMENT: LOW RISK PROGRAM
 - / SUCCESSFUL AVIONICS AND PROPULSION TESTING COMPLETE
- IOC
 - / SHUTTLE - JULY 1980
 - / T111(34)D - JULY 1980

Current IUS Vehicle Family



LAUNCH AND LANDING STATUS

● FACILITIES

- COMPLETED - RUNWAY, LAUNCH EQUIPMENT TEST FACILITY, LAUNCH CONTROL CENTER, ORBITER PROCESSING FACILITY HIGH BAY 1 STRUCTURE AND CRANES, HIGH BAY 3 & 4 STRUCTURES
- ALL OTHERS ON SCHEDULE FOR FMOF

● LAUNCH PROCESSING SYSTEM

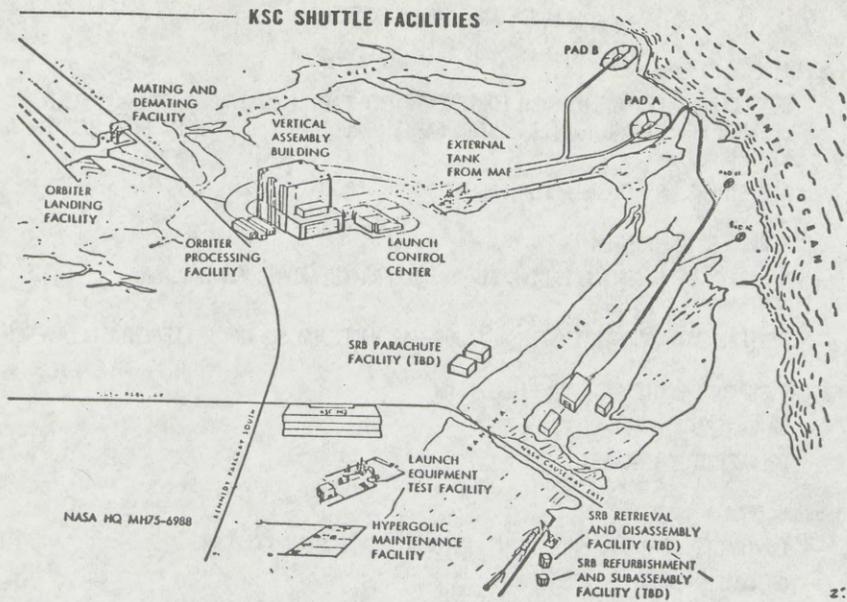
- MAJORITY OF HARDWARE DELIVERED TO KSC FOR CHECKOUT, CONTROL AND MONITORING SUBSYSTEM
- CENTRAL DATA SUBSYSTEM (LPS) MAJOR HARDWARE AND SOFTWARE ELEMENTS DELIVERED

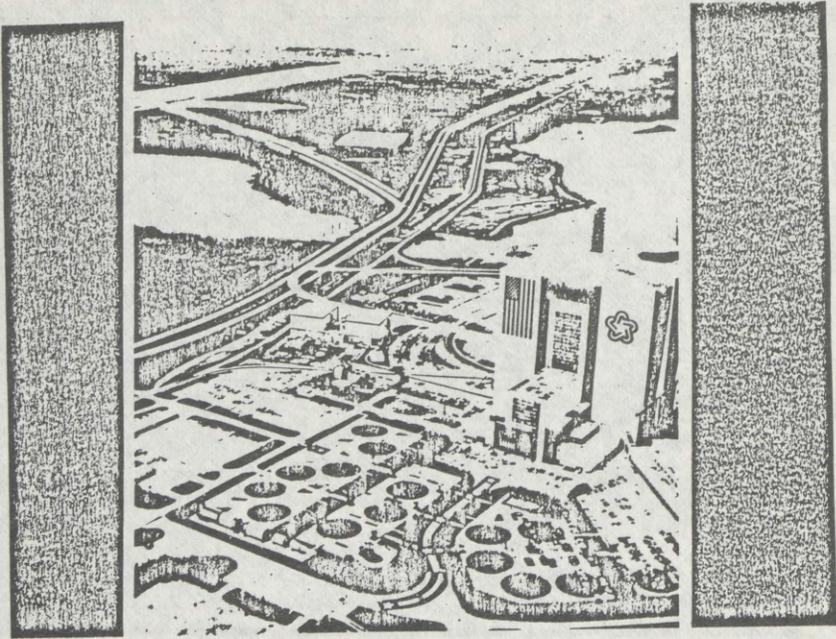
● GROUND SUPPORT EQUIPMENT FOR FIRST FLOW

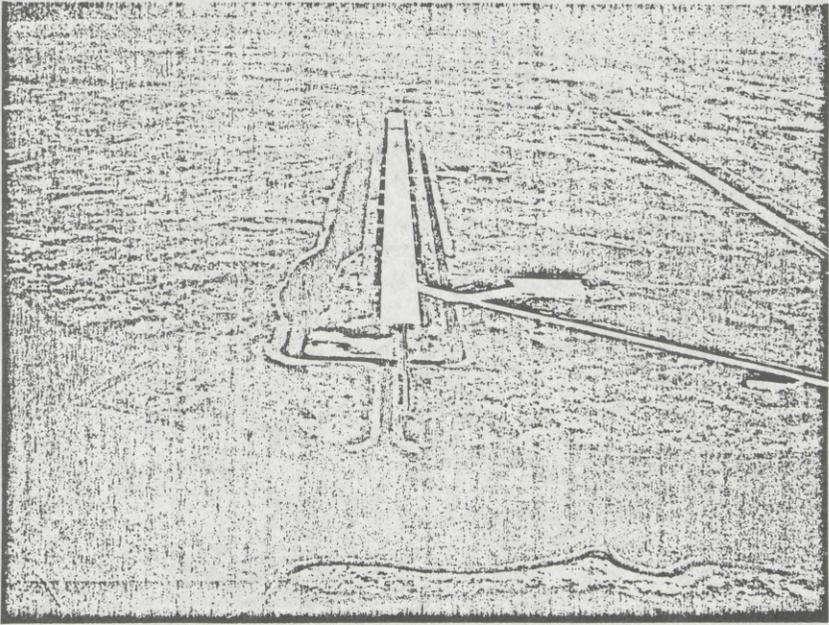
- ON CONTRACT - 80%
- DELIVERED - 10-15%

● LAUNCH TEAM

- CONTRACTS WITH RI, MMC, USBI, THIOKOL CONTRACT NEXT YEAR
- ON BOARD - 40%
- WORKING REQUIREMENTS, PROCEDURES





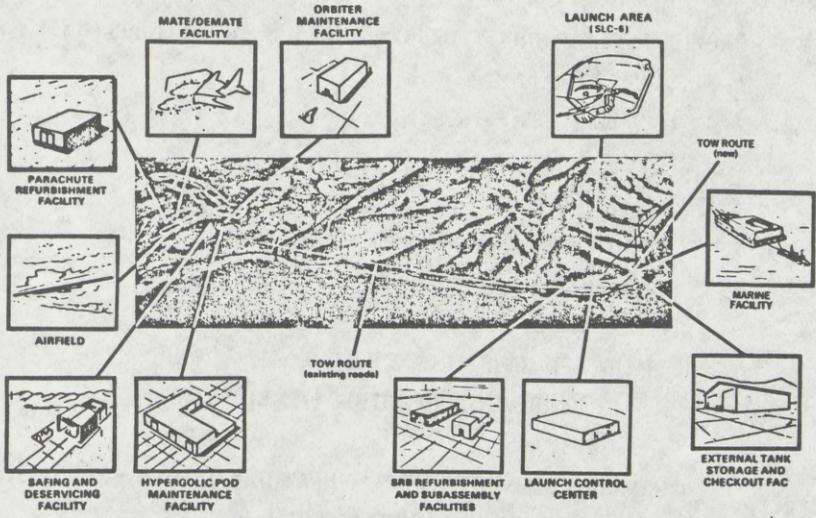


VANDENBERG AFB

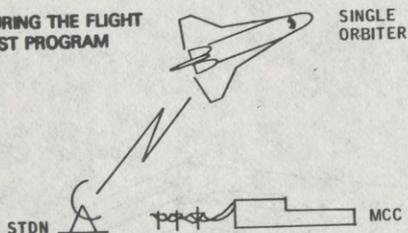
- PROVIDES STS CAPABILITY FOR POLAR AND SUN-SYNCHRONOUS MISSIONS
 - / SINGLE PAD AT SLC-6
 - / IOC - JUNE 1983

- STATUS
 - / DEFINITION CONTRACT IN PROGRESS
 - JULY 1976 TO JUNE 1978
 - ~\$28M
 - / STATION SETS IDENTIFIED
 - REQUIREMENTS DEFINITION ~75% COMPLETE
 - SYSTEM SPECIFICATIONS ~20% COMPLETE
 - / NASA/DOD COMMON SUPPORT EQUIPMENT DEFINITION ~90% COMPLETE
 - / VLPS INITIAL BUY SCHEDULED DECEMBER 1977
 - / FOLLOW-ON INTEGRATION CONTRACT JUNE 1978
 - / CONSTRUCTION START - APRIL 1979

Vandenberg STS Facilities

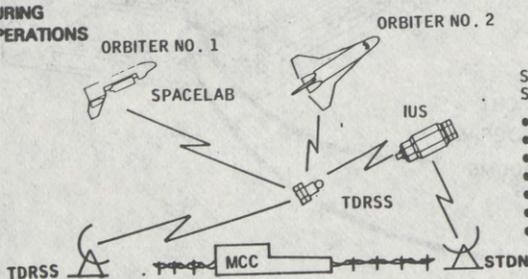


MISSION CONTROL CENTER SUPPORT

DURING THE FLIGHT
TEST PROGRAMSINGLE
ORBITER

SHUTTLE VEHICLE SUPPORT (ALT AND OFT)

- SINGLE ORBITER ONLY
- NO PAYLOAD SUPPORT

 LEVEL I STS SUPPORT CAPABILITY
 LEVEL II STS SUPPORT CAPABILITY
DURING
OPERATIONS

ORBITER NO. 1

ORBITER NO. 2

SPACELAB

IUS

TDRSS

TDRSS

MCC

STDN

SPACE TRANSPORTATION SYSTEM
SUPPORT (OPS)

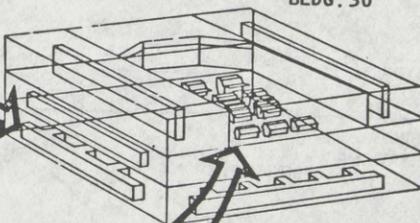
- MULTIPLE ORBITERS
- SPACELAB SUPPORT MODULE
- INTERIM UPPER STAGE
- CREW ACTIVITY PLANNING
- AUTOMATED MISSION DESIGN
- AUTOMATED FLIGHT SCHEDULING
- NO PAYLOAD DATA MANAGEMENT

FIGURE 1

MCC UPDATE PLAN**MODIFICATIONS TO SUPPORT
THE SHUTTLE FLIGHT TEST PROGRAM**

- COMM EXTERNAL INTERFACE
- OFT COMPUTERS
- COMMAND, CONTROL AND COMMUNICATIONS SOFTWARE

BLDG. 30

**MODIFICATIONS TO SUPPORT
THE STS OPERATIONS PROGRAM**

- FLIGHT CONTROL ROOMS
- MISSION PLANNING SUPPORT ROOMS
- MISSION PLANNING SOFTWARE

FIGURE 2

TASK II

LAUNCH/LANDING SITE CONSIDERATIONS

SPACE SHUTTLE SITE SELECTION

- SPACE SHUTTLE LAUNCH AND RECOVERY SITE REVIEW BOARD
 - NASA AND USAF MEMBERSHIP APPOINTED - 26 APRIL 1971
 - BOARD ACTIVITIES - 4 MAY 1971 - 6 APRIL 1972
- 140 CANDIDATE SITES SCREENED
 - SITES EVALUATED FOR MISSION CAPABILITY, BOOSTER RECOVERY, ET JETTISON, ABORT CAPABILITY, LOGISTICS, WEATHER AND CLIMATE, AIR AND WATER QUALITY, NOISE/SONIC BOOM
- STS CONFIGURATION REQUIRES COASTAL SITE
 - KSC EASIER FOR DEVELOPMENT FLIGHTS
 - VAFB FOR POLAR AND RETROGRADE MISSIONS
 - SINGLE NEW SITE POSSIBLE ON GULF COAST (MATAGORDA, TEXAS)
 - SELECTION BASED ON COST, PERFORMANCE AND ENVIRONMENT
- EVALUATION RESULTS
 - DUAL SITE SAVES FY71 \$228M AS COMPARED TO SINGLE SITE
 - NO PERFORMANCE ADVANTAGES FOR SINGLE SITE
 - SINGLE SITE HAS GREATER LAND ACQUISITION, COMMUNITY, AND WILDLIFE IMPACTS

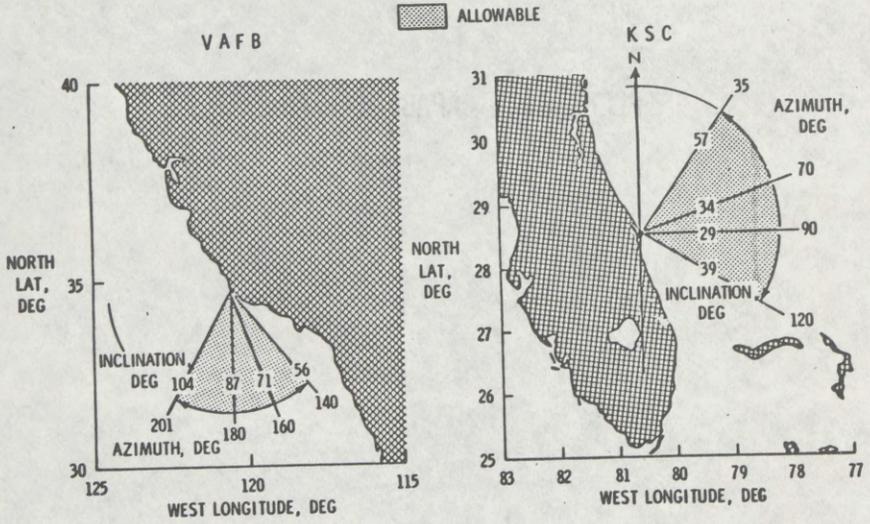
SPACE SHUTTLE SITE SELECTION (CONT'D)

- IN APRIL 1972, NASA SELECTED KSC AND VAFB AS SPACE SHUTTLE LAUNCH AND LANDING SITES
- IN APRIL 1972, DOD (DDR&E) CONCURRED IN THIS SITE SELECTION AND AGREED TO PROVIDE THE GENERAL PURPOSE SPACE SHUTTLE FACILITIES FOR ALL USERS AT VAFB

SPACE SHUTTLE LAUNCH & LANDING SITES

- KSC & VAFB SELECTED AS SHUTTLE LAUNCH AND RECOVERY SITES BASED ON -
 - KSC PROVIDES LOW INCLINATION ORBITS
 - 65K LBS DUE EAST REQUIREMENTS
 - VAFB PROVIDES HIGH INCLINATION ORBITS
 - 40K LBS SOUTH POLAR REQUIREMENT
 - ADEQUATE WATER DEPTH FOR SRB RECOVERY
 - ASCENT FOCUSED SONIC BOOM - INHABITED AREA AVOIDANCE
 - NO INHABITED AREA OVERFLIGHT EARLY IN LAUNCH TRAJECTORY
 - EXTERNAL TANK DISPOSAL IN REMOTE OCEAN AREA
 - ACCOMMODATION OF ABORT MODES

LAUNCH AZIMUTHS AND INCLINATIONS FROM VAFB AND KSC



TASK III

FLEET SIZE CAPABILITY ANALYSIS

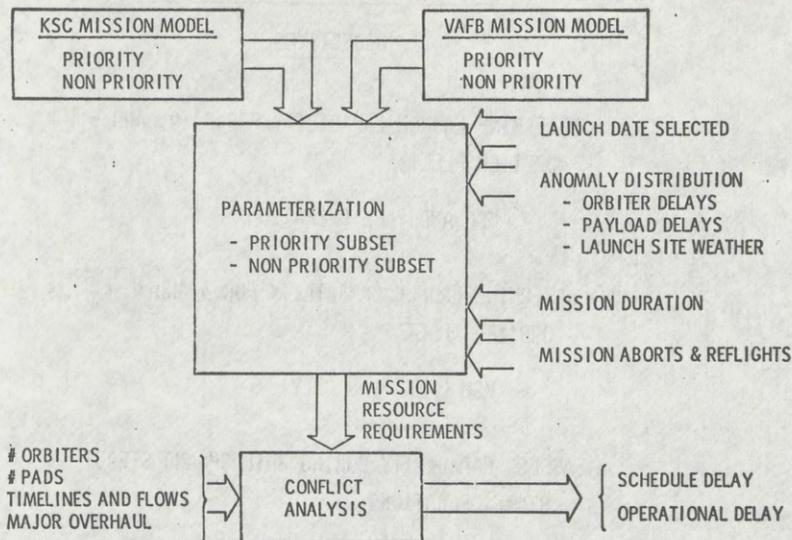
FLEET SIZE CAPABILITY ANALYSISOBJECTIVES

- o DETERMINE LAUNCH CAPABILITY FOR 3, 4, AND 5 ORBITER FLEET
 - KSC AND VAFB OPERATION

- o DETERMINE LAUNCH CAPABILITY FOR 3 AND 4 ORBITER FLEET
 - KSC OPERATION ONLY

- o ASSESS CAPABILITY DURING BUILDUP AND STEADY STATE OPERATIONS

ORBITER FLEET SIZING MODEL



PERFORMANCE EVALUATION STANDARD

0 A FLEET SIZE IS CONSIDERED ACCEPTABLE IF

/ DURING THE 10 YEAR PERIOD ALL FLIGHT REQUESTS ARE HONORED WITHIN 90 DAYS OF THE REQUEST

/ NO FLIGHT ENCOUNTERS AN OPERATIONAL LAUNCH DELAY GREATER THAN 30 DAYS

ADJUSTMENTS IN FLEET SIZE CAPABILITY ANALYSIS

- PLANNED ORBITER AVAILABILITY SCHEDULE
- UPDATED TURN-AROUND ESTIMATES DURING EARLY OPERATION
- OPERATIONAL EFFICIENCY IMPROVEMENT THROUGH LEARNING EFFECTS
- MINOR ADJUSTMENTS/REFINEMENTS IN SCHEDULING AND ANOMALY ASSESSMENTS
- REVISED MISSION DURATION ESTIMATES
- FULL OPERATIONAL EFFICIENCY ACHIEVED BY 1986 (AS DERIVED IN FY-76 STUDY)

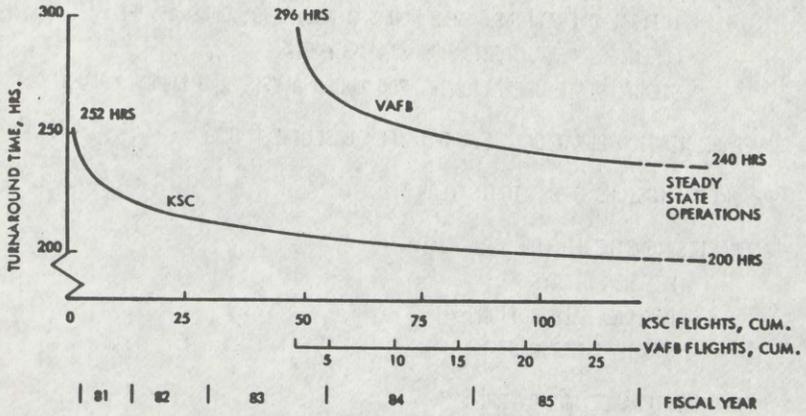
FLEET SIZE CAPABILITY

OPERATIONAL FACTORS CONSIDERED

- o GROUND TURNAROUND:
 - INITIAL OPERATIONS: 252 HOURS @ KSC; 296 HOURS @ VAFB
 - LEARNING COEFFICIENT APPROXIMATELY 97%
 - STEADY STATE OPERATIONS: 200 HOURS @ KSC; 240 HOURS @ VAFB
- o AVERAGE MISSION DURATION: 5.4 DAYS FOR BASELINE MODEL
- o PRIORITY MISSIONS 6-9 FLIGHTS/YEAR
- o ANOMALIES CONSIDERED FOR:
 - WEATHER DELAYS
 - PAYLOAD MALFUNCTIONS
 - STS MALFUNCTIONS
- o MAJOR MAINTENANCE AND OVERHAUL
- o FLIGHT DISTRIBUTION APPROXIMATELY 3:1 BETWEEN KSC AND VAFB
- o INTERCHANGEABILITY OF ORBITERS BETWEEN LAUNCH SITES

KSC/VAFB TURNAROUND TIME AND LEARNING

- 5 ORBITER/2 SITE
- \cong 97% LEARNING



GROUND RULES AND ASSUMPTIONS
(STEADY-STATE OPERATIONS)

CHARACTERISTIC	2 SITE OPERATIONS						1 SITE	
	5 ORBITER		4 ORBITER		3 ORBITER		4 ORBITER	3 ORBITER
	KSC	VAFB	KSC	VAFB	KSC	VAFB	KSC ONLY	KSC ONLY
MISSION PROFILE								
AVG. DURATION, DAYS	5.4		6.0		7.8		8.0	8.0
RANGE, DAYS	1-30		1-30		1-30		1-30	1-30
PRIORITY SUBSETS, # FLTS	9	8	9	8	6	3	9	6
FLT DISTRIBUTION, # FLTS	40	16	25	12	21	6	ALL	ALL
GROUND TIMELINE, HRS	200	240	200	240	200	240	200	200
ANOMALIES								
OCCURRENCE, %	51		51		51		51	51
DURATION RANGE, DAYS	1-4		1-4		1-4		1-4	1-4
AVERAGE DURATION, DAYS	3.7		3.7		3.7		3.7	3.7

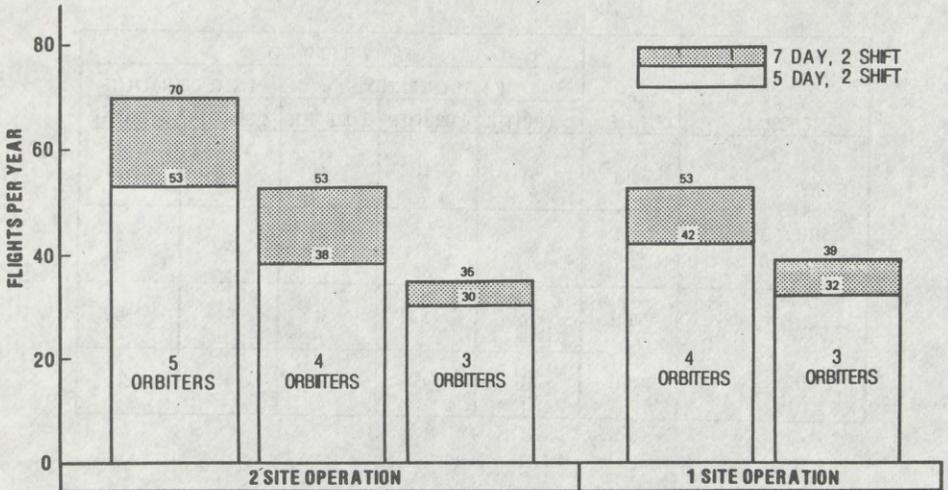
YEARLY FLIGHT CAPABILITY
(5 ORBITERS/2 SITES)

COMPARISON	FISCAL YEAR				
	81	82	83	84	85
5 DAY, 2 SHIFT					
50TH PERCENTILE	11	16	21	40	53
90TH PERCENTILE	8	11	14	33	44
7 DAY, 2 SHIFT					
50TH PERCENTILE	15	22	27	49	65
90TH PERCENTILE	11	16	21	39	57
ORBITER OPERATIONAL [↑] 102	[↑] 101		[↑] 103	[↑] 104	[↑] 105

ORBITER FLEET SIZE CAPABILITY
 (STEADY-STATE FLIGHT CAPABILITY)

WORK SCHEDULE	PER- CENTILE	YEARLY FLIGHT RATE				
		2 SITE OPERATIONS			1 SITE OPERATIONS	
		5 ORBITER	4 ORBITER	3 ORBITER	4 ORBITER	3 ORBITER
5 DAY, 2 SHIFT	50TH	53	38	30	42	32
	90TH	47	34	24	36	28
7 DAY, 2 SHIFT	50TH	70	53	35	53	39
	90TH	61	43	30	44	36

ORBITER FLEET SIZE CAPABILITY/UTILIZATION



FACTORS ESTABLISHING CAPABILITY:

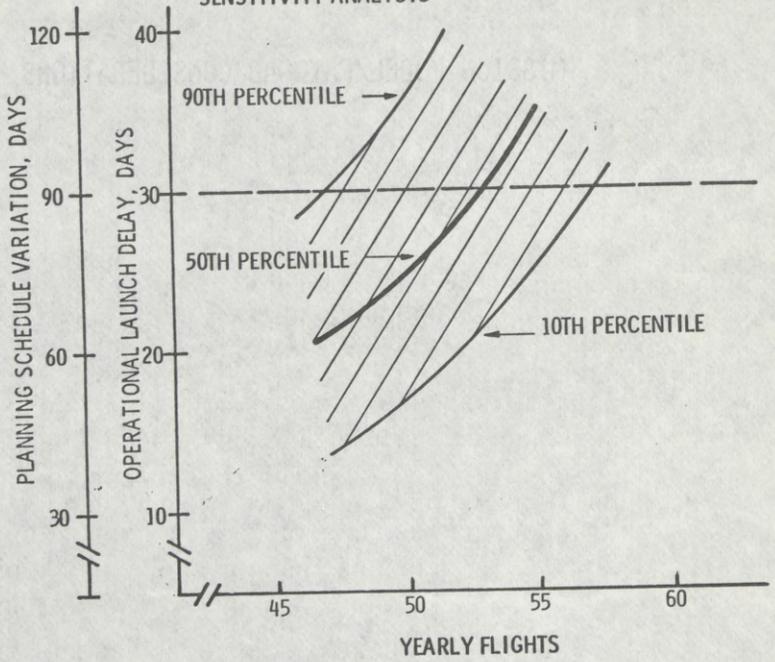
- KSC/VAFB TRAFFIC DISTRIBUTION
- GROUND TURNAROUND TIME
- MISSION DURATION
- RESOURCES, ANOMALIES, ABORTS

FLEET SIZE UTILIZATION:

- ACCOUNTS FOR ORBITER ATTRITION
- CAPABILITY LIMITED BY THE MAXIMUM FLIGHT LEVEL WITH ATTRITION ASSUMED

5 ORBITER FLEET (STEADY STATE)
 KSC AND VAFB LAUNCHES
 5 DAY WEEK
 SENSITIVITY ANALYSIS

DEGRADED
 SCHEDULING
 PERFORMANCE
 ↑
 ↓
 ACCEPTABLE
 SCHEDULING
 PERFORMANCE



TASK IV

MISSION MODEL/PAYLOAD CONSIDERATIONS

NATIONAL PAYLOAD MODEL

(OCT 1977)

- CIVIL PROGRAM
 - 1980-81 PROGRAM BASED ON FIRM COMMITMENTS (EARLY MISSION PLAN)
 - 1982-85 PROGRAM BASED ON:
 - (1) NASA UPDATE OF NON-NASA CIVIL PROGRAM
 - (2) NASA PROGRAM OFFICES PROJECTIONS FOR CURRENT PLANNING REQUIREMENTS
 - 1986-91 BASED ON 1976 PAYLOAD MODEL
- DOD PROGRAM BASED ON DOD TRANSITION PLAN (REVISION 6) DATED JULY 20, 1977
AS MODIFIED SEPT 6, 1977.

NATIONAL PAYLOAD MODEL

OCT 1977

- NASA PROGRAMS
 - / SCIENCE MISSIONS FOCUS ON SOLAR AND STELLAR ASTRONOMY EARTH-SUN DYNAMICS
 - / PLANETARY MISSIONS TO INNER/OUTER PLANETS
 - / APPLICATIONS FOCUS ON TECHNOLOGY BASE FOR USER ORIENTED SPACE SYSTEMS
 - / SPACELAB PAYLOADS
 - SPACE PROCESSING
 - LIFE SCIENCE
 - SCIENCE, APPLICATIONS AND TECHNOLOGY R&D EXPERIMENTS
- NON-NASA CIVIL PAYLOADS
 - DOMESTIC/FOREIGN SYNC EQ COMMUNICATIONS
 - DOMESTIC/FOREIGN SCIENCE
 - METEOROLOGY EARTH RESOURCES
 - EARTH ENVIRONMENT MONITORING
- DOD PAYLOADS
 - COMMUNICATIONS
 - NAVIGATION
 - METEOROLOGY
 - SURVEILLANCE
 - TECHNOLOGY

PAYLOAD MODEL DISTRIBUTION

<u>ETR</u>	<u>OBSERVATORIES</u>	<u>FREE-FLYERS</u>	<u>SPACELAB</u>	<u>TOTAL</u>
NASA	29	42	337	408
U. S. GOV'T	-	16	-	16
U. S. COM'L	-	77	18	95
FOREIGN	-	69	50	119
DOD	-	145	-	145
	<hr/>	<hr/>	<hr/>	<hr/>
SUBTOTAL	29	349	405	783
 <u>WTR</u>				
NASA	5	30	52	87
U. S. GOV'T	28	-	-	28
U. S. COM'L	7	-	-	7
FOREIGN	-	6	7	13
DOD	-	82	-	82
	<hr/>	<hr/>	<hr/>	<hr/>
SUBTOTAL	40	118	59	217
PAYLOAD MODEL TOTAL	69	467	464	1000

PAYLOAD MODEL COMPARISON
CURRENT VS. 1976 MODEL

	<u>CURRENT</u>	<u>1976 STUDY</u>
<u>NASA</u>		
AUTOMATED	106	111
SPACELAB	389	428
<u>U. S. GOVERNMENT</u>		
AUTOMATED	44	49
SPACELAB	-	-
<u>U. S. COMMERCIAL</u>		
AUTOMATED	84	89
SPACELAB	18	19
<u>FOREIGN</u>		
AUTOMATED	75	76
SPACELAB	<u>57</u>	<u>73</u>
TOTAL CIVIL	<u>773</u>	<u>845</u>
<u>DOD</u>		
AUTOMATED	<u>227</u>	<u>246</u>
PAYLOAD MODEL TOTAL	1,000	1,091

NATIONAL TRAFFIC DETERMINATION

TRAFFIC DETERMINATION GUIDELINES

- o FIRM MISSION REQUIREMENTS USED THROUGH 1981
- o TRAFFIC REQUIREMENT FROM 1982-85 BASED ON UPDATED PAYLOAD PROGRAM ESTIMATE
- o 1976 OMB STUDY TRAFFIC IS ASSUMED FOR POST-1985 PROGRAM

- o DOD TRAFFIC REQUIREMENTS PROVIDED BY DOD
- o NO MIXING OF CIVIL AND DOD PAYLOADS REQUIRED
- o SHUTTLE FLIGHTS MINIMIZED THROUGH:
 - MULTIPLE PAYLOADS, MULTIPLE STAGES
 - RETRIEVAL COMBINED WITH DELIVERY
- o ABORT REFLIGHTS INCLUDED
 - SHUTTLE DIRECT MISSIONS ~ 6½%
 - UPPER STAGE MISSIONS ~ 8½%
- o ELV TRAFFIC INCLUDED FOR PAYLOADS PRIOR TO STS TRANSITION
- o DOD BACKUP INCLUDED FOR TRANSITION ERA

STS REQUIREMENTS TRAFFIC MODEL

5 ORBITERS/2 SITS

(USERS)

	FY 80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
ETR														
NASA	1	5	12	15	16	15	24	25	22	24	24	23	6	212
U.S. GOV'T	-	1	-	1	-	1	-	-	1	-	1	1	-	6
U.S. COM'L	1	3	1	3	2	2	5	4	9	8	8	4	1	51
FOREIGN	1	2	4	4	3	2	2	5	5	5	7	8	2	50
DOD	-	-	2	6	7	8	7	5	8	6	7	9	2	67
SUBTOTAL	3	11	19	29	28	28	38	39	45	43	47	45	11	386
REFLIGHTS	-	1	2	3	1	3	4	2	1	3	1	3	-	24
TOTAL ETR	3	12	21	32	29	31	42	41	46	46	48	48	11	410
WTR														
NASA				6	9	9	5	5	6	4	6	6	2	58
U.S. GOV'T				-	-	-	2	2	4	2	4	2	1	17
U.S. COM'L				-	-	-	1	-	2	-	1	1	-	5
FOREIGN				-	-	1	2	3	1	2	1	1	-	11
DOD				2	4	5	4	6	6	6	4	6	1	44
SUBTOTAL				8	13	15	14	16	19	14	16	16	4	135
REFLIGHTS				-	1	1	1	1	-	1	1	1	-	7
TOTAL WTR				8	14	16	15	17	19	15	17	17	4	142
TOTAL SHUTTLE OPERATIONS	3	12	21	40	43	47	57	58	65	61	65	65	15	552

STS REQUIREMENTS TRAFFIC MODEL

5 ORBITERS/2 SITE

(FLIGHT ELEMENTS)

	FY 80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
ETR														181
S/L (DEDICATED)	-	5	11	12	11	12	18	22	20	21	21	23	5	(17)
S/L (PARTIAL)	(1)	(2)	-	(1)	(1)	(2)	(1)	(2)	(1)	(2)	(2)	(2)	-	24
LARGE STRUCTURES	-	-	-	-	-	1	3	3	4	4	4	4	1	150
UPPER STAGES	2	6	5	15	13	13	15	9	20	14	19	15	3	31
FREE-FLYERS	<u>1</u>	<u>-</u>	<u>2</u>	<u>2</u>	<u>4</u>	<u>2</u>	<u>2</u>	<u>5</u>	<u>1</u>	<u>4</u>	<u>3</u>	<u>3</u>	<u>2</u>	<u>386</u>
SUBTOTAL	3	11	19	29	28	28	38	39	45	43	47	45	11	24
REFLIGHTS	<u>-</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>1</u>	<u>3</u>	<u>4</u>	<u>2</u>	<u>1</u>	<u>3</u>	<u>1</u>	<u>3</u>	<u>-</u>	<u>-</u>
TOTAL ETR	3	12	21	32	29	31	42	41	46	46	48	48	11	410
WTR														45
S/L (DEDICATED)				4	4	6	5	5	5	5	5	5	1	(7)
S/L (PARTIAL)				(1)	(2)	(1)	(1)	(1)	(1)	-	-	-	-	12
UPPER STAGES				-	-	3	1	2	1	1	1	2	1	78
FREE-FLYERS				<u>4</u>	<u>9</u>	<u>6</u>	<u>8</u>	<u>9</u>	<u>13</u>	<u>8</u>	<u>10</u>	<u>9</u>	<u>2</u>	<u>135</u>
SUBTOTAL				8	13	15	14	16	19	14	16	16	4	7
REFLIGHTS				<u>-</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>-</u>	<u>1</u>	<u>1</u>	<u>1</u>	<u>-</u>	<u>142</u>
TOTAL WTR				8	14	16	15	17	15	15	17	17	4	
TOTAL SHUTTLE OPERATIONS	3	12	21	40	43	47	57	58	65	61	65	65	15	552

FLEET UTILIZATION

- o CONSISTENT WITH SHUTTLE TRAFFIC LEVEL RANGE ESTABLISHED
 - FLEET CAPABILITY
 - SINGLE ORBITER ATTRITION
- o FLEET CAPABILITY RANGES ARE:
 - 5 ORBITER FLEET - 480 TO 580 FLIGHTS
 - 4 ORBITER FLEET - 365 TO 480 FLIGHTS
- o 5 ORBITER FLEET WITHOUT ATTRITION ACCOMMODATES PROJECTED NATIONAL PAYLOAD PROGRAM (1000 PAYLOADS/552 FLTS)
- o SPACELAB PROGRAM ALLOWS FLEXIBILITY TO ADJUST TRAFFIC LEVEL TO ACCOUNT FOR ATTRITION
 - REQUIRES REDUCTION OF \sim 8/YEAR IN NASA STEADY STATE SPACELAB TRAFFIC
- o ANALYSIS OF THE NATIONAL PROGRAM BASED UPON TRAFFIC LEVEL ACCOUNTING FOR ATTRITION

FLEET SIZE CAPABILITY
STEADY STATE OPERATIONS

FLEET SIZE/LAUNCH SITE	WORK SCHEDULE		ASSUMED CAPABILITY WITH ATTRITION
	5 DAY/2 SHIFT	7 DAY/2 SHIFT	
5 ORBITERS/2 SITE	53	70	53
4 ORBITERS/2 SITE	38	53	35
3 ORBITERS/2 SITE	30	35	25
4 ORBITERS/1 SITE	42	53	39
3 ORBITERS/1 SITE	32	39	26

OMB STUDY SUPPLEMENT

STS TRAFFIC MODEL

5 ORBITERS/2 SITE

(USERS)

	<u>FY 80</u>	<u>81</u>	<u>82</u>	<u>83</u>	<u>84</u>	<u>85</u>	<u>86</u>	<u>87</u>	<u>88</u>	<u>89</u>	<u>90</u>	<u>91</u>	<u>92</u>	<u>TOTAL</u>
<u>ETR</u>														
NASA	1	6	10	10	18	17	19	18	15	17	17	16	3	167
U. S. GOV'T	1	1	-	-	1	-	-	-	1	-	1	1	-	6
U. S. COM'L	1	3	1	2	3	4	5	4	9	8	8	4	2	54
FOREIGN	-	1	3	3	3	3	3	5	5	5	6	6	1	44
DOD	-	-	2	6	7	8	7	5	8	6	7	9	2	67
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
SUBTOTAL	3	11	16	21	32	32	34	32	38	36	39	36	8	338
REFLIGHTS	-	1	1	1	2	2	2	2	2	2	2	2	1	20
	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>	<u> </u>
TOTAL ETR	3	12	17	22	34	34	36	34	40	38	41	38	9	358
<u>WTR</u>														
NASA				1	4	6	5	5	6	4	6	6	1	44
U. S. GOV'T				1	1	1	2	2	4	2	4	2	1	20
U. S. COM'L				-	-	-	1	1	-	-	-	1	-	3
FOREIGN				-	-	-	2	3	1	2	1	1	1	11
DOD				2	4	5	4	6	6	6	4	6	1	44
				<u> </u>										
SUBTOTAL				4	9	12	14	17	17	14	15	16	4	122
REFLIGHTS				-	-	1	1	1	1	1	1	1	-	7
				<u> </u>										
TOTAL WTR				4	9	13	15	18	18	15	16	17	4	129
TOTAL STS OPS	3	12	17	26	43	47	51	52	58	53	57	55	13	487

1976 STUDY

NATIONAL STS TRAFFIC MODEL
SINGLE PAD AT WTR
(USERS)

	FY	80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
ETR															
NASA		1	8	13	15	18	25	21	26	22	23	23	24	6	225
U.S. GOV'T		-	1	-	-	-	1	-	-	1	1	1	1	-	6
U.S. COM'L		-	2	1	3	5	5	6	3	9	7	8	4	1	54
FOREIGN		1	1	-	5	3	4	4	5	5	6	7	8	2	51
DOD		1	1	7	5	8	8	7	6	8	5	7	6	2	71
SUBTOTAL		3	13	21	28	34	43	38	40	45	42	46	43	11	407
ABORTS		-	1	2	3	3	1	4	2	1	3	1	3	-	24
TOTAL ETR		3	14	23	31	37	44	42	42	46	45	47	46	11	431
WTR															
NASA					2	3	5	4	5	5	4	6	6	2	42
U.S. GOV'T					1	1	2	3	2	4	2	4	2	1	22
U.S. COM'L					-	1	-	1	-	2	-	1	1	-	6
FOREIGN					1	1	1	2	3	2	2	1	1	-	14
DOD					1	5	5	5	3	6	5	3	4	1	38
SUBTOTAL					5	11	13	15	13	19	13	15	14	4	122
ABORTS					-	1	1	1	1	-	1	1	1	-	7
TOTAL WTR					5	12	14	16	14	19	14	16	15	4	129
TOTAL SHUTTLE OPS		3	14	23	36	49	58	58	56	65	59	63	61	15	560

OMB STUDY SUPPLEMENT

STS TRAFFIC MODEL

5 ORBITERS/2 SITE

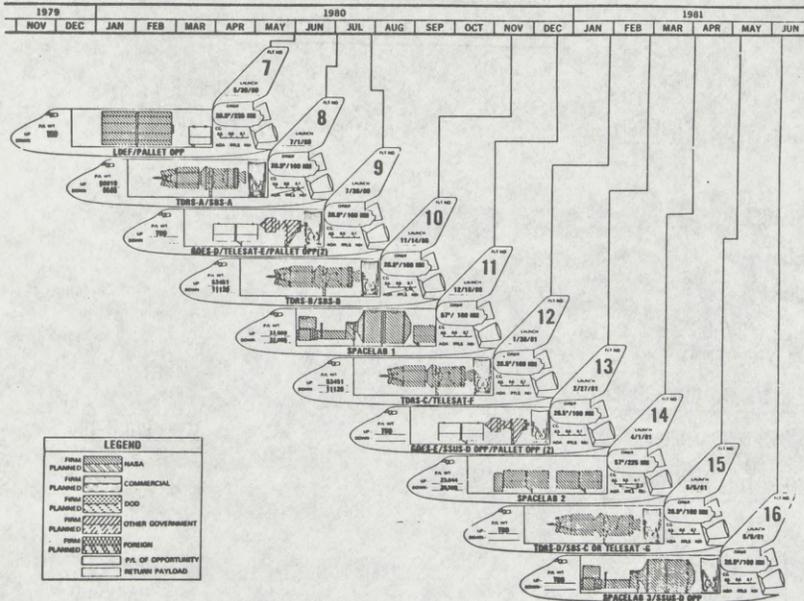
(FLIGHT ELEMENTS)

	FY 80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
<u>ETR</u>														
SPACELAB	-	6	8	10	14	16	17	18	17	18	17	18	3	162
UPPER STAGES	2	5	6	11	15	15	15	9	20	14	19	15	4	150
FREE-FLYERS	1	-	2	-	3	1	2	5	1	4	3	3	1	26
<u>SUBTOTAL</u>	<u>3</u>	<u>11</u>	<u>16</u>	<u>21</u>	<u>32</u>	<u>32</u>	<u>34</u>	<u>32</u>	<u>38</u>	<u>36</u>	<u>39</u>	<u>36</u>	<u>8</u>	<u>338</u>
REFLIGHTS	-	1	1	1	2	2	2	2	2	2	2	2	1	20
TOTAL ETR	3	12	17	22	34	34	36	34	40	38	41	38	9	358
<u>WTR</u>														
SPACELAB	-	-	-	-	3	4	5	5	5	5	5	5	2	39
UPPER STAGES	-	-	-	-	-	1	1	2	1	1	1	2	0	9
FREE-FLYERS	-	-	-	4	6	7	8	10	11	8	9	9	2	74
<u>SUBTOTAL</u>	<u>-</u>	<u>-</u>	<u>-</u>	<u>4</u>	<u>9</u>	<u>12</u>	<u>14</u>	<u>17</u>	<u>17</u>	<u>14</u>	<u>15</u>	<u>16</u>	<u>4</u>	<u>122</u>
REFLIGHTS	-	-	-	-	-	1	1	1	1	1	1	1	-	7
TOTAL WTR	-	-	-	4	9	13	15	18	18	15	16	17	4	129
TOTAL STS OPS	3	12	17	26	43	47	51	52	58	53	57	55	13	487

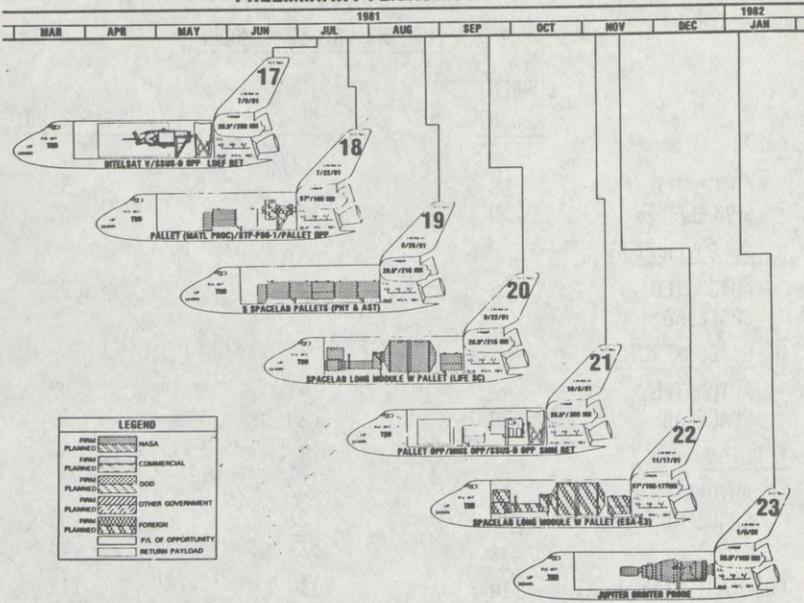
EARLY MISSION PLANNING
COMMITTED SHUTTLE PAYLOADS

<u>PROGRAM</u>	<u>NUMBER OF PAYLOADS</u>
<u>NASA</u>	
SPACELAB	5
LDEF	1
JOP	1
RETRIEVALS (LDEF, SMM)	2
<u>OTHER U. S. GOVERNMENT</u>	
GOES (NOAA)	2 + BACK-UP
<u>COMMERCIAL AND FOREIGN</u>	
COMSAT	2 + BACK-UP
SBS	2 + BACK-UP
TELESAT	2 + BACK-UP
TDRSS	6
<u>SMALL SELF CONTAINED PAYLOADS</u>	
INDUSTRIAL	29
UNIVERSITY	11
INDIVIDUAL	32

PRELIMINARY FLIGHT ASSIGNMENT



PRELIMINARY FLIGHT ASSIGNMENT



TRAFFIC MODEL COMPARISONCURRENT VS. 1976 MODEL

	<u>CURRENT REQ'MT</u>	<u>STUDY BASE</u>	<u>1976 STUDY</u>
<u>NASA</u>			
AUTOMATED	58	58	59
SPACELAB	230	167	230
<u>U. S. GOVERNMENT</u>			
AUTOMATED	28	28	28
SPACELAB		-	-
<u>U. S. COMMERCIAL</u>			
AUTOMATED	41	41	47
SPACELAB	20	20	19
<u>FOREIGN</u>			
AUTOMATED	32	32	32
SPACELAB	29	27	33
	438	373	448
<u>DOD (AUTOMATED)</u>	<u>114</u>	<u>114</u>	<u>112</u>
TRAFFIC MODEL	552	487	560

TRAFFIC DETERMINATIONGROUNDRULES AND ASSUMPTIONS FOR FLEET SIZE VARIATIONS

- o EQUIVALENT PAYLOAD PROGRAM RETAINED FOR ALL CASES
- o SHUTTLE/ELV MIX USED AS REQUIRED
- o SHUTTLE CAPABILITY CONSISTENT WITH FLEET SIZE ANALYSIS AND CONSIDERATION OF ORBITER ATTRITION
- o MANNED SPACELAB TRAFFIC AT VAFB TRANSFERRED TO KSC FOR SINGLE SITE CASE
- o CONVERSION OF SOME PALLET ONLY SPACELAB TO ELV'S AS REQUIRED
- o PRIORITY FOR PAYLOAD RETENTION ON SHUTTLE
 - MANNED SPACELAB
 - DOD PAYLOADS
 - OBSERVATORY PAYLOADS
 - PLANETARY PAYLOADS
 - PALLET ONLY SPACELAB
 - SMALL FREE FLYERS

STS TRAFFIC COMPARISONS

USERS	KSC/VAFB OPERATIONS						KSC OPERATIONS ONLY			
	5 ORBITER		4 ORBITER		3 ORBITER		4 ORBITER		3 ORBITER	
	STS	ELV	STS	ELV	STS	ELV	STS	ELV	STS	ELV
EIR	(358)	(13)	(253)	(160)	(210)	(211)	(365)	(65)	(249)	(193)
NASA	167	0	117	45	116	46	185	-0-	154	16
OTHER CIVIL	104	3	56	105	52	118	92	55	51	130
DOD	67	10	67	10	30	47	67	10	30	47
REFLIGHTS	20	0	13	0	12	0	21	0	14	0
WIR	(129)	(35)	(98)	(66)	(48)	(128)		(166)		(166)
NASA	44	2	18	28	9	46	-0-	46	-0-	46
OTHER CIVIL	34	3	31	8	28	16	-0-	42	-0-	42
DOD	44	30	44	30	8	66	-0-	78	-0-	78
REFLIGHTS	7	0	5	0	3	0	-0-	0	-0-	0
MISSION MODEL	(487)	(48)	(351)	(226)	(258)	(339)	(365)	(231)	(249)	(359)
NASA	211	2	135	73	125	92	185	46	154	62
OTHER CIVIL	138	6	87	113	80	134	92	97	51	172
DOD	111	40	111	40	38	113	67	88	30	125
REFLIGHTS	27	0	18	0	15	0	21	0	14	0

STS TRAFFIC COMPARISONS

SITE/STUDY	KSC/VAFB OPERATIONS						KSC OPERATIONS ONLY			
	5 ORBITER		4 ORBITER		3 ORBITER		4 ORBITER		3 ORBITER	
	STS	ELV	STS	ELV	STS	ELV	STS	ELV	STS	ELV
<u>KSC</u>										
CURRENT	358	13	253	160	210	211	365	65	249	193
OMB 1976	431	30	420	60	283	303	439	140	373	282
<u>VAFB</u>										
CURRENT	129	35	98	66	48	128	0	166	0	166
OMB 1976	129	53	76	116	103	131	0	159	0	159
<u>MISSION MODEL</u>										
CURRENT	487	48	351	226	258	339	365	231	249	359
OMB 1976	560	83	496	176	386	434	439	299	373	441

TASK V

COST EFFECTIVENESS ANALYSES

ALTERNATIVES ANALYZED

- 5, 4, AND 3 ORBITER FLEETS
/ KSC AND VAFB SHUTTLE OPERATION

- 4 AND 3 ORBITER FLEETS
/ KSC SHUTTLE OPERATIONS ONLY

GROUND RULES AND ASSUMPTIONS FOR COST ANALYSIS

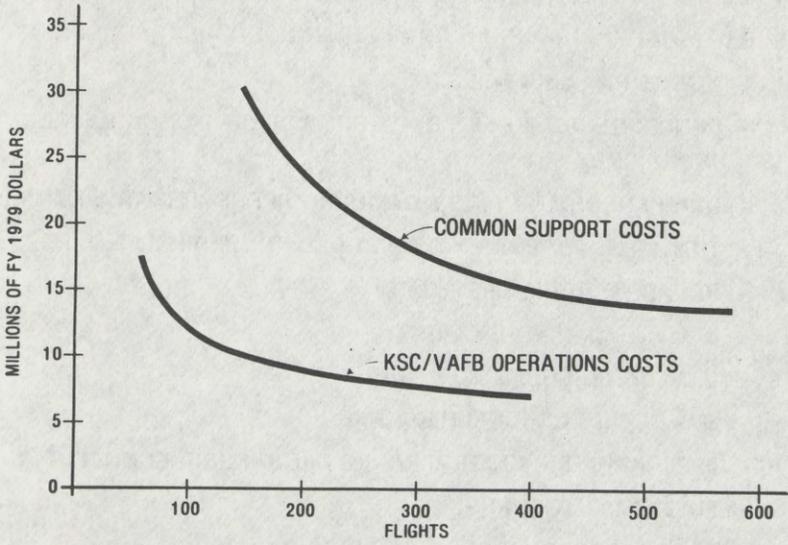
- ALL COSTS SHOWN IN FY 1979 DOLLARS
- ESCALATION FACTOR OF 7% TO 8% USED
- DOD COSTING
 - FOR 2 LAUNCH SITE CASES REIMBURSEMENT TO NASA IS BASED ON MATERIALS AND SERVICES CONSISTENT WITH THE NASA/DOD MOA ON STS LAUNCH REIMBURSEMENT (MARCH 7, 1977)
 - FOR 1 LAUNCH SITE CASES REIMBURSEMENT IS BASED ON NORMAL REIMBURSEMENT AS APPLIED TO CIVIL U.S. GOVERNMENT USERS
- NO OPTIONAL SHUTTLE SERVICES INCLUDED
- CONSIDERATIONS INCLUDE:
 - (1) IUS DEVELOPMENT
 - (2) VAFB INVESTMENT
 - (3) SECURITY
 - (4) STS AND ELV OPERATIONS COSTS
 - (5) INCREMENTAL PAYLOAD PROCUREMENT COSTS

GROUND RULES AND ASSUMPTIONS FOR COST ANALYSIS

(CONTINUED)

- SHUTTLE COST FOR CIVIL PROGRAMS DERIVED FROM COST/FLT VS FLIGHT RATE CURVES
- ELV COSTING
 - ADJUSTED FOR LAUNCH RATE EFFECTS
 - INCLUDES ALL COST ELEMENTS EQUIVALENT TO SHUTTLE COSTS AS DEFINED IN USER CHARGE STUDY
 - LAUNCH SITE PECULIAR COSTS ACCOUNTED FOR IN EACH ALTERNATIVE EXAMINED
 - TITAN SERIES RECONFIGURED TO COMMON CORE FOR SYNERGISTIC BENEFITS
 - DOD BACK-UP REQUIREMENTS INCLUDED
 - NO CIVIL BACK-UP REQUIREMENTS
- SPACELAB COSTING BASED UPON COST FOR:
 - SPARES - DIRECT RATIO TO FLIGHT RATE
 - DIRECT MANPOWER - REDUCED AT 1/2 THE RATE OF FLIGHT REDUCTION
 - FIXED COSTS - CONSTANT

COST PER FLIGHT VS. FLIGHT RATE (FY 1979 DOLLARS)



GROUND RULES AND ASSUMPTIONS FOR COST ANALYSIS

(CONTINUED)

● UPPER STAGE COSTING:

- \$2.0M FOR SSUS-D
- \$3.0M FOR SSUS-A
- \$8.0M FOR TWO-STAGE IUS
- \$9.5M FOR THREE-STAGE IUS

● CIVIL PAYLOAD COSTING

- UTILIZES OCTOBER 1973 MISSION MODEL ANALYSIS AS BASIS FOR DERIVING LOW COST, RELIABILITY, AND REUSE EFFECTS
- PAYLOAD COST PENALTIES FOR REUSABILITY, RELIABILITY, DUAL COMPATIBILITY, AND ASSOCIATED WEIGHT/VOLUME ARE INCLUDED

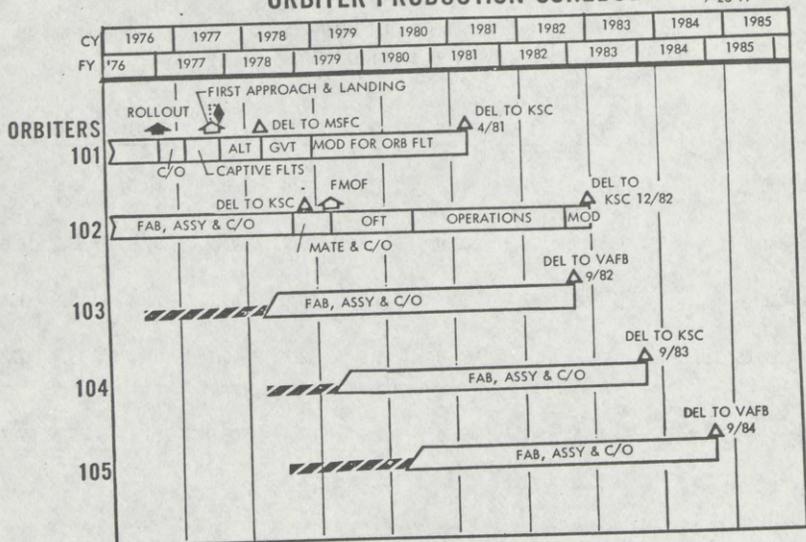
● STS FACILITIES AND INVESTMENT COSTS PROVIDED BY PROGRAMS FOR EACH ALTERNATIVE

CIVIL COST ANALYSIS

PRODUCTION COST AND SCHEDULE

ORBITER PRODUCTION SCHEDULE

9-28-77



ALT - APPROACH & LANDING TEST
 GVT - GROUND VIBRATION TEST
 OFT - ORBITAL FLIGHT TEST

SPACE SHUTTLE
 PRODUCTION COST ESTIMATES
 (FY 79 \$ IN MILLIONS)

	<u>FY 77</u>	<u>FY 78</u>	<u>FY 79</u>	<u>FY 80</u>	<u>FY 81</u>	<u>FY 82</u>	<u>FY 83</u>	<u>FY 84</u>	<u>TOTAL</u>
● MOD. 1 & 2	32.0	27.5	201.5	131.0	66.9	0.5	0.3		459.7
● BUILD 3, 4, & 5	33.0	6.5	208.0	478.8	525.2	343.2	203.0	53.2	1850.9
● GSE	5.0	7.7	20.5	45.0	46.5	43.0	21.8	8.9	198.4
● SPARES/EQUIP.			28.0	45.5	68.8	60.2	61.8	13.7	278.0
TOTAL	70.0	41.7	458.0	700.3	707.4	446.9	286.9	75.8	2787.0

SPACE SHUTTLE
ORBITER PRODUCTION IMPACTS
(FY 79 \$ IN MILLIONS)

<u>PRODUCTION PROGRAM</u>	<u>PRODUCTION REMOVED</u>	<u>PRODUCTION PENALTY</u>	<u>TOTAL COST</u>
5 ORBITERS (BASELINE)	-	-	2787.0
4 ORBITERS	-585.4	+220.0	2421.6
3 ORBITERS	-1260.8	+275.0	1801.2

CIVIL INVESTMENT COSTS
(MILLIONS OF FY 79 \$)

	5/2 BASELINE			DELTA COSTS			
	<u>NASA</u>	<u>OTHER</u>	<u>TOTAL</u>	<u>4/2</u>	<u>3/2</u>	<u>4/1</u>	<u>3/1</u>
<u>DDT&E</u>							
SHUTTLE	7311	80	7391	-	-	-	-
SPACELAB	100	575	675	-	-	-	-
IUS	44	-	44	-	-	-	-
SSUS	-	33	33	-	-	-	-
<u>PRODUCTION</u>							
ORBITERS	2509	-	2509	-365	-926	-365	-926
SPARES & EQUIPMENT	278	-	278	-	-60	-	-60
OPS CAPABILITY	148	-	148	-	-	-	-
SPACELAB	277	-	277	-30	-30	-15	-30
<u>FACILITIES</u>							
	460	-	460	-	-	-	-
TOTAL	<u>11127</u>	<u>688</u>	<u>11815</u>	<u>-395</u>	<u>-1016</u>	<u>-380</u>	<u>-1016</u>

PAYLOAD COSTS COMPARISONMILLIONS OF 79 \$

	<u>CURRENT PROGRAM</u>	<u>1976 STUDY</u>
NASA	\$12,944	\$20,865
NASA RELATED	\$ 2,475	\$ 2,850
OTHER CIVIL	\$11,856	\$11,175

CIVIL PROGRAM COST COMPARISON

(MILLIONS '79 DOLLARS)

COST CATEGORY	DELTA COSTS (TO 5/2 CASE)				
	BASELINE 5/2	CASE 4/2	CASE 3/2	CASE 4/1	CASE 3/1
STS NON-RECURRING INVEST.	(11,815)	(-395)	(-1016)	(-380)	(-1016)
SHUTTLE DDT&E	7,391				
ORBITER PROCUREMENT	2,787	-585	-1261	-585	-1261
PRODUCTION PENALTY		+220	+ 275	+220	+ 275
SPACELAB/SSUS/IUS	1,029	- 30	- 30	- 15	- 30
FACILITIES	460				
OPS CAPABILITY	148	-	-	-	-
OPERATIONS	(9,654)	(+2,510)	(+3,885)	(+1,754)	(+3,833)
SHUTTLE	8,262	-1,857	-1,899	-1,336	-2,086
SSUS/IUS	674	- 445	- 503	- 167	- 362
SPACELAB	503	- 42	- 40	- 20	- 50
ELV	215	+4,854	+6,327	+3,277	+6,331
PAYLOADS	(27,275)	(+2,142)	(+3,331)	(+2,725)	(+4,036)
NASA	12,944	+1,163	+1,772	+ 771	+1,380
OTHER CIVIL	14,331	+ 979	+1,559	+1,954	+2,656
MISSION MODEL TOTAL	48,744	+4,257	+6,200	+4,099	+6,853

CIVIL PROGRAM COST COMPARISON

(MILLIONS OF 1979 DOLLARS)

COST CATEGORY	BASELINE 5/2		DELTA COSTS							
	CURRENT	OMB76	4/2		3/2		4/1		3/1	
			CURRENT	OMB76	CURRENT	OMB76	CURRENT	OMB76	CURRENT	OMB76
INVESTMENT	11,815	11,326	-395	-387	-1,016	-1,060	-380	-394	-1,016	-1,063
OPERATIONS	9,654	11,296	+2,510	+823	+3,885	+3,242	+1,754	+2,076	+3,833	+2,651
PAYLOAD	<u>27,275</u>	<u>34,891</u>	<u>+2,142</u>	<u>+1,357</u>	<u>+3,331</u>	<u>+2,282</u>	<u>+2,725</u>	<u>+1,856</u>	<u>+4,036</u>	<u>+2,203</u>
TOTAL	48,744	57,513	+4,257	+1,793	+6,200	+4,464	+4,099	+3,538	+6,853	+3,791

DOD COST ANALYSIS

DOD TOTAL PROGRAM COST COMPARISON
(MILLIONS OF FY 79 DOLLARS)

COST CATEGORY	KSC AND VAFB			KSC ONLY	
	5 ORBITERS	DELTA COST		DELTA COST	
		4 ORBITERS	3 ORBITERS	4 ORBITERS	3 ORBITERS
INVESTMENT	(2964)	(+ 69)	(-806)	(-1086)	(-1731)
SHUTTLE RDT&E	140	0	0	- 18	- 18
GROUND SUPPORT SYSTEM	993	0	- 64	- 890	- 921
IUS DEVELOPMENT	235	0	0	0	0
MOS ACQUISITION	67	0	- 27	0	- 27
PAYLOAD TRANSITION	936	0	-548	- 249	- 598
ELV MODIFICATION	187	0	+239	+ 226	+ 239
BACKUP ELV	406	+ 69	-406	- 155	- 406
OPERATIONS	(5333)	(- 30)	(+1653)	(+ 859)	(+1255)
STS	3363	- 34	-1546	-1055	-2206
ELV	1486	0	+3056	+1672	+3298
RELIABILITY (LOSSES)	242	+ 4	+ 25	+ 56	+ 51
OTHER	242	0	- 82	- 14	- 88
PAYLOAD	NOT INCL	0	+ 200	+ 200	+ 200
TOTAL	8297	+ 39	+ 847	- 227	- 476

NATIONAL COST SUMMARY

NATIONAL TOTAL PROGRAM COST COMPARISON

(MILLIONS OF FY 79 DOLLARS)

COST CATEGORY	KSC AND VAFB OPERATIONS			KSC OPERATIONS ONLY	
	COST 5 ORBITERS	DELTA COSTS		DELTA COSTS	
		4 ORBITERS	3 ORBITERS	4 ORBITERS	3 ORBITERS
CIVIL PROGRAM	(21,469)	(+4,257)	(+6,200)	(+4,099)	(+6,853)
NON-RECURRING	11,815	- 395	-1,016	-380	-1,016
OPERATIONS	9,654	+2,510	+3,885	+1,754	+3,833
PAYLOADS	NOT INCL	+2,142	+3,331	+2,725	+4,036
DOD PROGRAM	(8,297)	(+ 39)	(+ 847)	(- 227)	(- 476)
NON-RECURRING	2,964	+ 69	-806	-1,086	-1,731
OPERATIONS	5,333	-30	+1,453	+ 659	+1,055
PAYLOADS	NOT INCL	0	+ 200	+ 200	+ 200
MISSION MODEL TOTAL	29,766	+4,295	+7,047	+3,872	+6,377

4 ORBITER FLEET SENSITIVITY
(BILLIONS OF 79 DOLLARS)

	<u>2 SITE</u>	<u>PROGRAM COST*</u> <u>1 SITE</u>	<u>COST Δ</u>
BASELINE ANALYSIS	34.1	33.7	-.4
INCREASE OF 6 FLIGHTS/YR	32.1	32.3	+.2

* EXCLUDES PAYLOAD INVESTMENT COSTS

SPACE TRANSPORTATION SYSTEM
INVESTMENT VERSUS UTILIZATION

(FY79 \$ IN MILLIONS)

ELEMENTS	TOTAL	FUNDING		SOURCE
		NASA	DOD	OTHER
SPACE SHUTTLE DDT&E	7,531	7,311	140	80
PRODUCTION ORBITERS	2,509	2,509	-	-
IUS	279	44	235	-
FACILITIES & EQUIP.	460	460	-	-
VAFB ACQUISITION	993	-	993	-
BACK-UP ELV	406	-	406	-
NASA OTHER	803	803	-	-
DOD OTHER	1,190	-	1,190	-
OTHER CIVIL	608	-	-	608
TOTAL	14,779	11,127	2,964	688

USER	NO. OF FLIGHTS	UTILIZATION	"FAIR SHARE"
NASA	225	47 %	6,828
OTHER CIVIL	148	30 %	4,491
DOD	114	23 %	3,460
	487	100 %	14,779

INVESTMENT VS. UTILIZATION

(FY 79 \$ IN MILLIONS)

NASA OTHER

SPACELAB DDT&E	100
SPACELAB PROCUREMENT	277
ORBITER SPARES & EQUIPMENT	278
OPS CAPABILITY	<u>148</u>
	803

DOD OTHER

PAYLOAD TRANSITION	936
ELV MODIFICATIONS	187
MOS ACQUISITION	<u>67</u>
	1,190

OTHER CIVIL

SPACELAB DDT&E	575
SSUS DDT&E	<u>33</u>
	608

STS USER CHARGE POLICIES

OBJECTIVES OF PRICING POLICY

- ENCOURAGE THE FULL USE OF STS TO BENEFIT THE U. S.
- FISCAL INTEGRITY THROUGH RECOVERY OF THOSE REASONABLE COSTS INCURRED BY NASA
- PROVIDE SHUTTLE PRICING FLEXIBILITY TO COMPENSATE FOR UNCERTAINTIES IN FORECASTED OPERATING COSTS
- ASSURE FAIRNESS OF RATE STRUCTURE BY CHARGING EACH CLASS OF USER
 - / ON THE BASIS OF STS CAPABILITY REQUIRED
 - / ON A NON-DISCRIMINATORY BASIS FOR SIMILAR SERVICES
- ASSURE EASE OF ADMINISTRATION BY HAVING AS SIMPLE A RATE STRUCTURE AS POSSIBLE

SHUTTLE USER CHARGE
COST RECOVERY ELEMENTS

<u>MATERIALS & SERVICES</u>	<u>ADDITIVE</u>	<u>TOTAL OPERATIONS</u>	<u>AGGREGATE COST</u>
<ul style="list-style-type: none"> ● SSME ● SRBs ● ETs ● ORB SPARES ● CREW GFE ● CONTRACT ADMIN. 	<ul style="list-style-type: none"> ● TOTAL OPERATIONS LESS NASA BASE 	<ul style="list-style-type: none"> ● DIRECT AND INDIRECT OPERATIONS 	<ul style="list-style-type: none"> ● TOTAL OPERATIONS + FACILITIES AND EQUIPMENT DEPRECIATION ● FLEET AMORTIZATION

THE PRICING POLICY - DOD

● FOR A DEDICATED STANDARD SHUTTLE FLIGHT

PHASE I THE PRICE WILL BE:

THROUGH FY 86 - A FIXED PRICE OF \$12.2M IN FY 75 DOLLARS,
COMPRISED OF THE FORECASTED MATERIALS AND
SERVICES COST AVERAGED OVER SIX YEARS PLUS
A RESERVE FOR CONSIDERATION OF PROGRAMMATIC,
OPERATIONAL AND TECHNICAL SERVICES UNCERTAINTIES.

PHASE II THE PRICE WILL BE:

AFTER FY 86 - THE ACTUAL COSTS PROJECTED EACH YEAR FOR MATERIALS
AND SERVICES.

THE PRICING POLICY - CIVIL U. S. GOVERNMENT
AND PARTICIPATING FOREIGN GOVERNMENTS

● FOR A DEDICATED STANDARD SHUTTLE FLIGHT

- PHASE I THE PRICE WILL BE:
- THROUGH FY 83 - A PRO-RATA SHARE OF THE FORECASTED ADDITIVE COSTS AVERAGED OVER THREE YEARS
- THE PRICE SHALL NOT BE LESS THAN A PRO-RATA SHARE OF THE FORECASTED TOTAL OPERATIONS COSTS AVERAGED OVER 12 YEARS
- PHASE II THE PRICE WILL BE A PRO-RATA SHARE OF THE FORECASTED TOTAL OPERATIONS COSTS AVERAGED OVER 12 YEARS
- AFTER FY 83

USER CHARGE POLICYSUMMARY

- USER CHARGE RECOVERS ALL NASA OUT-OF-POCKET COST FOR USER FLIGHTS DURING INITIAL PHASE OF STS OPERATIONS.
- NASA RECOVERS TOTAL OPERATIONS COSTS FOR ALL USER MISSIONS OVER THE 12 YEAR SPAN OF MODEL.
- POLICY PROVIDES INCENTIVES FOR USERS FOR EARLY TRANSITION TO SHUTTLE.
- EARLY TRANSITION FROM ELV TO SHUTTLE PROVIDES SIGNIFICANT COST SAVING IN SPACE TRANSPORTATION.

TASK VI

ANALYSIS OF REDUCED LEVELS

OF

SPACE ACTIVITY

REDUCED LEVELS OF SPACE ACTIVITY

CASES EXAMINED

- o PAYLOAD PROGRAMS AT FOUR LEVELS - EQUIVALENT TO SHUTTLE FLIGHT LEVELS OF 487, 425, 360 AND 300
- o FLEET SIZES OF 3 - 4 - 5 ORBITERS
- o OPERATIONS AT KSC ONLY OR AT BOTH KSC AND VAFB

REDUCED LEVELS OF SPACE ACTIVITYGUIDELINES

- o TRAFFIC CAPABILITY AS DEFINED IN FLEET SIZE CAPABILITY ANALYSIS
- o PAYLOAD PROGRAM REDUCTION APPROACH FOR REDUCED LEVELS OF EQUIVALENT SHUTTLE FLIGHTS
 - 487 CASE - BASELINE FOR REDUCTIONS
 - 425 CASE - SPACELAB REDUCED ABOUT 30%
 - 360 CASE - SPACELAB REDUCED ABOUT 60%
 - 300 CASE - SPACELAB REDUCED 60%
 - NASA AUTOMATED REDUCED 40%
 - CIVIL AUTOMATED REDUCED 35%
- o DOD PAYLOAD PROGRAM RETAINED FOR ALL CASES
- o SAME EQUIVALENT PAYLOAD PROGRAM SUPPORTED WITH SHUTTLE OR SHUTTLE/ELV MIX AS REQUIRED
- o VAFB SPACELAB TRAFFIC TRANSFERRED TO KSC FOR SINGLE SITE STS OPERATIONS (DEGRADED SCIENTIFIC RETURN)
- o SHUTTLE COSTS ADJUSTED FOR FLIGHT RATE EFFECT
- o OVERALL COST COMPARISONS INCLUDE INVESTMENT, OPERATIONS, AND Δ PAYLOAD COSTS

PAYLOAD PROGRAM LEVELS AND DISTRIBUTION

NUMBERS OF EQUIVALENT SHUTTLE FLIGHTS

	<u>487 CASE</u>	<u>425 CASE</u>	<u>360 CASE</u>	<u>300 CASE</u>
<u>KSC</u>	358	308	257	212
NASA	(178)	(140)	(101)	(81)
AUTOMATED	45	45	45	25
SPACELAB	133	95	56	56
CIVIL	(111)	(99)	(87)	(62)
AUTOMATED	72	72	72	47
SPACELAB	39	27	15	15
DOD	(69)	(69)	(69)	(69)
<u>VAFB</u>	129	117	103	88
NASA	(47)	(37)	(26)	(21)
AUTOMATED	13	13	13	8
SPACELAB	34	24	13	13
CIVIL	(37)	(35)	(32)	(22)
AUTOMATED	29	29	29	19
SPACELAB	8	6	3	3
DOD	(45)	(45)	(45)	(45)
TOTAL	487	425	360	300

TRAFFIC COMPARISON SUMMARYSTS/ELV TRAFFIC

	<u>487</u>		<u>425</u>		<u>360</u>		<u>300</u>	
	<u>STS</u>	<u>ELV</u>	<u>STS</u>	<u>ELV</u>	<u>STS</u>	<u>ELV</u>	<u>STS</u>	<u>ELV</u>
<u>KSC AND VAFB</u>								
5 ORBITERS	487	48	425	55	360	55	300	55
4 ORBITERS	351	226	365	150	360	58	300	58
3 ORBITERS	258	339	254	272	254	190	225	127
 <u>KSC ONLY</u>								
4 ORBITERS	365	231	319	188	263	187	218	159
3 ORBITERS	249	359	273	232	225	219	180	191

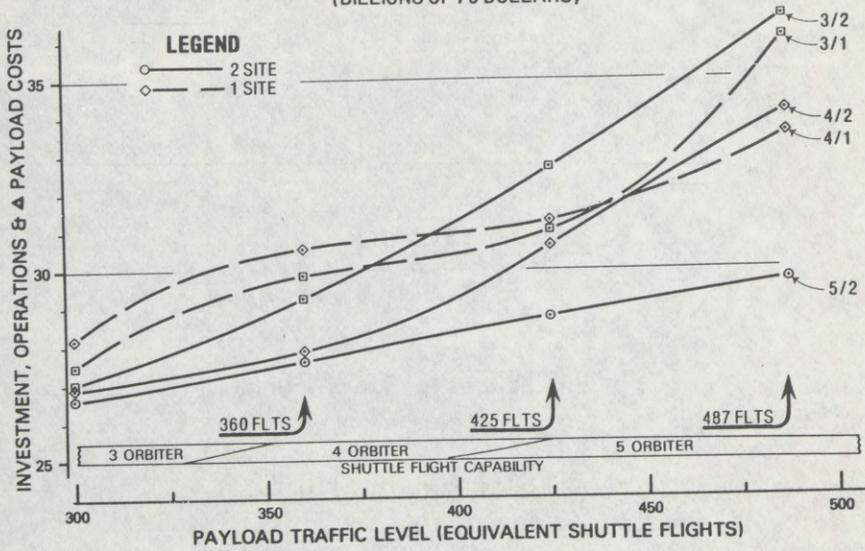
COST SUMMARY
(BILLIONS OF 1979 DOLLARS)

	487 CASE					425 CASE				
	KSC AND VAFB			KSC ONLY		KSC AND VAFB			KSC ONLY	
	5	4	3	4	3	5	4	3	4	3
INVESTMENT	14.2	13.9	12.8	12.9	11.9	14.2	13.9	12.8	12.9	11.9
OPERATIONS	15.5	18.1	20.4	17.8	20.0	14.6	15.7	17.9	16.0	16.6
△ PAYLOAD	-	2.1	3.5	2.9	4.2	-	1.1	2.0	2.4	2.5
TOTAL	29.7	34.1	36.7	33.6	36.1	28.8	30.7	32.7	31.3	31.0

	360 CASE					300 CASE				
	KSC AND VAFB			KSC ONLY		KSC AND VAFB			KSC ONLY	
	5	4	3	4	3	5	4	3	4	3
INVESTMENT	14.2	13.9	12.8	12.9	11.9	14.2	13.9	12.8	12.9	11.9
OPERATIONS	13.5	14.1	15.7	15.3	15.6	12.5	13.0	14.1	13.9	14.2
△ PAYLOAD	-	-	.8	2.4	2.4	-	-	.2	1.4	1.4
TOTAL	27.7	28.0	29.3	30.6	29.9	26.7	26.9	27.1	28.2	27.5

FLEET SIZE COST RELATIONS TO PAYLOAD TRAFFIC REQUIREMENTS

(BILLIONS OF 79 DOLLARS)



TASK VII

SPACE BENEFITS & SPIN-OFFS

FORECAST FOR THE FUTURE

APPLICATIONS/BENEFITS OF SPACE PROGRAMS

- o COMMUNICATIONS
 - LOWER COST
 - GREATER CAPABILITY

- o EARTH RESOURCES
 - AGRICULTURAL CROP FORECASTING
 - WATER RESOURCES MANAGEMENT
 - MINERAL AND PETROLEUM EXPLORATION
 - LAND USE ASSESSMENT
 - FOREST AND RANGELAND RESOURCES ASSESSMENT
 - IMPROVED REGIONAL AND WORLD MAP ACCURACY

- o POLLUTION MONITORING

- o WEATHER AND CLIMATE OBSERVATION AND FORECASTING

- o OCEAN CONDITION MONITORING AND FORECASTING

- o SEARCH AND RESCUE

- o MATERIALS PROCESSING IN SPACE

SPINOFF CONTRIBUTIONSHEALTH

- o Rechargeable Cardiac Pacemaker
- o Biological Isolation Garments
- o Emergency Medical Units
- o Vision Acuity Tester
- o Ultrasonic Diagnosis
- o Prosthetic Devices

SAFETY

- o Firemen's Breathing Apparatus
- o USCG Fire Fighting Module
- o 747 Escape Chutes
- o Emergency Lighting Systems
- o Security Alarm Systems
- o Railroad Bearing Failure Detector

ENVIRONMENT

- o Forest Fire Index Monitor
- o Activated Carbon Sewage Treatment
- o Packaged Waste Treatment
- o Auto Exhaust Emission Analyzer

INDUSTRIAL PRODUCTIVITY

- o Bonded Lubricants
- o NASTRAN (Structural Analysis)
- o Strain Gage Technology
- o Production Line Quality Control Methods
- o Computerized Banking & Retail Systems
- o Fracture Toughness Tests

TRANSPORTATION

- o Automatic Traffic Control Systems
- o Inertial Navigation System
- o Highway Grooving
- o Ultrasonic Rail Inspection
- o Skid Resistance Test System
- o Automobile Battery Technology

HOUSING AND CONSTRUCTION

- o Flat Wire
- o Corrosion Resistant Paint
- o Water Reclamation System
- o Fire Resistant Coatings

NEAR TERM BENEFITS

CAPABILITY

INCREASE WEIGHT AND VOLUME

INCREASE RELIABILITY

PAYLOAD RECOVERY/REFURBISHMENT

MAN-IN-SPACE

ON-ORBIT CHECKOUT

BENEFITS

LOW COST DESIGN

STANDARDIZED SPACECRAFT

INCREASE MISSION CAPABILITY

MULTIPLE PAYLOAD CAPABILITY

REDUCED PAYLOAD LOSSES

LOWER COST

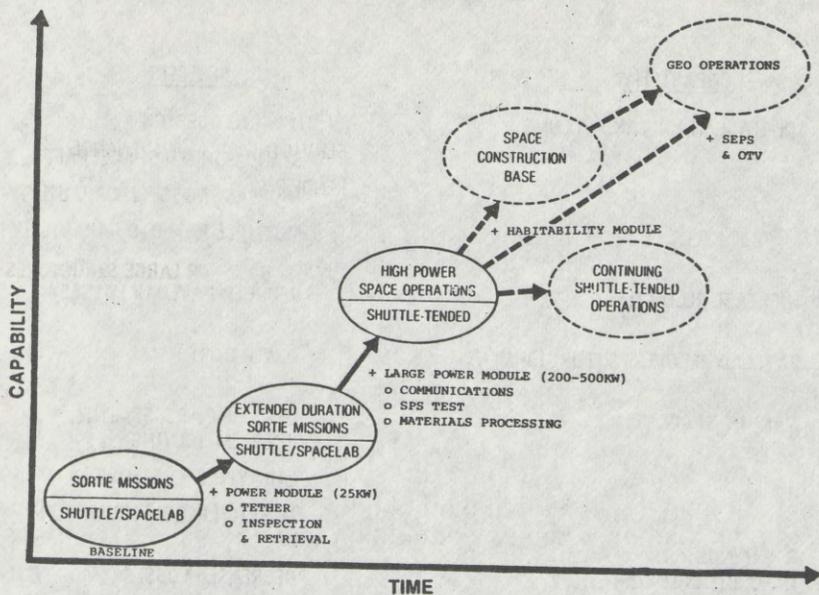
REAL TIME ASSESSMENT/
PROBLEM SOLVING

LAB TYPE OPERATIONS

MISSION RECONFIGURATION

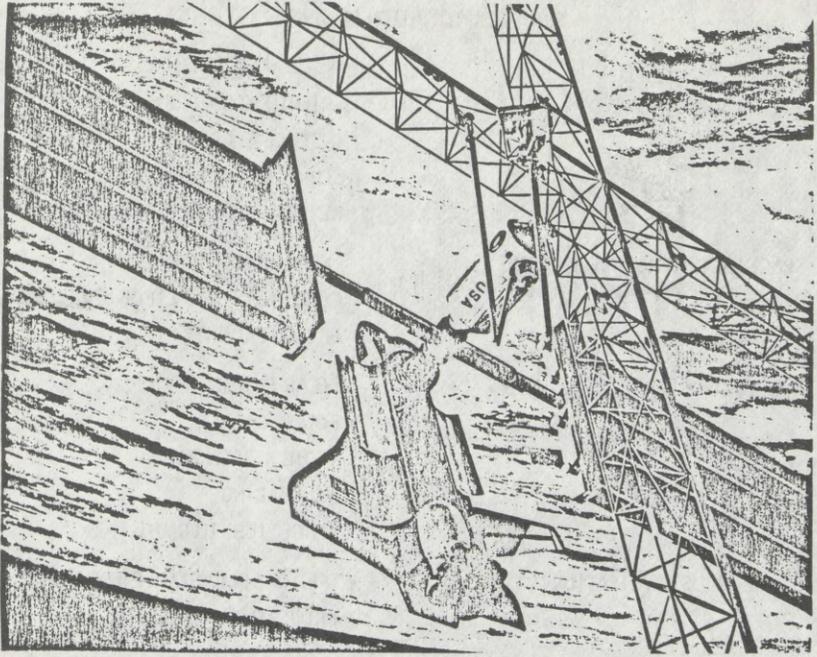
DECREASED LOSSES

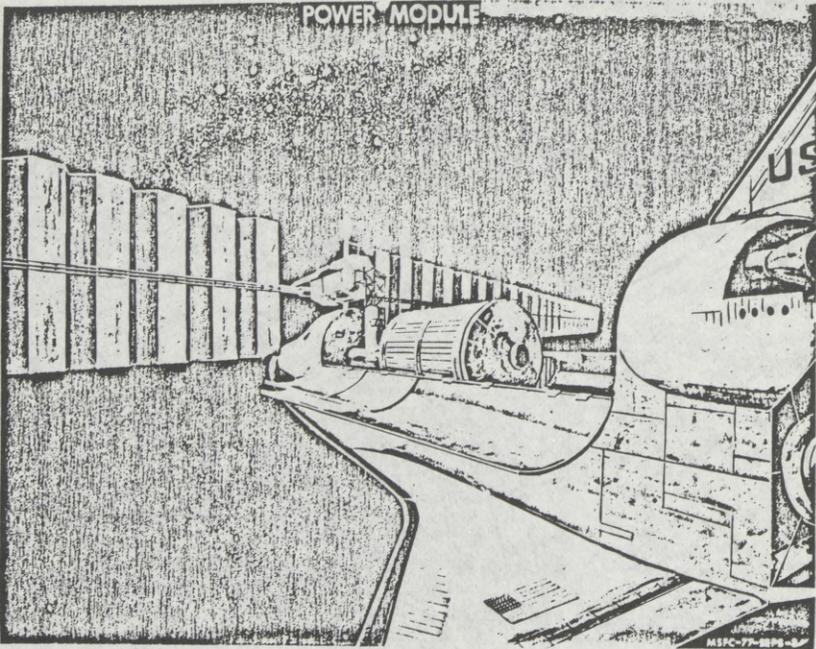
STS EVOLUTION

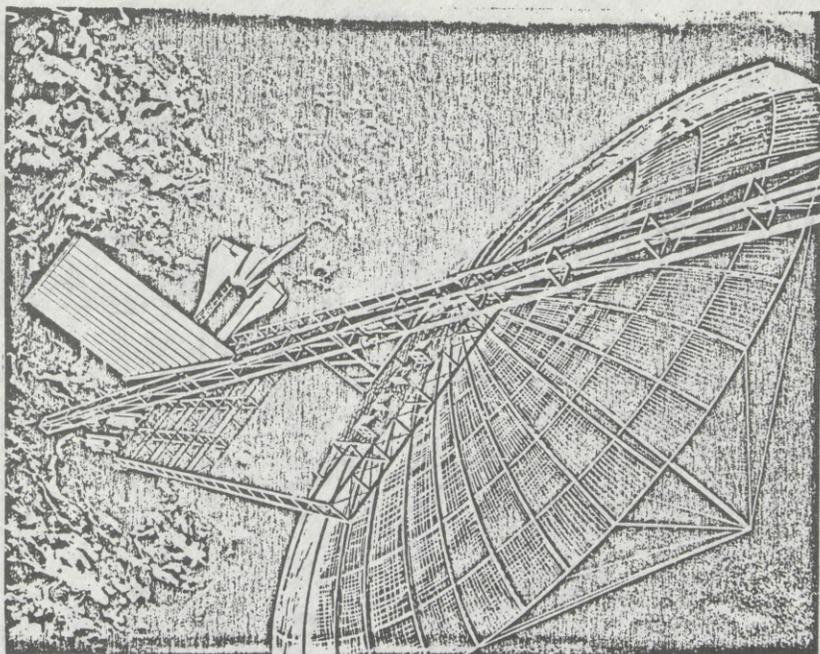


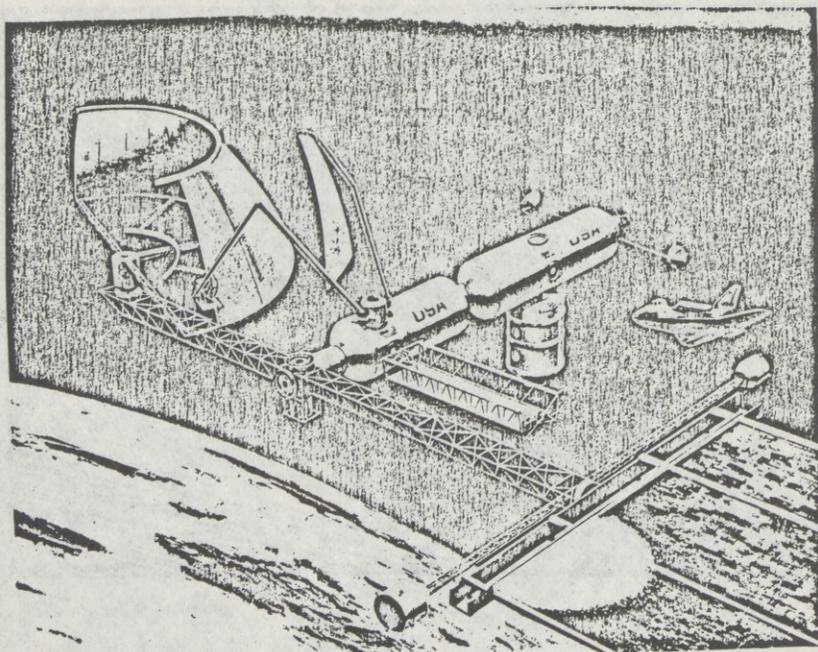
FUTURE EXPLOITATION OF SPACE

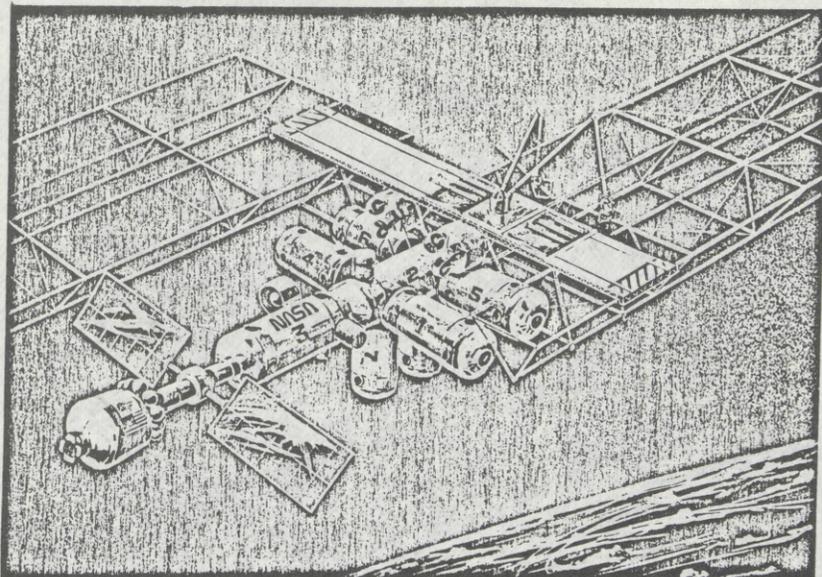
<u>CAPABILITY</u>	<u>APPLICATIONS</u>
ORBITAL OPERATIONS	SCIENTIFIC ON-ORBIT EXPERIMENTS INST. DEVELOPMENT SERVICING AND MAINTENANCE RENDEZVOUS AND INSPECTION
SPACE FACILITY (SPACE STATION)	EXPANSION OF ORB. OPS CONST. BASE FOR LARGE STRUCTURES BASING FACILITY
ASSEMBLY OF LARGE STRUCTURES	SOLAR POWER POWER RELAY RADIO ASTRONOMY 3-D IMAGING SPACE LIGHT ILLUMINATION
SPACE INDUSTRIALIZATION	FAB. OF SOLID STATE PIECE PARTS PROD. OF PHARMACEUTICALS
ENERGY FROM SPACE	SPACE SOLAR POWER STATION

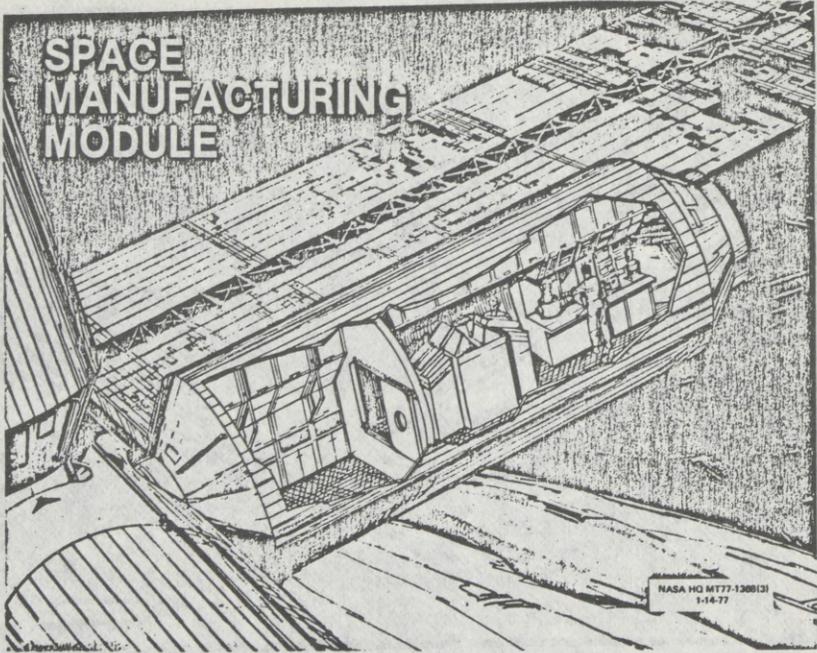


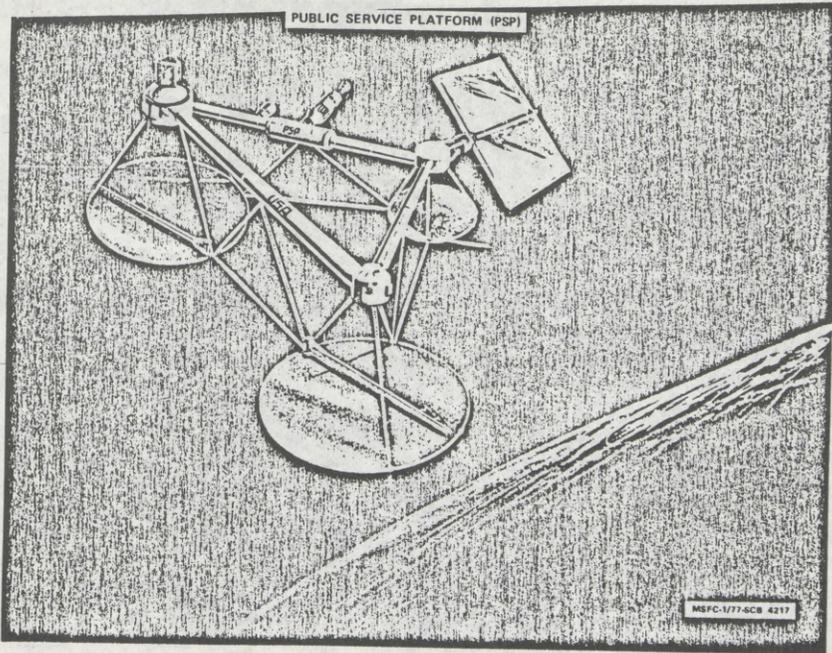


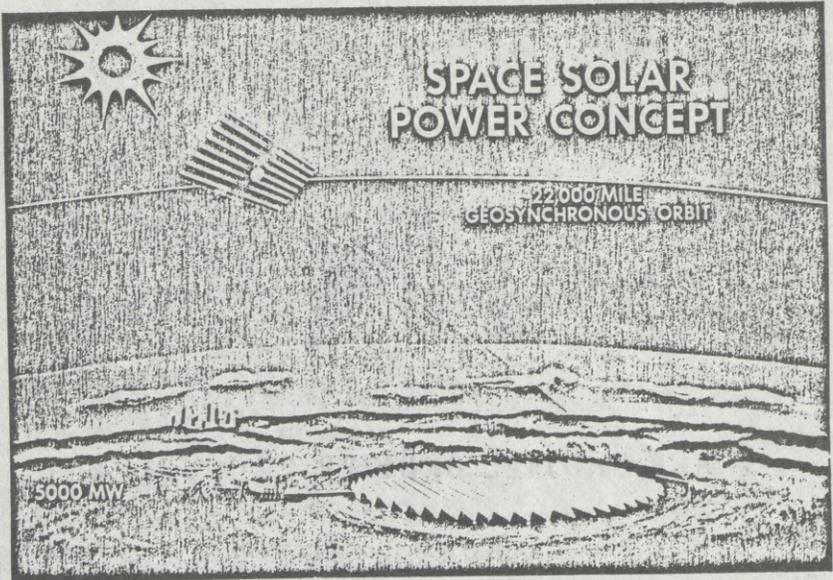












**SPACE SHUTTLE ORBITER PROCUREMENT
CONCLUSIONS**

SPACE SHUTTLE ORBITER PROCUREMENTCONCLUSIONS

- SPACE SHUTTLE IS THE KEY ESSENTIAL ELEMENT WHICH ESTABLISHES THE FUTURE SPACE CAPABILITY OF THE NATION AND GREATLY ENHANCES EXPLOITATION OF SPACE
 - EXPLOITATION OF NEW AND UNIQUE SHUTTLE CAPABILITIES TO SIGNIFICANTLY IMPROVE AND EXPAND MILITARY AND CIVIL SPACE ACTIVITIES
 - NATIONAL STRENGTH AND PRESTIGE THROUGH CONTINUED PREEMINENCE IN MANNED SPACE FLIGHT AND WORLD LEADERSHIP IN SPACE TECHNOLOGY
 - GREATER DIRECT BENEFITS AND SPIN-OFFS TO IMPROVE THE WAY-OF-LIFE FOR MANKIND
 - ROUTINE, LOW COST SPACE OPERATIONS

- FIVE ORBITER FLEET/2 SITE OPERATIONS MINIMUM ACCEPTABLE TO MEET FORECASTED NATIONAL REQUIREMENTS
 - PROMOTES EARLY TRANSITION FOR ALL CLASSES OF USERS
 - TOLERATES ONE ORBITER ATTRITION
 - MORE COST EFFECTIVE THAN ANY SHUTTLE/ELV MIX

- 5 ORBITER/2 SITE OPERATION REMAINS THE MOST COST EFFECTIVE FOR PAYLOAD TRAFFIC REQUIREMENTS WELL BELOW THAT WHICH MIGHT BE EXPECTED FOR A MINIMUM NATIONAL SPACE EFFORT

Mr. COUGHLIN. In doing that, the figures you provided for the record before divided the cost comparison into investment, transportation and payloads. Could you detail for the record what each of those consists of?

Mr. YARDLEY. Yes.

Mr. COUGHLIN. In the material you are going to provide.

Mr. YARDLEY. It is all broken down.

[NASA information follows:]

The cost breakdowns requested by Mr. Coughlin are shown on the attached sheets. Sheet 1-1 shows the breakdown of the civil and DOD programs into non-recurring, operations and payload costs. Sheets 2-1 and 3-1 show a detailed breakdown of these cost categories for the civil and DOD programs, respectively. Sheet 2-2 shows a further breakdown of the STS civil non-recurring investment costs identified in sheet 2-1. Mr. Yardley has indicated in his testimony that operation of a 3 Orbiter fleet from KSC with ELV's flown from KSC and VAFB is about \$6 billion more expensive than a 5 Orbiter fleet/2 site operation. The attached sheets obtained from the OMB study show that operation of a 3 Orbiter fleet and ELV's is, in total, \$6.4 billion more expensive than operation of a 5 Orbiter fleet from 2 sites.

[GAO Information follows:]

We think that the cost figure of \$6.4 billion is overstated and misleading. The figure comes from studies prepared for OMB by NASA and DOD. The basic study, "Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues," is dated October 15, 1976, and was intended to provide OMB the comprehensive data and analyses necessary to determine the number of orbiters needed for the national operational fleet.

These specific figures are included in the October 1977 update of the above study. Here again, the update was prepared by NASA and DOD for OMB's use in evaluating the agencies' budget requests, particularly as concerned the five-orbiter position. The study shows the costs of 3-Orbiter/1 site and 4-Orbiter/1 site programs essentially as follows:

COST INCREASES (DECREASES) WITH LESS THAN 5 ORBITERS/2 SITES

[In billions of fiscal year 1979 dollars]

Cost-category	3-orbiters/ 1-site	4-orbiters/ 1-site
Nonrecurring.....	(\$2.747)	(\$1.466)
Operations.....	4.888	2.413
Payload benefits lost.....	4.236	2.925
Net cost increase.....	6.377	3.872

According to the NASA/DOD analysis, a Shuttle program with less than 5 orbiters 2 sites is not cost-effective due to increased operations cost and lost payload benefits. The increased operations costs are for the extensive use of ELVs. In turn, use of these ELVs, says NASA, will not generate payload cost savings offered by the Shuttle (in other words, the cost category called "Payload benefits lost" represents opportunity costs).

We disagree with the approach used in the 1976 and 1977 studies for several reasons, as discussed below.

CONSTANT MISSION MODEL

Even though the NASA/DOD study examined various fleet size cases (three, four and five Orbiters, operating from one and two sites) each of the cases was analyzed in relation to a constant mission model for the 1980-91 timeframe. The constant mission model, however, was developed largely to complement the capabilities of a five-orbiter Shuttle fleet. Any analysis which retains the maximum program developed for 5 Orbiters would obviously show that a smaller fleet size would not be cost effective. If, however, a varying program level had been used to reflect a more reasonable increase in space activity, the costs assigned for additional ELVs and payload benefits lost would have been greatly reduced.

NATIONAL TOTAL PROGRAM COST COMPARISON

(MILLIONS OF FY 79 DOLLARS)

COST CATEGORY	KSC AND VAFB OPERATIONS			KSC OPERATIONS ONLY	
	COST 5 ORBITERS	DELTA COSTS		DELTA COSTS	
		4 ORBITERS	3 ORBITERS	4 ORBITERS	3 ORBITERS
CIVIL PROGRAM	(21,469)	(+4,257)	(+6,200)	(+4,099)	(+6,853)
NON-RECURRING	11,815	- 395	-1,016	-380	-1,016
OPERATIONS	9,654	+2,510	+3,885	+1,754	+3,833
PAYLOADS	NOT INCL	+2,142	+3,331	+2,725	+4,036
DOD PROGRAM	(8,297)	(+ 39)	(+ 847)	(- 227)	(- 476)
NON-RECURRING	2,964	+ 69	-806	-1,086	-1,731
OPERATIONS	5,333	-30	+1,453	+ 659	+1,055
PAYLOADS	NOT INCL	0	+ 200	+ 200	+ 200
MISSION MODEL TOTAL	29,766	+4,296	+7,047	+3,872	+6,377

CIVIL PROGRAM COST COMPARISON

(MILLIONS '79 DOLLARS)

COST CATEGORY	BASELINE 5/2	DELTA COSTS (TO 5/2 CASE)			
		CASE 4/2	CASE 3/2	CASE 4/1	CASE 3/1
STS NON-RECURRING INVEST.	(11,815)	(-395)	(-1016)	(-380)	(-1016)
SHUTTLE DDT&E	7,391				
ORBITER PROCUREMENT	2,787	-585	-1261	-585	-1261
PRODUCTION PENALTY		+220	+ 275	+220	+ 275
SPACELAB/SSUS/IUS	1,029	- 30	- 30	- 15	- 30
FACILITIES	460				
OPS CAPABILITY	148	-	-	-	-
OPERATIONS	(9,654)	(+2,510)	(+3,885)	(+1,754)	(+3,833)
SHUTTLE	8,262	-1,857	-1,899	-1,336	-2,086
SSUS/IUS	674	- 445	- 503	- 167	- 362
SPACELAB	503	- 42	- 40	- 20	- 50
ELV	215	+4,854	+6,327	+3,277	+6,331
PAYLOADS	(27,275)	(+2,142)	(+3,331)	(+2,725)	(+4,036)
NASA	12,944	+1,163	+1,772	+ 771	+1,380
OTHER CIVIL	14,331	+ 979	+1,559	+1,954	+2,656
MISSION MODEL TOTAL	48,744	+4,257	+6,200	+4,099	+6,853

DOD TOTAL PROGRAM COST COMPARISON
(MILLIONS OF FY 79 DOLLARS)

COST CATEGORY	KSC AND VAFB			KSC ONLY	
	5 ORBITERS	DELTA COST		DELTA COST	
		4 ORBITERS	3 ORBITERS	4 ORBITERS	3 ORBITERS
INVESTMENT	(2964)	(+ 69)	(-806)	(-1086)	(-1731)
SHUTTLE RDT&E	140	0	0	- 18	- 18
GROUND SUPPORT SYSTEM	993	0	- 64	- 890	- 921
IUS DEVELOPMENT	235	0	0	0	0
MOS ACQUISITION	67	0	- 27	0	- 27
PAYLOAD TRANSITION	936	0	-548	- 249	- 598
ELV MODIFICATION	187	0	+239	+ 226	+ 239
BACKUP ELV	406	+ 69	-406	- 155	- 406
OPERATIONS	(5333)	(- 30)	(+1653)	(+ 859)	(+1255)
STS	- 3363	- 34	-1546	-1055	-2206
ELV	1486	0	+3056	+1672	+3298
RELIABILITY (LOSSES)	242	+ 4	+ 25	+ 56	+ 51
OTHER	242	0	- 82	- 14	- 88
PAYLOAD	NOT INCL	0	+ 200	+ 200	+ 200
TOTAL	8297	+ 39	+ 847	- 227	- 476

CIVIL INVESTMENT COSTS
(MILLIONS OF FY 79 \$)

	5/2 BASELINE			DELTA COSTS			
	NASA	OTHER	TOTAL	4/2	3/2	4/1	3/1
<u>DDT&E</u>							
SHUTTLE	7311	80	7391	-	-	-	-
SPACELAB	100	575	675	-	-	-	-
IUS	44	-	44	-	-	-	-
SSUS	-	33	33	-	-	-	-
<u>PRODUCTION</u>							
ORBITERS	2509	-	2509	-365	-926	-365	-926
SPARES & EQUIPMENT	278	-	278	-	-60	-	-60
OPS CAPABILITY	148	-	148	-	-	-	-
SPACELAB	277	-	277	-30	-30	-15	-30
<u>FACILITIES</u>	460	-	460	-	-	-	-
TOTAL	11127	688	11815	-395	-1016	-380	-1016

In addition, it should be noted that most of the payloads in the mission model will require Government appropriations, even though no specific space objectives for the 1980s have been set forth by either the executive branch or the Congress. We therefore question the appropriateness of using the mission model as a constant in evaluating alternative fleet sizes.

ORBITS ACHIEVABLE WITH 1-SITE OPERATIONS

Neither of the joint studies considered that a KSC-based Shuttle could be launched to polar and near-polar orbits. These studies thus assumed that (1) ELVs would be required to launch most of the payloads destined for these orbits; and (2) these payloads would not be accessible to the Shuttle for retrieval. A northerly-launched KSC Shuttle could, however, achieve these orbits and be capable of launching and retrieving (where appropriate) all payloads presently planned for Vandenberg launch.

BACKUP POSTURE

Both joint studies assumed that an extensive ELV backup posture would be required if fewer than 5 Orbiters were procured. Considering turnaround times, however, any size Orbiter fleet may provide more responsive backup than the Nation is currently experiencing with ELVs. For instance, the planned two-weeks turnaround time for the Shuttle is much faster than for ELVs. At KSC, 17 weeks (without overtime work) are needed to ready a replacement Titan III. At Vandenberg, ELVs are assembled on the pad, and turnaround time for a replacement ELV is about 4 to 6 months (without overtime). These turnaround times are lengthy because under current operations, ELV launches are not "backed-up" with a standby ELV; the production pipelines must provide replacements.

RECOVERY AND REUSE OF PAYLOADS

NASA expects that the Shuttle's capability to return however, bulkier payloads would allow payload cost saving techniques such as modular design, less sophisticated components, and more rugged hardware. However, in a recent report ("Space Transportation System: Past, Present, Future"; PSAD-77-113; May 27, 1977), we cautioned that:

"* * * evidence indicates * * * extensive use of these techniques is unlikely during the 1980s."

"Although NASA and DOD, the major users, plan some recovery and reuse, Battelle [Columbus Laboratories] surveyed potential non-Government users and found they do not believe these techniques will be widely used during this period. These users believed the demonstrated reliability of current satellites is quite satisfactory and the return of a 7- or 10-year-old satellite having antiquated technology would not be particularly useful. In addition, many satellites, such as those in geostationary orbits, cannot be reached by the orbiter, and its limited ability to maneuver in space may not allow satellites to be routinely and economically recovered."

* * * * *

"In 1973 the Federation of American Scientists stated that, while savings are possible, low-cost design is inconsistent with the trend in the American aerospace industry which emphasized high reliability, microminiaturization, and ruggedness. Furthermore, NASA's proposed user charge policy for flight sharing may encourage the continued design of compact, lightweight satellites because NASA bases charges on weight or length, whichever is greater."

For these reasons we think it inappropriate for NASA to count "payload benefits lost" so heavily when evaluating alternative programs and that the \$6.4 billion cost figure is overstated and misleading.

COST COMPARISON FOR FOUR ORBITER FLEET

Mr. COUGHLIN. You have a second comparison I would like to get if I could.

Can you provide a cost comparison showing a 4-orbiter fleet only out of Kennedy in which one orbiter is used as an orbiting launch

vehicle to put payloads into the polar orbit, using IUS or a smaller booster, compared to the 5 orbiters—2 sites? There are 2 different comparisons here.

Mr. YARDLEY. It is 4 orbiters operating out of Kennedy only, versus 5 orbiters operating at 2 sites. The 4-orbiter Kennedy only case is \$3.9 billion more expensive.

Mr. COUGHLIN. Can you provide that study for the record?

Mr. YARDLEY. Yes, sir, it is in the same table.

Dr. LOVELACE. It is in the same study and the details that provide that back-up. We will provide that for the record.

[NASA information follows:]

Material requested showing a cost comparison for a four orbiter fleet at KSC only, versus a five orbiter fleet operating at two sites has been based on the results of the 1977 OMB Study Update. This scenario assumes that all high inclination payloads that can be launched from KSC using upper stages for plane change from the 57 degree Shuttle park orbit will be flown in that manner. The remaining high inclination payloads, too large for such a maneuver, will remain at VAFB and will be launched on expendable launch vehicles.

The results indicate that an additional 132 Shuttle flights requiring 97 Inertial Upper Stages would be needed to accommodate launching the high inclination payloads with the four orbiter fleet operating at KSC only. In addition, 17 DOD ELV launches would be required at VAFB to accommodate payloads exceeding the Shuttle/IUS delivery capability at KSC. High inclination Spacelab missions would be transferred to KSC with attendant loss of payload objectives. The costs for this four orbiter fleet, one site operation is about \$3.7 billion more than the five orbiter, two site operations.

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For these reasons we think it inappropriate for NASA to count "payload benefits lost" so heavily when evaluating alternative programs and that the \$6.0 and \$3.9 billion cost figures quoted by NASA are overstated and misleading.

Mr. COUGHLIN. In the two cases, I wanted to make clear in one case I was not talking about orbital launches, and in the other case I was.

Mr. YARDLEY. Not talking about orbital launches?

Dr. FROSCHE. Polar?

Mr. COUGHLIN. Polar orbital launches.

Dr. FROSCHE. In the first case you are talking about polar launches; in the second case all polar launches will be with expendable launch vehicles out of Vandenberg.

Mr. COUGHLIN. That is correct.

Mr. YARDLEY. What we have is providing polar launches the cheapest way.

Dr. FROSCHE. Yes. We will provide that.

MAIN ENGINE RATED POWER LEVEL

Mr. COUGHLIN. NASA indicated in its January hearings a plan of approximately 10,000 seconds of 100 percent rated power level on the main engine prior to the first manned orbital flight. Have they achieved 100 percent to date in 1978?

Mr. YARDLEY. What was the question?

Mr. COUGHLIN. Have you achieved a 100 percent level power rated test of the main engine to date in 1978?

Mr. YARDLEY. Yes, but a very short one. We have a total of something like 700 seconds at 100 percent power out of 14,000 total seconds.

Mr. COUGHLIN. In 1978 you have how much?

Mr. YARDLEY. We achieved it once. It was only for a short burst, several seconds.

Mr. COUGHLIN. When was your last main engine test?

Mr. YARDLEY. Yesterday, on March 8.

Mr. COUGHLIN. How many seconds and at what power level was that?

Mr. YARDLEY. That was an acceptance test of the third engine to go into "the" main propulsion test assembly, where we will be testing 3 engines at a time. The acceptance test was something like 60 seconds long and the first 40 seconds were at 90 percent and the next 20 were at 70 percent. It was not a long duration test.

FIRST SPACE SHUTTLE LAUNCH

Mr. COUGHLIN. Do you still expect your first Shuttle launch in June 1979?

Mr. YARDLEY. We are hoping for June, we are actually scheduling earlier than that, but we are a little pessimistic about being able to make it earlier than June.

Mr. COUGHLIN. Then a couple of questions for the GAO if I might.

The analysis that you have made, you have indicated is with NASA data, essentially.

Mr. GUTMANN. Yes, sir.

GAO STUDY OF SPACE SHUTTLE

Mr. COUGHLIN. How many man-hours of time went into the study that you made? Can you give me an estimate of that roughly?

Mr. DAY. Over the last couple of years we have probably expended 1,200 staff days each year, somewhere in that magnitude.

Mr. COUGHLIN. You studied the Shuttle program itself?

Mr. DAY. Yes, the entire Shuttle program or the aspects of the Shuttle program that we were concentrating on.

Mr. GUTMANN. There have been a variety of reports issued besides this one we have under consideration today. One of them dealing with user charges, for example.

Mr. TOLER. We have looked at the development program in several reports, and of course the operational aspects of the program, also. But was your question Mr. Coughlin directed at our total study?

Mr. COUGHLIN. My immediate question was, how many man-hours or staff years or however you want to put it went into the study that you prepared that we are looking at today?

Mr. GUTMANN. About 1200 staff days.

Mr. COUGHLIN. 1200 man-days?

Mr. GUTMANN. Yes, sir.

Mr. COUGHLIN. Are there within NASA professionals who would agree with the conclusions of your study?

Mr. GUTMANN. Well, that is difficult to say. There are those who will agree and those who will not agree.

Mr. COUGHLIN. Are there some who would agree?

Mr. GUTMANN. Yes, there are some who would agree with portions of our conclusions.

This issue was raised earlier by Mr. Edwards. He suggested that in all probability perhaps GAO has not worked closely enough with NASA at the headquarters level. For example, with respect to the two main issues bearing upon the expenditure of over \$3 billion for Vandenberg, one has to do with the maximum payload capacity that one can lift into polar orbit from Kennedy. Now there are possibly 10 or 15 different elements that go into that computation, each one of which requires some assumptions with respect to the need or lack thereof for certain equipment aboard the vehicle to perform certain missions.

So you have a wide range, possibly, of estimates of maximum payload capacity. That is one question bearing upon this \$3 billion expenditure you are concerned with, and we should sit down with NASA, at whatever level NASA suggests, whether it includes the Johnson people and the headquarters people or whatever, and agree, as best we can, as to what that figure is and what assumptions went into developing that figure, and where we have differences we should be prepared to explain to you what those differences are.

Mr. COUGHLIN. I understand that, but I was asking the general question as to whether there were professionals within NASA who agree with the conclusions of your study.

Mr. GUTMANN. Yes, my answer to that question is, yes. Perhaps I elaborated on a different question.

Mr. COUGHLIN. Thank you, Mr. Chairman.

Mr. GUTMANN. Let me address, if I may, the second important aspect of your deliberations over the question of a site at Vandenberg, and that is the overflight issue and certain other issues that would perhaps be discussed in closed session. These two things bear heavily upon an extremely expensive decision that you are going to make. I am not sure either one of us here, any of us at the witness table,

have dealt completely with those two questions, and I would hope that very shortly GAO and NASA can get together and agree on these two issues or at least identify where we disagree and why we disagree, and I think if we can do that, we would be really performing a service for this committee.

Mr. COUGHLIN. If there are factors that should be discussed in closed session, I think we should do that quickly, Mr. Chairman.

Mr. YARDLEY. I want to point out something that may be confusing. I noticed in Mr. Gutmann's paper and in the remarks that the implication is that if we don't put in Vandenberg we are going to save \$3.6 billion. That is not the case at all. The flights that you were going to make at Vandenberg go out at Kennedy or they will stay at Vandenberg on expendables. We have studied the total problem with or without Vandenberg, assuming you can overfly which we don't agree with. There are no savings we can identify, no matter how you do it. So it is not a \$3 billion to \$4 billion decision at all.

Mr. TOLER. Of course we would disagree, and I guess this is one of the things Mr. Gutmann is talking about in terms of cost figures, payload carrying capability, et cetera. There needs to be some reconciliation of figures because our estimates show from \$2.3 billion to \$3.5 billion savings, depending upon the flight rate that actually occurs in the future.

Dr. FROSCHE. Mr. Chairman, we entirely agree that there needs to be a much closer reconciliation of figures. We would very much like to have the data and work with GAO to find out what those computations mean.

GAO CALCULATIONS OF SAVINGS FROM SINGLE SITE

Mr. BOLAND. That ought to be a simple matter.
[GAO information follows:]

As shown below, a single-site STS program could save the Government from \$2.3 billion to \$3.5 billion, depending upon the annual launch rate from KSC.

COST ADVANTAGES OF ONE SITE (KSC) SHUTTLE PROGRAM

[Dollar amounts in billions]

Annual launch rate from KSC	Cost savings of not modifying Vandenberg to accommodate Shuttle Operations (real year dollars)		
	Facilities	Manpower (fiscal year 1983-92)	Total
40.....	\$1.0	\$2.5	\$3.5
60.....	.8	1.5	2.3

Savings accrue from single-site operations because Vandenberg Facilities would not be built and manpower to operate the site would not be needed (see charts 1 and 2). These savings, however, must be offset by the additional facilities and manpower required at KSC to handle any additional workload. Planned facilities and manpower at KSC can handle over 40 Shuttle flights a year. However, additional facilities (costing about \$0.2 billion—see chart 3 below, note d) and manpower (costing about \$1.0 billion—see chart 4 below, note 3) would be needed at KSC to support 60 or more yearly launches, thus slightly reducing overall facility savings to \$0.8 billion (\$1.0 billion minus \$0.2 billion) and overall operations

savings to \$1.5 billion (\$2.5 billion minus \$1.0 billion). Based upon present and past levels of about 26 to 35 expendable launch vehicle flights per year, 40 Shuttle launches a year is a more realistic level of activity than 60; thus, KSC-only STS operations could save the Government up to \$3.5 billion over the next decade. It is important to note that the \$3.5 billion establishes the maximum savings due to elimination of Vandenberg. Under certain circumstances, a portion of the \$3.5 billion savings could be achieved by simply reducing the flight level of a two site operation from 60 to 40 flights per year.

The detail and sources of the \$2.3 billion to \$3.5 billion potential savings are given in the following five charts:

CHART 1.—Vandenberg facilities investment

Category:	[Millions of real year dollars]	Amount
Research and development	-----	¹ \$338. 0
Support equipment	-----	¹ 269. 0
Communications equipment	-----	¹ 44. 0
Military construction	-----	¹ 226. 0
Subtotal	-----	² 877. 0
Launch pad No. 2	-----	³ 175. 7
Total	-----	1, 052. 7
Costs incurred through fiscal year 1978	-----	⁴ (80. 9)
Vandenberg facilities savings	-----	⁵ 971. 8

¹ These are the estimated amounts through fiscal year 1983. The figures are as presented by General Coy in his testimony.

² According to General Coy's testimony the upper bound of this estimate is \$1.2 billion. Therefore, potential facilities savings could be higher than shown on this chart.

³ This estimate was provided us by the Air Force's Space and Missile Systems Organization (SAMSO).

⁴ See Chart 5.

⁵ This figure rounds to \$1.0 billion.

CHART 2.—Vandenberg manpower costs (direct and indirect) fiscal years 1983-92

Fiscal Year	[Millions of real year dollars]	Amount
1983	-----	¹ \$168. 5
1984	-----	¹ 241. 8
1985	-----	¹ 258. 9
1986	-----	¹ 265. 0
1987	-----	¹ 276. 6
1988	-----	¹ 295. 9
1989	-----	¹ 316. 7
1990	-----	¹ 338. 8
1991	-----	¹ 362. 5
1992	-----	¹ 96. 8
Subtotal	-----	2, 621. 5
Minus overhead	-----	² (100. 0)
Total	-----	³ 2, 521. 5

¹ The source of these costs, is the *Space Shuttle Preliminary Cost Data Base*, dated June 1977, prepared by the Operations Resources Analysis Office, Johnson Space Center. The figures were given in FY 1975 dollars; we converted them to real year dollars, using an annual inflation factor of seven percent. The source document contained the following introductory comments: "The resources data contained within this document covers all those costs and associated manpower (direct and indirect) to provide the standard Shuttle services * * * for the current STS Flight Traffic Model."

² According to NASA Headquarters and DOD (Pentagon) officials, the manpower estimates for Vandenberg include about \$100 million of overhead costs which may not disappear if Shuttle operations do not materialize at Vandenberg.

³ This rounds to \$2.5 billion.

CHART 3.—*Single-site Shuttle program: additional facilities costs at KSC if launch rate increases from 40 flights per year to 60*

[Millions of real year dollars]

Shuttle research and development:	
Launch processing system.	
Equipment.	
Equipment surcharge for non-Government-furnished equipment.	
Site activation.	
Design support.	
Subtotal	Cost
-----	\$69
Payload research and development:	
Ground support equipment.	
Launch processing system.	
Design support.	
Subtotal	24

Construction of facilities:	
Mobile launch platform No. 3.	
SRB disassembly workstands.	
Orbiter processing facility.	
Subtotal	2 88

Additional mobile launch platform No. 4	25

Other:	
Program ground support equipment.	
Spares.	
Propellants.	
Payload support.	
Shop capability.	
Subtotal	3 40

Total	1 4 246

¹ This total, and the detailed breakdown given above, were provided us by Mission Analysis and Integration, NASA Headquarters.

² Present planning, which anticipates 40 flights a year at KSC, calls for three mobile launch platforms. Therefore, this figure (\$88 million) is overstated by \$25 million.

³ We disagree with these costs; they appear to be operations costs which would not represent "additional" facilities costs associated with single-site operations.

⁴ This total, adjusted per notes 2 and 3, is \$181 million, which rounds to \$0.2 billion.

CHART 4.—*Single-site shuttle program: additional manpower costs at KSC if launch rate increases from 40 flights per year to 60*

[Millions of Real Year Dollars]

Fiscal year:	Amount
1983	1 \$282. 6
1984	1 277. 7
1985	1 297. 2
1986	1 318. 0
1987	1 340. 2
1988	1 364. 0
1989	1 389. 5
1990	1 416. 8
1991	1 446. 0
1992	1 122. 7

Subtotal (times 30 percent)	2 3, 254. 7

Total	2 976. 4

¹ The source of these costs is the document indicated in Chart 2, note a.

² Kennedy Space Center, as currently planned, will support 40 Shuttle flights per year. Based upon discussions with officials at NASA Headquarters, Johnson Space Center (JSC), and KSC, apparently no studies have been made of how much additional manpower would be required at KSC to support up to 60 Shuttle flights a year (a 50 percent increase in the currently planned flight activity). However, JSC and KSC representatives have commented informally that any increase in manpower requirements would be minimal but could approach 30 percent. On March 30, 1978, officials in NASA Headquarter's Space Transportation System Operations Office stated that 60 launches a year from KSC might require slightly more than a 30 percent increase in the proposed shuttle manpower level at KSC. However, as stated above, this information was not based on any detailed evaluation.

CHART 5.—VANDENBERG FACILITIES COSTS INCURRED THROUGH FISCAL YEAR 1978

[In millions of real year dollars]

Category	Prior years	Fiscal year 1978	Totals through fiscal year 1978
Research and development.....	\$31.2	\$24.3	\$55.5
Support equipment.....		17.2	17.2
Communications equipment.....		8.2	8.2
Military construction.....			
Total.....	31.2	49.7	80.9

Note: The figures are as presented by General Coy in his testimony.

INFORMATION RECEIVED FROM CONSULTANTS

Mr. BOLAND. Let me ask you this: I take it from Mr. Gutmann, Mr. Toler and Mr. Day's responses that this information that was developed comes from NASA figures, and that most of it comes from the Johnson Space Center.

How much of it comes from consultants?

You say that you consulted with people who are familiar in this area, or have some expertise and knowledge.

How much of the information that you developed is actually predicated on judgments by consultants that you referred to, Mr. Gutmann?

Mr. GUTMANN. I don't know if I can quantify that.

Would you have a feel for that?

Mr. TOLER. Yes, sir, I would say as far as our decisions or analysis being based on the consultant's work, very little. What we do is use him to confirm the information that we get, and to help us assess its reasonableness. If we find areas which we believe are weak, we will then go back to NASA and try to seek out additional information.

Mr. BOLAND. With respect to the consultants, Mr. Gutmann indicated he uses, you don't have any quarrel with them, do you?

Dr. FROSCH. I don't know who they are.

Mr. BOLAND. He mentioned the one that was a professor at Penn State.

What is his name?

Mr. GUTMANN. Dr. Kaplan.

Mr. BOLAND. Is he an acknowledged leader in this field?

Dr. FROSCH. I don't know.

Mr. GUTMANN. He is acknowledged to be a very competent man in this field by Dr. Mark, the Under Secretary of the Air Force. He knows him.

Mr. BOLAND. Dr. Hans Mark?

Mr. GUTMANN. Yes, sir.

Mr. BOLAND. For whom I have incidentally a high regard and respect.

DR. MARK'S VIEWS ON LAUNCHING TO POLAR ORBIT OUT OF KSC

Dr. PERRY. I would like to make a comment about the reference to Dr. Mark's views on this problem which were introduced into the record this morning. Mr. Gutmann pointed out that in discussions

with Dr. Mark, that he had verified that I think the figure was a 32,000 or 34,000 payload could be achieved in polar orbit out of Kennedy.

I discussed this with Dr. Mark over the lunchtime to get his view on that issue, and I would like to report to you now what he told me.

First of all he said that his discussions on this problem, what he had said, was that you can achieve approximately the same payload on a polar orbit going north out of Kennedy as you can going south out of Vandenberg, which is certainly a true statement, but that that ignores several important features.

First of all, in going north out of Kennedy, a dog leg will be required which will introduce inefficiencies and therefore reduce the payload weight that can be deployed.

Secondly, he said that in his view any launch out of Kennedy that went over the ground portions of the United States were totally unacceptable to him, because of the danger of abort, and the hazard to life, and that he would not accept any responsibility for a decision for a northerly launch out of Kennedy.

Finally, he said that a single site program was unacceptable to him, because of the danger, because of the possibility of an accident at the launch pad, which could be serious enough that could hold up the whole program for 6 to 12 months, and certainly in the programs which he is most interested in and most responsible for, that is an unacceptable delay. That is a more complete reflection of Dr. Mark's view on the question that was presented this morning.

If you desire, I will have Dr. Mark make a statement for the record addressing these issues, rather than having different people at the witness table quoting him.

Mr. BOLAND. I think you made a statement for the record. That is about what he would say, isn't it?

Dr. PERRY. That is what he told me.

FIRST SPACE SHUTTLE LAUNCH

Mr. BOLAND. Mr. Coughlin touched upon engine testing and the possible launch date of June 1, 1979. I don't know whether you said that is the date, that is the target date, is that correct, for launch?

Mr. YARDLEY. I said our general target date is still March. June is our external date. We are fairly comfortable with June. We think there is a fairly low probability that we will launch in March.

Mr. BOLAND. And you indicated, I think, Dr. Frosch, that you will not fly in the first manned Shuttle mission until you have accumulated 80,000 seconds of engine testing time total.

Mr. YARDLEY. 80,000 seconds.

Mr. BOLAND. And 10,000 seconds at 100 percent power; is that correct?

Dr. FROSCH. I think that is right, yes.

Mr. YARDLEY. That sounds about right.

Mr. BOLAND. Doesn't that requirement mean that it would be nearly impossible to meet a June 30, 1979 launch date?

Mr. YARDLEY. No, sir.

Dr. FROSCH. We don't think so.

Mr. BOLAND. Mr. Addabbo?

Mr. ADDABBO. Thank you, Mr. Chairman.

RETIRED MILITARY PERSONNEL WORKING ON SHUTTLE

Dr. Frosch, I would appreciate it if you would supply for the record the number of retired military personnel that are now employed by NASA and aiding in the Space Shuttle program. It would appear to me that a lot of this pricing has the DOD syndrome of high pricing everything and anything.

Because of the ability to diversify and split the dollars between the DOD Appropriations Subcommittee and all of these other Subcommittees, the American people don't realize how much is being spent for the Space Shuttle. Unless we have a hearing like this, we don't realize where there is possible duplication and waste, so I would like for the record to have you give us these numbers.

[NASA information follows:]

NASA does not discriminate between applicants having a military or civilian employment history. It is NASA policy to consider all candidates for employment, including retired military personnel, on the basis of previous records of performance, proven ability, and special skills. The best qualified candidate available is selected to fill each vacancy.

Historically, retired military personnel have made up about 2.6% of the total NASA civilian work force. By comparison, Civil Service Commission statistics as of June 1975 indicate that approximately 5% of the total Federal work force are retired military. The data for NASA for 1971 to 1977 is as follows:

RETIRED MILITARY AS PERCENT OF TOTAL PERMANENT EMPLOYMENT

	Total permanent	Retired military	Percent retired military
June 1971.....	29,478	780	2.6
June 1972.....	27,428	715	2.6
June 1973.....	25,955	664	2.5
June 1974.....	24,854	647	2.6
June 1975.....	24,333	623	2.6
September 1976.....	23,979	1 655	2.7
September 1977.....	23,569	1 621	2.6

¹ Includes title 10 Reserve (citizen reservists who obtained entitlement at age 60 with 20 years or more Reserve participation).

SHUTTLE TRANSITION COST

Mr. ADDABBO. In handling some of the other DOD budgets and parts within the budget, some officials have indicated that the Shuttle transition cost should be so-called above the line, that is these transition costs should be in addition to normal baseline budgets for space activities, and these officials justify this position on the grounds that during the transition period, there will be little or no advantages to this Shuttle, just extra cost.

Does NASA and DOD consider Shuttle cost as above the line or in addition to base budget?

Dr. FROSCHE. I am afraid I don't understand the terminology at all. The Shuttle program has been a part of the NASA budget. I don't understand what it means for it to be above the base or below the base. We don't have, as far as I know, an established base without it.

Mr. ADDABBO. Dr. Perry, would you venture an answer?

Dr. PERRY. From Department of Defense point of view, there will be an investment or startup costs in the program as in any program

we get into. As we proceed after 1985, we view the Shuttle as being an economical program. It will actually reduce the costs that would otherwise have incurred to us from the expendable launch vehicles.

Mr. ADDABBO. The question will be in the record and we may have to classify some of the answers after it has been discussed further.

[NASA information follows:]

In formulating the NASA budget the operations costs for all STS missions are defined based on firm requirements for launch services thru 1981. Estimates of subsequent launches are included based on launch requirements as defined in the 1977 NASA mission model (487 flights).

Reimbursements are then determined based on the requirements for launches by reimbursable users consistent with published NASA reimbursement policies for Non-NASA Civil U.S. government, DOD, Commercial and Foreign users. Payments expected from these reimbursable users are deducted from the total estimated operations costs. STS and the remaining operations costs are included as a basic part of the NASA budget requirements.

SHUTTLE RELIABILITY CRITERIA

Turning to the question of possible overland launches, range safety criteria is an important variable in considering the various Shuttle options. This is particularly true in regard to the question whether or not flight over inhabited areas should be permitted as would be required under the GAO proposal to conduct polar launching from Kennedy in lieu of building Vandenberg.

Dr. Frosch and Dr. Perry, the GAO's statement indicates that the risk of a TITAN 3C booster impacting land and hitting a person is 1 in 6,250. You indicated this morning that the risk of a Shuttle doing the same thing is a good deal more than 1 in 160,000. It would be less than 1 in 160,000.

Is the risk of the Shuttle having to abort and injuring people on the ground more or less than the 1 in 6,250 for the TITAN 3C?

Dr. FROSCHE. I have absolutely no way of answering that question, because it is not clear to me that we have any way of knowing whether those numbers mean anything in terms of direct hazard. Those are numbers which are not really intended to be used for hazard analysis. What they are used for is to make estimates of how much work it is worth putting into the reliability of components in order to achieve a balanced reliability. The 1 in 6,000 number has got to be a theoretical number for the simple reason that there have never been enough TITANs flown to have an experimental measurement. In fact there haven't been that kind of accidents, so that we have no idea whether that number is right.

All we can say is that in a manned vehicle, we take extraordinary care to make it reliable, because we are flying people in it. The 166,000 number I mentioned this morning appears to be taken from one number in a table of numbers in a report. The table covers a number of different kinds of assumptions in order to get to the numbers. That happens to be the most extreme number, and it includes, as I mentioned this morning, the assumption that all of the people in the footprint area, in the area that would be affected in case of catastrophe, are under significant cover, and it also includes a fuel dispersal system which doesn't exist for the Shuttle. If you use other assumptions, then the assumption that there would be someone impacted in case of a catastrophe can rise by as much as a factor of 1,000. The numbers

are very difficult to use, and essentially are not meaningful when used in this kind of category.

Mr. McDADE. Would you yield?

This says a DOD contractor. If it is that spurious and speculative, why in the name of God did you let the contract? How much did the contract cost?

Dr. FROSCHE. I have no idea.

Mr. McDADE. Who does?

Dr. FROSCHE. The number is a useful number for a different kind of purpose. It is used in engineering as part of the way in which one sets design criteria. It is not particularly a meaningful, absolute number.

Mr. McDADE. Having to do with safety?

Dr. FROSCHE. Having to do with reliability in the system.

Mr. McDADE. Doesn't that mean safety to a layman? If I sit up here and ask you if that doesn't concern itself with safety, does it or doesn't it?

Dr. FROSCHE. It has to do with the safety, but it is not a number that you can immediately use and believe as telling you what the safety is. This is an area in which what we really know from such numbers is that the reliability is very high, but the number itself is not a number that you can use for much.

Mr. McDADE. We have seen numbers games played around here every day, every week, with statistics and everything else. What the study apparently shows is that following the design criteria for the Shuttle, and bearing in mind NASA's recognition that it is a man-carrying vehicle, that it is a highly safely designed piece of equipment; is that correct or incorrect?

Dr. FROSCHE. Absolutely. It will be as safe as we know how to make it.

Mr. McDADE. You know we sit here and hear figures about whether or not we are going to have a nuclear accident, and I have been through all of those statistics, and I am sick of listening to them, and you know you have let a contract to try to make some kind of judgment, or the DOD did.

Now you are telling me your own contract doesn't make any sense.

Dr. FROSCHE. I am telling you that you cannot use the number in the contract in the way in which the GAO proposes to use it. You can use it for many other purposes.

Mr. McDADE. If I asked you to set the order of the vehicle crashing over a land area, based on the studies that you have done, what would be the mathematical probabilities of a crash?

Dr. FROSCHE. I cannot give you a number.

Mr. McDADE. Because you can't be 100 percent accurate.

Dr. FROSCHE. Because I can't find a reasonable number other than to say that it is going to be extremely low.

Mr. McDADE. We can play that game.

Is there a 10 percent factor?

Dr. FROSCHE. It is probably much lower than that.

Mr. McDADE. Is there a 1 percent factor?

Dr. FROSCHE. I have no idea. I don't know what the number is.

Mr. McDADE. You don't want to answer the question it seems to me. Yet you let the study, and when the GAO relies on a study of reliability and safety that impacts on the way you design the study, then you denounce the statistic.

Dr. FROSCHE. No, I am sorry. The GAO used a number from a table of numbers, and they used the one that was convenient for their computation.

Mr. McDADE. Let's stop right there.

What did your study show as a result of this contract?

Dr. FROSCHE. It showed that if you make those computations depending on the kinds of assumptions you want to make about the circumstances, you can get a set of numbers that vary by as much as a factor of 1,000. That is what it shows.

Mr. TOLER. May I say something here?

We selected that number for several reasons. One is because it is what Aerospace Corporation indicated would be necessary in order for the economics of the Shuttle to be worthwhile, because you cannot afford to lose orbiters at \$1 billion a copy.

Dr. FROSCHE. That is right.

Mr. TOLER. And, two, you would need that sort of a reliability factor in order to protect the crew on the orbiter. Now, one should keep in mind that we have many of the nation's best minds on this space vehicle—no longer just specially trained astronauts. We have scientists that we are putting on it. If we don't achieve this 1 in 167,000, you could not expect the Shuttle to be economical or provide the degree of assurance that we need.

Dr. FROSCHE. I am afraid you are missing the point entirely. I agree on the necessity for doing everything we can to make the vehicle successful, but it is very simple. We are never going to know whether we have met 166,000. If we fly the entire maximum model 560 flights, and there is never an accident, we will simply not know whether we are doing better than 1 in 560.

Mr. McDADE. You are reducing this whole study to pure speculation. What did you base your numbers on when you decided on how you would operate the Shuttle? I mean obviously I assume you did the study for more than just pure speculation, didn't you?

Dr. FROSCHE. We didn't do it.

Mr. McDADE. All right, maybe the Defense Department is the one. Did you rely on it?

Dr. FROSCHE. I don't believe we have relied on it.

Mr. McDADE. Did you do one that is comparable?

Dr. FROSCHE. I simply don't know.

Mr. McDADE. I thought you said it was involved in your design criteria.

Dr. FROSCHE. I said that is the way those numbers are characteristically used. What we are doing is basing our designs on the engineering experience in the whole sequence of manned flights up through Apollo, and mind you, what we know about the whole sequence of manned flights up through Apollo is that we were at least good enough so that we never had a launch abort in a manned flight.

Mr. McDADE. We are aware of that. You have a remarkable record. You built in all these contingencies in the vehicles and never had to use them.

Dr. FROSCHE. We are doing all of that in the Shuttle as well, so it is at least better than none in 32.

Mr. McDADE. Wouldn't you conclude that the GAO's statistics have some validity, since you never had a problem in the Apollo pro-

gram? You never aborted a vehicle. In fact we used one for the extravaganza in space in the Skylab mission with the Russians. We had it and so we used it. We bought more vehicles than we needed because you were so skillful.

Dr. FROSCHE. What NASA is aiming for is a program in which we have, in the course of the whole 12 years of flying, no aborts and no catastrophes.

Mr. McDADE. Right.

Dr. FROSCHE. And that is what we are designing to try and get to.

Mr. McDADE. Right.

Dr. FROSCHE. All I am saying is that quoting a large number is not very helpful in that.

Mr. McDADE. Doctor, let me ask you a question. From a safety point of view, wouldn't you say that the Shuttle is a less difficult technical problem from a safety point of view than was the Apollo program?

Dr. FROSCHE. No, it is considerably more difficult.

Mr. McDADE. You consider it to be considerably more difficult.

Dr. FROSCHE. Given starting from today's technology and doing what we are trying to do, it is more difficult. It is a little hard to compare it to Apollo, because we started that program knowing almost nothing.

Mr. McDADE. Apples and oranges, but I mean you have to give some kind of statement to the committee it seems to me about your assessment, your engineering assessment, your scientific assessment, about the safety of this vehicle.

Dr. FROSCHE. I can give that assessment in terms of what I think we will have to be satisfied with before we are willing to fly.

Mr. McDADE. Will you state that for the record, please?

Dr. FROSCHE. I think that I will have to be satisfied that we understand all the possible modes of failure as well as it is possible to understand in advance, the consequences of all of those failures, and that we have eliminated, as well as we know how, the possibility of serious failures by redundancy or other means. That is not a guarantee that we have thought of everything and done everything.

Mr. McDADE. Are there such guarantees in life?

Dr. FROSCHE. There are no such guarantees.

Mr. McDADE. On anything.

Dr. FROSCHE. Right.

Mr. McDADE. So let's get down to cases, because we are talking about GAO saying you have got a safe overland route and you can take it, you are going to fly overland over other parts of the world with this vehicle, and some way you have got to tell us this. You have got to quantify it first.

Dr. FROSCHE. Let me repeat what I have said this morning, and it is perhaps not a numerical quantification but I think it is a clear statement.

Mr. McDADE. Please, I would appreciate it.

Dr. FROSCHE. I see a considerable difference between flying over water and flying over land during the crucial initial phase of launch. Having a problem in this interval is much more serious than having a flight is considered for most of the ascent. We are trying to make the Shuttle as reliable as is possible to make it so that the

crew of up to seven people, who are trained professionals and skilled volunteers, will have a safe and reasonable chance of getting to and from orbit. However, a catastrophic accident early in the flight certainly is more serious if pieces are dropped on the most densely populated areas of the United States and Canada where there are 50 million people living. That seems to me to be a considerable difference in risk.

Even with or without numbers, if I have the understanding that everybody involved is willing to accept the small risk of losing the crew and of an extremely expensive vehicle, to me it is entirely different to include the additional risk of flying over a heavily inhabited area. I simply said this morning I would not be willing to take the responsibility.

Mr. McDADE. You wouldn't ban all the airliners from flying in the same pattern obviously, would you?

Dr. FROSCHE. No, I certainly would not, but let me make a statement about reliability.

Mr. McDADE. Please do.

Dr. FROSCHE. Certainly for military aircraft we do not regard a military aircraft as being out of its test phase where it has flown fairly restricted for something like the first 100 to 200 flights. We simply cannot treat a space program in that way, and so rather than restrict it in that way and regard it as test, we say that over a several hundred flight program we simply do not want to fly it over inhabited areas, but rather regard the whole thing as in some sense—

Mr. ADDABBO. Will the gentleman yield on that point?

You know, Dr. Frosch, it is very comical to me, and it shouldn't be, it is a strange word to use, comical, strange, that we are talking about an American Shuttle that is manned, and you say in 5 minutes it is still going to be over 50 million people, which again I would ask you to expand on that for the record, placing it in orbit over land just where it would be at any given point.

Dr. FROSCHE. It would not yet be in orbit.

Mr. ADDABBO. Just as a general observation, and I will yield back to Mr. McDade, but this Government of ours and the FAA gave to the people of my district, over 2 million people, a flying rocket filled with high octane gas, known as the Concorde, and they didn't give a damn about people on the ground or living near a dangerous weapon like that.

Mr. McDade.

Mr. BOLAND. Do you adopt the question, Joe?

Mr. McDADE. One of the recommendations that the GAO makes is some balancing between your launches out of Kennedy and the use of expendables until you demonstrate reliability.

Dr. FROSCHE. I can respond to that.

Mr. McDADE. All right, I wish you would please.

Dr. FROSCHE. This is a question, that then becomes a question of cost. What is proposed in that option is that we continue with expendable launch vehicles at Vandenberg until we have achieved some demonstration of reliability, and then build Vandenberg and make the transition.

Mr. McDADE. I don't think we go that far. The question is until you demonstrate reliability or safety, call it what you will, in the Shuttle.

[GAO information follows:]

No GAO proposal recommends the option described by Dr. Frosch. We believe a firm decision on Vandenberg should be made now based on available information concerning the acceptability of a single KSC launch site.

Dr. FROSCHE. What I think I have done in my own mind is said that after a few flights that were successful with two people, I would be willing to accept flights with seven people, but in my mind even after a couple of hundred flights, I would not be willing to accept flights that put at risk the safety of 50 million people. That is the closest I can come to differentiating the relationship between reliability and—

Mr. McDADE. So you are talking about 14 flights, aren't you?

Dr. FROSCHE. No, I am saying that the reliability comes out of the whole collection of flights. The question of cost is simply that, and the reason why I referred to waiting for Vandenberg. If we happen to have a number of flights, say, until mid-1985 and then decide to build Vandenberg, but keep using expendable launch vehicles out of Vandenberg until Vandenberg is ready for the Shuttle, then the additional cost for doing that over what we are proposing to do is something like \$3 billion.

Mr. McDADE. Did GAO hear that?

Mr. TOLER. We have looked at their figures on the \$3 billion. The first thing is that they assume if you don't achieve the desired degree of reliability, that you would go ahead with Vandenberg. We are not sure that this is a good assumption. If you haven't achieved the degree of reliability which would allow you to have land overflight, we question whether the Shuttle would be a viable program. Again it gets back to the DOD study, which shows the 1 in 166,000, that this is based on a degree of reliability which would be necessary for the Shuttle to be viable.

There are several other things that I think should be taken into account here. The Aerospace Corporation went back to see what degree of reliability or what casualty expectation figures have normally been allowed for our expendable launch vehicles, and they found that it has been as high as 1 in 12,500, and generally is around 1 in 100,000 as compared to the expected 1 in 167,000 for the Shuttle. This is not for the United States, the 1 in 12,500 or 1 in 100,000, but for Europe, Africa and other nations.

Secondly, another Aerospace Corporation study which looked into this whole thing asked what should we accept as a degree of risk in land overflight. Aerospace concluded that an individual would be a great deal safer from the Shuttle flying north over the United States than he would be from swimming, skiing, driving an automobile, or having a smallpox vaccination.

[GAO information follows:]

"* * * for the Shuttle to be viable." Is in reference to economics and safety. These requirements which were discussed in the reliability assignment process performed by Aerospace Corporation, resulted in a 0.9999 reliability goal. One in 166,000 is the calculated casualty expectation based on that degree of reliability.

Aerospace corporation officials stated that the 1 in 12,500 casualty expectation was the result of Southerly KSC launches of expendable vehicles where the vehicle passed over Cuba and the Panama Canal Zone. They attributed these launches to the European Space Agency (ESA).

Dr. FROSCHE. I am sure that is all correct and I am smoking a pipe which puts me in considerably more jeopardy, but I am not sure what the relevance of that is.

Mr. TOLER. The relevance is that you have to make judgmental decisions. Range safety officials do so on a daily basis—based on casualty expectation statistics and other data as to what degree of reliability they will accept for flights of expendable launch vehicles over continents of Africa and others. You have to have some basis.

Mr. YARDLEY. My understanding is the range safety general rule is 1 in 1,000,000, which even your 1 in 160,000 doesn't come to.

Mr. TOLER. We have never seen that. There is not a set criteria. The only thing you can do is go back and see what casualty expectation has characteristically been allowed from the Cape. It is not 1 in 1,000,000 according to the Aerospace study. It is somewhere around 1 in 100,000.

Secondly, I think you have to look at the Space Shuttle in another perspective. Not only does it have the redundant critical systems and is expected to be safer than prior manned vehicles, its most critical phase is over water. That is, the period from liftoff to SRB separation is considered the most critical phase. If something occurs in that time, there would be no danger of anything impacting on land. The statistics that we have thrown around here today don't take that into account.

Mr. BOLAND. Do you agree with that statement?

Dr. FROSCH. The most risky part is the early several minutes of flight certainly up until solid rocket booster separation, but that doesn't change my view that there is still risk beyond that.

Mr. YARDLEY. That is not quite true.

Dr. FROSCH. Okay, you have a different perception.

Mr. YARDLEY. I was talking about the fact that you will hit water. The instantaneous impact point begins to go over land at about 2½ minutes into flight with this trajectory. I am not talking about where the thing is. It is the impact of the coasted vehicles, the ballistic impact.

Dr. FROSCH. Of what we understand the trajectory to be.

[GAO information follows:]

In the case of a catastrophic event prior to or shortly after solid rocket booster separation the system would impact in the ocean. The impact point for the Orbiter and external tank would not begin to cross over land until about two and one-half to three minutes into the launch rather than in "less than one minute" as quoted by Mr. Yardley in the preceding statement. Up to and through this time, the Shuttle systems will be monitored from both mission control and by the Orbiter's crew. Any anomalies within onboard systems will be adjusted for by redundancy within the systems themselves or by other means available, thereby reducing the possibility of a catastrophic event occurring.

It should be noted that prior to any overland launches, NASA will have a large amount of data on the Shuttle vehicle in actual flight, and modifications to the systems will probably have been made and tested in flight. All of this will add to the reliability of the vehicle and increase the probability of successful launches.

Mr. BOLAND. Has there ever been a polar launch out of Kennedy north or south that you are aware of?

Dr. FROSCH. I do not know.

Mr. BOLAND. Under any of the programs?

Mr. YARDLEY. I have heard that there have been one or two.

Mr. BOLAND. Do I understand from what you have said, all of what you have been saying for the last few minutes or hours, is that a polar orbit is not acceptable, is not an acceptable risk out of Kennedy as far as NASA is concerned?

Dr. FROSCH. As far as I am concerned, yes, that is correct.

Mr. BOLAND. But it is an acceptable risk as far as GAO is concerned; is that correct?

Mr. TOLER. Based on the projected reliability of the Space Shuttle, it should be.

Mr. YARDLEY. Based on GAO's perspective of the reliability. Aerospace in that report took no position on the reliability. As a matter of fact, they said we will take 10 to 1.

[GAO information follows:]

Aerospace said that the reliability of 100 parts per million (ppm) was based on economics and crew safety. The "10 to 1" figure was in reference to the Aerospace 1976 report on hazards for high inclination Shuttle launches. The Aerospace Corporation said in that study that probability of vehicle loss has not been determined by NASA; therefore, they assumed a 100 ppm failure rate, a value which had evolved from an earlier study, then bracketed it with 1000 ppm, a value approaching the reliability of current vehicles. It should be noted that calculations using the lower reliability figure did not consider sheltering as a parameter.

Mr. BOLAND. Whether it is 1 out of 8,250 or whether it is 1 out of 600 or 1 out of 166,000, I am not sure that the figures mean very much frankly in this instance. If it is 1 out of 166,000 but it happens and it is going over an area where there are 5 million people, I think it makes a difference.

Mr. Sikes?

SHUTTLE RELIABILITY—DOD STUDY

Dr. PERRY. Mr. Chairman, would you like me to comment on the DOD report?

Mr. BOLAND. Yes, that is the one we are talking about.

Dr. PERRY. First of all, I will make a personal comment.

None of the numbers I have heard bandied about for statistical reliability have any meaning at all to me. I could not support any of them.

Mr. ADDABBO. Dr. Perry, please supply for the record, who the DOD contractor was, when that contract was given out, what it cost, and what was the purpose of that contract, and who used the data received from that contract.

[DOD information follows:]

The casualty expectation study contractor was the Aerospace Corporation. The initial analyses were performed in 1969 under joint DOD/NASA contract. Since that time, the study has been updated and expanded under both DOD & NASA contract. The specific data contained in the GAO testimony was developed under NASA contract in 1976. The casualty expectation analysis was a single task in a comprehensive integrated STS Operations Study which had a value of \$100K. An estimated \$2-3K was expended for this particular casualty expectation update. The study was initially performed to provide data in support of determining the number of shuttle launch sites required and their location. Since selection of KSC and VAFB it has been used by the DOD to respond to inquiries as to why all shuttle missions should not be launched from KSC.

Dr. PERRY. Mr. Addabbo, the second point I was going to make is in anticipation of your request.

Mr. ADDABBO. Thank you.

Dr. PERRY. We have what is apparently an interoffice memo prepared by Aerospace Corporation. I have the memo here and I would be happy to put it in the record. I also have a critique of the GAO evaluation of the data in this report by the sponsoring office, SAMSO, who sponsored the work. I will put that critique in the record.

[DOD information follows:]

The Aerospace Corporation memo is provided for the record.

THE AEROSPACE CORPORATION

INTEROFFICE CORRESPONDENCE

A76 5434.4-15

TO:	R. R. Wolfe	CC:	Alder, J. R. Kulakowski, L. J. Zambelli, E. D. PAD Managers	DATE:	23 June 1976
SUBJECT:	Predicted Hazard for Shuttle from ETR into Near Polar Orbits	FROM:	<i>O. A. Reffing</i> O. A. Reffing	BLDG:	A3 ROOM: 2283
		EXT:	87226		

Attachment 1 summarizes the results of our analyses of the hazards associated with attaining polar/near polar orbits from ETR with the Shuttle. In the analysis, no consideration was given to other possible constraints such as water depth and the possible sonic boom problem. It should be noted that the latter item comes within the purview of ETR Safety as does the debris impact problem.

Attachments: (1) Predicted Hazards for Shuttle Flights from ETR Into Near Polar Orbits.

Approved: *R. G. Stern*

R. G. Stern, Associate Head
Performance Analysis Department
Guidance & Flight Dynamics Subdivision

26-636 532

Predicted Hazard for Shuttle Flights from ETR Into
Near Polar Orbits

This document presents the results of a preliminary hazard analysis for Shuttle flights into near polar orbits from ETR. Launches in both northerly and southerly directions were considered using initial flight azimuths of 8° * and 145° respectively. After the Solid Rocket Boosters (SRBs) are jettisoned dogleg maneuvers are executed to attain the desired orbit. The location of the ground tracks are shown in Figure 1 for a 97° orbit.

Two situations can create a ground hazard. They are: (1) the impact of objects which are jettisoned in the sequence of normal events and, (2) the impact of the vehicle or debris resulting from malfunctions that can occur.

The SRBs are assumed, for the ground tracks considered here, to impact in open ocean areas sufficiently far from land so that the hazards to the land areas are low. The hazards to ships were not evaluated but they are also characteristically low. The other object jettisoned in the course of normal events is the External Tank (ET). It was assumed in this analysis that the impact area for this object would also be in an open ocean area sufficiently removed from land masses so that the hazard would be acceptably low. Additional comments on this situation are provided in a subsequent section of this report.

For the malfunction analysis, the basic parameters used in evaluating the overflight hazards are:

- (1) The vehicle's malfunction characteristics and probability of occurrence
- (2) The debris characteristics of the vehicle, if a malfunction occurs
- (3) The population characteristics of the land area affected

*An initial azimuth of 12° is currently being considered; the analysis results are relatively insensitive to the initial azimuth change.

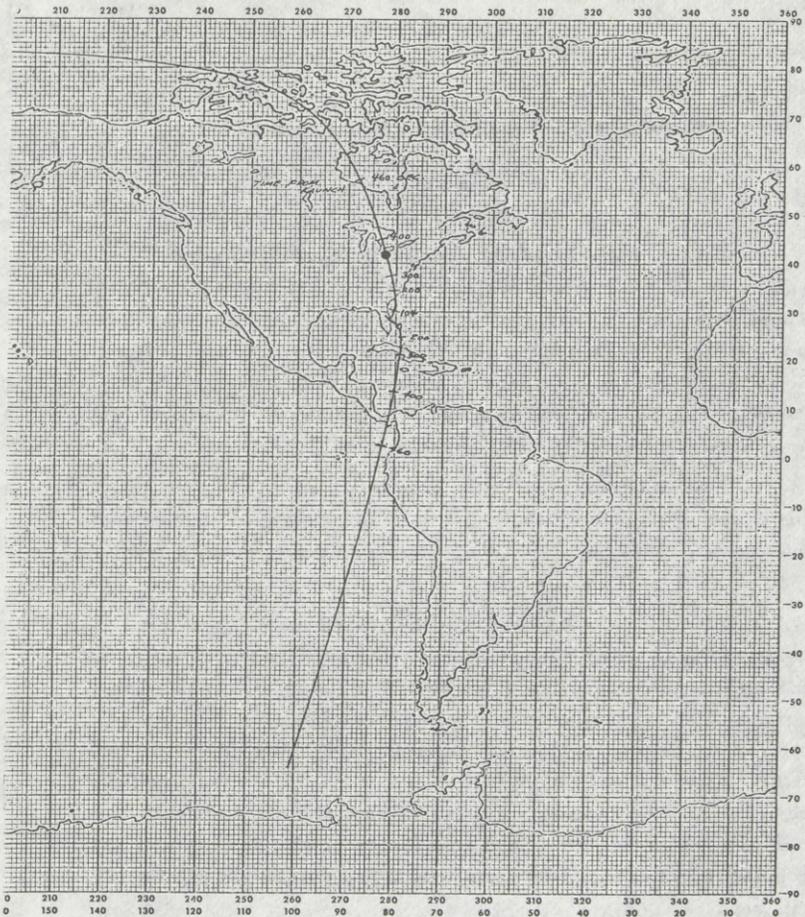


FIGURE 1
I I P TRACKS INTO 97° ORBIT

Each of these items will be briefly discussed for better understanding of the results.

The above data applies to the case where a malfunction occurs and the vehicle flight is terminated. In the analysis, two basic types of malfunctions were considered: an explosion - type and a non-explosion-type. In the former situation, it was assumed that both the orbiter and the ET are destroyed and that they impact as debris. Seventy-six percent of the vehicle loss failures were assumed to be in this category. The other 24 percent were in a non-explosion type malfunction in which the orbiter lands or crashes in an unpopulated area (some control of the impact area is assumed) and the ET tank separates from the orbiter. The probability of a vehicle loss has not been determined for the shuttle vehicle. Therefore two values were considered: 100 ppm and 1000 ppm. The former value (100 ppm) is based on a reliability goal of .9999 for a complete mission. However for this analysis these values were used as the probability of vehicle loss from SRB jettison to ET jettison. The hazards for earlier flight times were considered to be low and confined primarily to the launch area where the population can be controlled. The higher value (1000 ppm) was considered to show the effect of probability of failure values approaching those of current vehicles on the results.

A failure probability of 100 ppm during the indicated time period yields a failure rate of $.27 \times 10^{-6}$ failures/second if it is assumed that failures are equally likely to occur at any time. A comparison of this failure rate with that for other vehicles is shown in Figure 2. From this data it is apparent that the failure rate based on 100 ppm of failure is significantly lower than is characteristic of earlier launch vehicles.

The debris model used in the analysis is shown in Figure 3. As indicated there, the debris casualty area for the Shuttle is substantially higher than that for the Saturn or the other indicated vehicles. The debris model was based on our Aerospace breakup analysis for each of the objects.

FIGURE 2

RELIABILITYDATA USED IN ANALYSIS

- PROBABILITY OF FAILURE BASED ON MISSION RELIABILITY GOAL OF .9999 (100 PPM)
- 100 PPM USED AS P_F FROM SRB JETTISON TO ET JETTISON
- FAILURE RATE: $.27 \times 10^{-6}$ FAILURE/SEC (CATASTROPHIC-TYPE)
- ASSUMED THAT FAILURES ARE EQUALLY LIKELY TO OCCUR AT ANY TIME

FAILURE RATE DATA FOR OTHER VEHICLES

• SATURN V					
	SIC PHASE	<u>VEHICLE LOSS</u>	<u>MISSION LOSS</u>	<u>ALL FAILURES</u>	
		6.3×10^{-6}	8.1×10^{-6}	36.3×10^{-6}	
	SII PHASE	1.6×10^{-6}	2.6×10^{-6}	38.8×10^{-6}	
• TITAN III C				<u>ABORT</u>	
	SRM JET TO STAGE I JET			42×10^{-6}	
	STAGE II			23×10^{-6}	

OBSERVATION

- FAILURE RATE FOR SHUTTLE BASED ON .9999 IS LOWER THAN IS CHARACTERISTIC OF OTHER VEHICLES

FIGURE 3

DEBRIS MODEL

DATA USED IN ANALYSIS

- DEBRIS CASUALTY AREA: ORBITER ~ 35,000 SQ FT
ET ~ 85,000 SQ FT
120,000 SQ FT
- SHELTERING WAS CONSIDERED USING ETR SAFETY APPROACH

DEBRIS CASUALTY AREA DATA FOR OTHER VEHICLES

- TITAN III STAGE 1: 13,336 SQ FT
- SATURN S-1B/S-IVB: 59,824 SQ FT (INERT)
- ATLAS BOOSTER: 9,600 SQ FT

OBSERVATION

- DEBRIS CASUALTY AREA FOR SHUTTLE IS SUBSTANTIALLY HIGHER THAN FOR CURRENT VEHICLES

The population characteristics for the area overflown are also required to evaluate the hazard. For this analysis the hazards for the ground tracks shown in Figure 1 were evaluated. Figure 4 presents a map of the US showing in more detail the areas overflown. For this purpose, it was assumed that the failures would be manifested as either a pitch-type failure or a yaw-type failure. In the first, it is assumed that the vehicle malfunction results in impacts within a crossrange distance defined by the guidance and performance dispersions and wind effects. A normal distribution of impacts was assumed with a 3σ value of 20 n miles as shown in Figure 5. In the case of yaw-type failures, it is assumed that the impacts occur within the crossrange distance defined by the previously indicated quantities and the turning characteristics of the vehicle. In this case a pseudo-normal distribution was obtained by convoluting the various effects. A distribution of 75% and 25% on the pitch-and yaw-types of failures was used based on the characteristics of other vehicles. The analysis results do not appear to be very sensitive to this distribution. 1970 population data was used to define the population exposed to the flight hazards within the indicated corridors.

Using the above approach and input data, the hazards associated with the overflight of the various land masses were calculated. The results of the analysis are tabulated in Figure 6. For the overflight of the U.S., data is also shown for the case where sheltering is included. Sheltering reduces the hazard approximately an order of magnitude for countries such as the United States where much of the population is protected both day and night by building, cars etc. In many other countries, the effect would be considerably lower than indicated for the U.S. and Canada. The analysis shows that if sheltering is not considered, there is approximately two orders of magnitude difference between north and south launches. If sheltering were considered, the difference would be slightly smaller.

FIGURE 4
HIP TRACKS

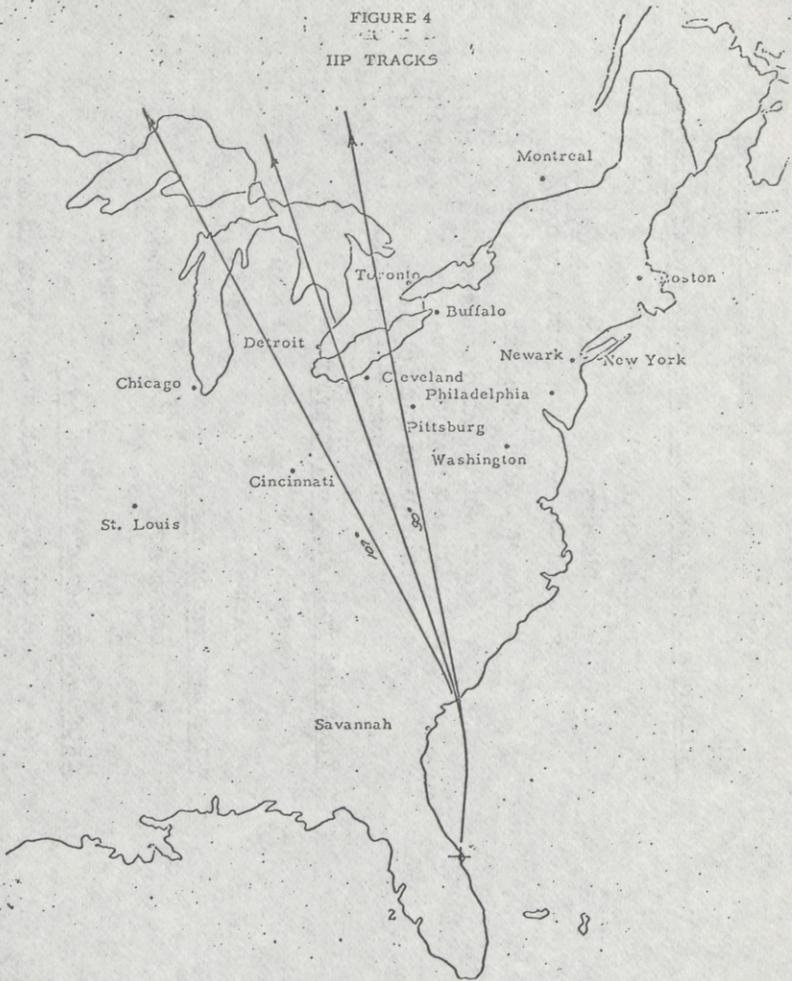


FIGURE 5

LATERAL IMPACT DISPERSIONSGUIDANCE & PERFORMANCE DISPERSION + WIND EFFECTS

- USED IN ANALYSIS
 - DISPERSIONS: 20 N MI MAX
 - BASIS: SATURN V DATA
- DATA FOR OTHER VEHICLES
 - TITAN III D (RADIO GUIDANCE) 5.2 N MI
 - ATLAS F (RADIO GUIDANCE) 12.4 N MI
 - THORAD (RADIO GUIDANCE) 6.9 N MI
 - TITAN III C (INERTIAL GUIDANCE) .6 N MI (FP7D&E)

TUMBLING TURN CHARACTERISTICS

- DISPERSION: 11.5 N MI
- BASIS: SATURN V

WIND EFFECTS ON DEBRIS

- DISPERSION: ~ 10 N MI ($w/C_{DA} = 3$)
- BASIS: AEROSPACE STUDY

CROSSRANGE IMPACT DISTRIBUTION

- "PITCH-TYPE" FAILURES: NORMAL DISTRIBUTION
- "YAW-TYPE" FAILURE: PSEUDO-NORMAL DISTRIBUTION

The analysis results shown in Figure 6 are for a 97° orbit. Other analyses have indicated that the hazards for flights into 90° orbits would be substantially the same for launches in either direction as are shown for the 97° orbit case.

There are several safety concerns associated with the proposed northerly flown mission in addition to the level of overflight hazards as indicated in Figure 6:

- (1) Disposal of the ET for a nominal mission.
- (2) Disposal of the ET for successful abort.

In connection with (1), the assumption was made in this analysis that the ET could be impacted safely in open ocean for all polar/near polar missions. This problem will need further study to provide a high level of assurance that this will occur with for all ground tracks of interest and considering the sensitivity of the impact range with separation characteristics as implied in Figure 7.

In connection with (2) above, successful RTLS abort requires that the ET be jettisoned. For ground tracks over the U.S. and Canada (northerly launches from ETR), the usual RTLS abort procedure would not be satisfactory and alternative RTLS procedures are required. The primary safety concern here is the impact of the jettisoned ET. Impact in water areas is the general approach for more conventional azimuths and has been stated by ETR Safety as a requirement for consideration of the northerly azimuths for Air Force Missions. A review of the standard RTLS procedure indicates that the ET impact area would be in Georgia for all near polar missions. Alternatives that might be considered include possible impact of the ET in the Great Lakes or in preselected low population areas or to use alternate RTLS procedures, if possible, to attain impact in the Atlantic Ocean. All involve revised RTLS procedures and technical studies to establish their viability.

FIGURE 6

RESULTS OF ANALYSIS

 $i = 97^\circ$

<u>Launch Direction</u>	<u>Reliability</u>	<u>Sheltering</u>	<u>PDS*</u>	<u>Casualty Expectation</u>
North	R = .9999	No	No	$.6 \times 10^{-3}$
	R = .9999	Yes	Yes	$.6 \times 10^{-5}$
	R = .999	No	No	$.6 \times 10^{-2}$
South	R = .9999	No	Yes	$.8 \times 10^{-5}$
	R = .999	No	Yes	$.8 \times 10^{-4}$

* Propellant Dispersion System

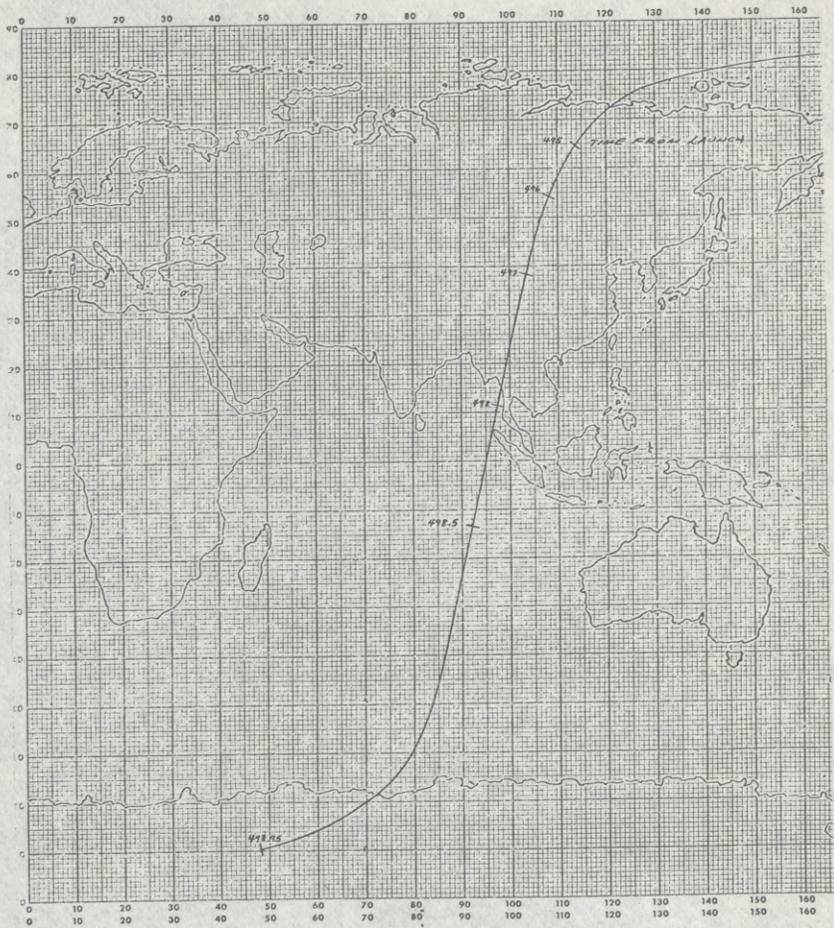


FIGURE 7
IPP TRACK OVER ASIA AND INDIAN OCEAN, 97° ORBIT

In connection with the southerly launches, no specific range safety concerns of the magnitude indicated for the northerly launches are apparent. It appears that both the SRB's and the ET impacts using a normal RTLS procedure would be in open ocean areas using an initial azimuth of 145° . In fact, it appears that more westerly initial azimuths may also be feasible from a range safety standpoint if they are required for performance reasons. For instance, the SRB impact area appears to be in a safe area for azimuths greater than 155° . While the overflight hazards were not evaluated for azimuths other than 145° , it does not seem likely that they would be significantly higher for other azimuths which would keep the SRB impact footprint in water.

Critique of Casualty Expectation Study

107 DoD
 (The information follows:)

88 Critique of the GAO evaluation of the Aerospace Corporation memo by its author is provided for the record.

THE AEROSPACE CORPORATION



Post Office Box 92957, Los Angeles, California 90009, Telephone: (213) 648-5000
 78-2610, 2-039
 14 March 1978

Subject: Draft GAO Report Review - Launch Hazards Analysis Portion

To: SAMSO (LVG/Col J. Herriott)
 P. O. Box 92960
 Worldway Postal Center
 Los Angeles, California 90009

1. In response to Maj J. Wormington's request, the results of the Aerospace Corporation review of the launch hazards analysis portion of the January 1978 draft GAO Report are formally transmitted. The GAO report was primarily based upon Aerospace Report A76-5434, 4-15 dated 23 June 1976 and discussions with its author, Mr. O. A. Refling and myself.

2. The following critique of the GAO report was prepared by Mr. Refling and approved by me prior to your use of it.

a. The GAO report states on page iii that "Range Safety officials have acknowledged that approval of high inclination launches from KSC depends basically on whether or not STS facilities are built at VAFB". This implies that approval will more or less be automatic if VAFB is not available. In view of the widespread public opposition to the proposed over-land flights of vehicles such as Minuteman from operational sites, it cannot be assumed that over flight of major populated land masses in the U. S. will be routinely accepted. This is especially true for a continuing flight program such as that of the Shuttle. It should also be pointed out that range safety approval has always involved need vs risk considerations. If the need is high enough and if there are no alternative approaches, the chance of approval are obviously enhanced.

b. The reference to the fact that "contractor studies have continually cited a reliability factor of 0.999" implies a high level of confidence in this value and a more extensive examination of the reliability than actually was the case. The value of 0.999 quoted in the report was used in range safety analyses to show the increase in hazard for a lower reliability than the baseline value of 0.9999. The baseline value of 0.9999, which was considered only as a reliability goal, resulted from a review of generic reliability characteristics for other systems including aircraft and space vehicles and was not developed from a reliability study of the Shuttle itself. The necessary

reliability analyses had not been performed at that time and are still not available to our knowledge. A value of 0.999 yields a failure rate of 2.7×10^{-6} failures/second from SRB jettison to ET tank jettison; this compares to vehicle loss failure rates for the Saturn of 6.3×10^{-6} and 1.6×10^{-6} during SIC operation and S II operation respectively. Differences in vehicle external configuration, redundancy, and the reuse aspect of the Shuttle are the basis for concern that the safety reliability of the Shuttle may actually be lower rather than higher than that for the Saturn vehicle.

c. The "one in 166,667", value indicated as a predicted hazard level in contractor studies was probably based on a casualty expectation of 0.6×10^{-5} (1/166,667) from a study which was an extension of studies made for launch site evaluations some years ago. This particular value was based on a reliability goal of 0.9999 and assumes that a propellant dispersion system would be used. The GAO implies that the one in 166,667 value is based on a reliability of 0.999. The predicted casualty expectation for a 0.999 would be 0.6×10^{-4} (1/16,667).

d. The GAO statement that the Shuttle "would pose fewer problems than commercial airlines" is very misleading. The average probability of a takeoff or landing accident for commercial aircraft is approximately 1×10^{-6} which is certainly lower than predicted for the Shuttle. On the other hand, the comparison may be on a yearly basis, with the hazard based on the estimated number of Shuttle flights per year versus the several million commercial aircraft flights per year. However, it is our opinion that putting the Shuttle in the same safety category as commercial aircraft is completely unbased at this time point.

e. The treatment of the comparison between the Shuttle ascent hazards and the Titan IIC orbital debris reentry hazards is equally misleading. The use of the casualty expectation as a hazard parameter should be supplemented with other hazard parameters to provide more of an insight into the differences in the two situations. Another hazard parameter of interest in ascent analyses is the "conditional hazards", that is, the casualty expectation if a catastrophic failure occurs during ascent flight. In the case of the Shuttle, the area on the surface of the earth that would be affected by impacting debris would be several orders of magnitude larger than for the Titan orbital debris. Thus the consequences of a catastrophic failure of the Shuttle during ascent could be many times more serious than for the impact of Titan space debris in an area of similar demography.

f. Another hazard parameter that should be considered is the individual risk (i.e., the probability that a specific person would be harmed). In the case of the Shuttle ascent hazards, the risk is to a relatively small number of people along the ground track compared to the billions of people that might be exposed to a risk from the reentry of Titan space debris.

Other studies have shown that the average individual risk associated with the proposed Shuttle ascent flight plan is at least several orders of magnitude higher than the average individual risk associated with the reentry of Titan debris. It is our opinion that all these factors should be considered in evaluating the real risk that is being imposed on people. This is especially true of the "conditional hazard" mentioned above since Shuttle safety reliability data, which is unavailable, is not considered in this hazard parameter. Based on these hazard parameters the risk for Shuttle flight is considerably higher than for reentry of Titan orbital debris.

g. The reference that the Shuttle system "could most likely ditch in the ocean or be blown up with pieces falling into the ocean" is an oversimplification of the problem in that it assumes that an RTLS abort or abort to orbit is possible in most cases. As with all types of complicated mechanisms involving large quantities of explosive materials and operating in adverse environments, there is always the probability that catastrophic failures such as explosions, tank ruptures, nozzle burn-thru, structural and control failures may occur. These failures would likely preclude successful abort of the Shuttle and impact of the ET on land would occur with a high risk of casualties occurring.

3. Based on these points, it is our opinion that safety considerations in the GAO report were handled in a superficial manner and that the report lacks an appreciation of the many technical and non-technical factors that are considered in the range safety decision making process relative to flight plan approval.



J. H. Ashmore, Director
Systems Engineering Analysis
Space Transportation Directorate
Vehicle Systems Division

JHA:la

cc: LTC C. Essmeier/LVRE
Maj J. Wormington/LVGR

I will read you the last paragraph of that, if you will.

It says "Based on these points, it is our opinion that safety considerations in the GAO report were handled in a superficial manner, and that the report lacks an appreciation of the many technical and nontechnical factors that are considered in the range safety decision-making process relative to flight plan approval."

The third point I would like to make, Mr. Chairman, is that whatever we decided and whatever you decide on this issue, before we conduct such a flight, we will have environmental impact statements to file. I have been through a considerable amount of that in the last year, and it is not at all clear that we would ever get approval for this.

Mr. BOLAND. If you go through that, it will be the year 2000.

[GAO information follows:]

In response to Aerospace's three page critique, it must be emphasized that the GAO has not arbitrarily used either the casualty expectation figure or the 0.9999 reliability factor. The source for the reliability figure is an Aerospace Corporation study titled, "Evaluation of the Intact Abort Concept for the Space Transportation System," ATM 70 (5758)-9, dated September 19, 1969. The study stated the following:

"In this ATM [Aerospace Technical Memorandum] vehicle loss probability goals for the STS are derived consistent with the intact abort concept."

"In order for this concept to be justified on a safety or cost basis, the probability of loss of control or propulsion must be reduced drastically compared with present manned space boosters."

"Based on the following arguments, a preliminary loss criteria goal of 100 losses per million [0.9999] missions is recommended."

"1. From * * * cost effective considerations * * * a vehicle loss criteria of one thousand per million missions is optimum. Loss criterion in excess of this value are not cost effective just due to the replacement costs of a very expensive vehicle. The replacement costs for a complete flight crew complement was ignored."

"2. By comparison with present day manned space programs, the next generation of vehicles should afford less crew risk per mission. The manned space missions of this decade were conducted primarily to ascertain man's utility and adaptability to the space environment. The risk of life was high, of necessity, due to the limitations of our technology. The STS by contrast utilizes the demonstrated capability of the man to aid in conduct of the missions on a routine basis. While a present day astronaut may fly only three or four manned space missions during his entire career, a STS crew member may fly ten times that number or perhaps even more. This consideration then suggests an upper limit for crew risk of about 500 losses per million flights [0.9994]."

"3. The number of flight crew members for STS is two or three times the number for Gemini and MOL [Manned Orbiting Laboratory]. Moreover, the STS will carry passengers for the space station resupply mission."

"4. Commercial airline statistics are probably not achievable for the first generation STS due to the inability to attain test history for the rocket engine comparable to the inflight experience with jet engines."

"The loss probability requirement is thus bounded between commercial airline loss experience and F-84 loss experience. A loss criteria goal of 100 per million [0.9999] flights due to equipment failure thus appears reasonable. * * * It is worthwhile to note that 38% of the military accidents were caused by pilot error * * *. Taking this fact into account, and the fact that not all reported accidents were catastrophic with respect to damage or injury, then the STS loss goal would be roughly equivalent to century series fighter experience." (Underscoring supplied.)

Similarly, the casualty expectation figure (1 in 166,667) was taken from an Aerospace Corporation study—"Predicted Hazard for Shuttle from ETR [Eastern Test Range] Into Near Polar Orbits," IOC A76 5434.4-15, dated June 23, 1976. The study contained the following comments:

"In the analysis, two basic types of malfunctions were considered: an explosion-type and a non-explosion type. In the former situation, it was assumed that both the orbiter and the ET [external tank] are destroyed and that they impact as debris. Seventy-six percent of the vehicle loss failures were assumed to be in this category. The other 24 percent were in a non-explosion type malfunction in which the orbiter lands or crashes in an unpopulated area (some control of the impact

area is assumed) and the ET tank breaks up or is destroyed. The probability of a vehicle loss has not been determined for the shuttle vehicle. Therefore two values were considered: 100 ppm [parts per million] and 1000 ppm. The former value (100 ppm) is based on a reliability goal of .9999 for a complete mission. However, for this analysis these values were used as the probability of vehicle loss from SRB [solid rocket booster] jettison to ET jettison. The hazards for earlier flight times were considered to be low and confined primarily to the launch area where the population can be controlled. The higher value (1000 ppm) was considered to show the effect of probability of failure values approaching those of current vehicles on the results.¹

Figure 6 in the study arrayed the following results of the analysis for a northerly launch (97 degrees inclination) from KSC:

Reliability	Sheltering	Casualty expectation
0.9999	No	0.6×10^{-3}
0.9999	Yes	1.6×10^{-5}
0.999	No	$.6 \times 10^{-2}$

¹ Equals 1/166,167.

GAO's Los Angeles Office discussed these casualty expectation figures with the study's author on several occasions during the course of the review. Specifically, our workpapers include records of discussions on October 4, 12, 17, 18, and 28, 1977. During those discussions, the author stated in substance that:

The casualty expectation for .9999 reliability and sheltering appeared to be a good figure and was consistent with other analyses where ET fuel dispersion break-up are assumed;

Inclusion of the sheltering and ET fuel dispersion system would be the best assumptions for northerly STS launches from KSC;

The $.6 \times 10^{-5}$ casualty expectation is the most reasonable for .9999 reliability, sheltering, and ET fuel dispersion.

The study did not include any consideration that in some abort cases, the crew might be able to follow RTLS (return-to-launch-site) procedures wherein the ET could be released over the ocean or unpopulated areas; exclusion of such RTLS possibilities results in higher calculated casualty expectation figures.²

The failure rate values used in the analysis (100 ppm and 1000 ppm) were based on assumed reliabilities of .9999 and .999, respectively. Since detailed probability of failure data was not determined for STS, the values selected were intended to bracket the probable range for the STS. The 100 ppm value was based on the .9999 STS design goal and the 1000 ppm was judgmentally selected as a value 10 times greater than the design goal and approaching the failure probabilities of other current vehicles.

In the study, the probability of failure values for a complete mission were used for the phase from SRB jettison to ET jettison; this was a conservative approach.

As the foregoing suggests, range safety considerations weigh heavily in any discussion as to whether high inclination STS launches from KSC are feasible. During our review we discussed potential hazards of such launches with knowledgeable representatives of the Aerospace Corporation and the Air Force System Command's Space and Missile Systems Organization (SAMSO). They provided us with the following documents pertaining to various studies of the subject:

REFERENCE AND DOCUMENT

I. Aerospace Technical Memorandum 70 (5758)-9, dated September 19, 1969 "Evaluation of the Intact Abort Concept for the Space Transportation System" (mentioned above)

II. Aerospace Technical Operating Report (TOR) 0059 (6770-04)-11, dated May 6, 1971, "Safety Hazard Criteria for STS Vehicle Launches"

III. "DOD Shuttle Launch Requirements" (an undated Aerospace document said to have been prepared in the Fall of 1975)

IV. Aerospace TOR-0059 (6770-04)-12, May 6, 1971, "Ground Hazards Associated with Flight Operations at Los Angeles International Airport"

V. Aerospace Interoffice Correspondence (IOC) A 76 5434.4-15, dated June 23, 1976, "Predicted Hazards for Shuttle from ETR Into Near Polar Orbits" (mentioned above)

VI. Reentry Safety Data (SAMSO Form 4), dated May 3, 1977, for Program 624A, T III C Vehicle 32.

We recognized that there were several problems in using and comparing the casualty expectation statistics included in the referenced documents. Some inconsistencies between data in the different reports had not been adequately explained. Also, some of the data were several years old. Thus, in October 1977, we requested Aerospace Corporation, through SAMSO, to review and update, if necessary, the casualty expectation calculations as shown in references I, IV, and V. SAMSO declined to have Aerospace Corporation reevaluate and update the 1971 study of the ground hazards associated with aircraft operations at busy airports such as Los Angeles International Airport (reference IV); they said the manpower required to do the job could not be spared. However, Aerospace did review their latest study (reference V) on the hazards of northerly Shuttle launches from KSC.

Aerospace confirmed that the basis for the 100 parts per million failure rate (i.e., a reliability design goal of .9999) used in their STS safety analyses was a study they had performed in 1969 for NASA; the study (reference I above) recommended a preliminary loss criteria goal for STS of 100 losses per million missions. Although the STS vehicle concept/design has changed since 1969, an Aerospace representative said the changes would not significantly affect the logic and conclusions reached in the study. He noted that ATM 70 (5758)-9 was a generic-type study and was not really dependent on STS vehicle configuration.

Further, an Aerospace representative said they do not know any more about the STS vehicle reliability now than they did in 1976 when they performed the hazard analysis (reference V). Accordingly, he said the casualty expectation statistics developed in IOC A76 5434.4-15 would represent their best estimates without having STS reliability data furnished by NASA. Aerospace and SAMSO officials said that on more than one occasion they had formally requested NASA to furnish such reliability data, but that NASA apparently saw no need for such data and analyses. In contrast, SAMSO uses detailed vehicle reliability data for calculating risks associated with launch and flight of their own standard vehicles.

To avoid confusion in interpreting and using any of the aforementioned reliability and hazard studies, we presented to SAMSO on November 14, 1977, a written outline of our understanding (for discussion at a subsequent exit conference) of these studies. Applicable sections of the outline are presented here for the record:

"ITEMS FOR DISCUSSION AT GAO EXIT CONFERENCE REVIEW OF STS ASSIGNMENT CODE 952181)

* * * * *

V. Range safety constraints at KSC

* * * * *

C. Aerospace IOC A76 5434.4-15, June 23, 1976, is apparently the most recent study of risks of northerly STS launches from KSC. For launches from 8° azimuth to 90° or 97° orbits it shows:

Reliability	Sheltering	Casualty expectation
0.9999	Yes	0.6×10^{-5}
0.9999	No	$.6 \times 10^{-3}$
0.999	No	$.6 \times 10^{-2}$

D. The .9999 reliability is based on a 1969 Aerospace study recommending a preliminary loss criteria goal for STS of 100 ppm. Since NASA has never furnished specific STS reliability data, the statistics noted in C above would still represent Aerospace's best estimate of CE risk for STS (for northerly KSC launches).

E. SAMSO uses detailed vehicle reliability data for calculating risks associated with launch and flight of their own standard launch vehicles. They have requested similar reliability data from NASA, but NASA apparently sees no need for establishing specific numerical goals for launch and mission success or safe return.

NASA indicated, however, they saw no problem in Air Force using recommended STS reliability goals for planning purposes.

F. Aerospace Studies in 1971 made interesting comparisons of calculated STS risks with ground hazards associated with living near busy airports and other safety hazard criteria. SAMSO declined to have any of these studies updated, because they consider launch site selection issues settled.

G. An interesting comparison—The calculated casualty risk—of $.6 \times 10^{-5}$ for a northerly STS launch from KSC (assuming sheltering and a fuel dispersion system) is apparently unacceptable, whereas the higher world-wide risk of 1.6×10^{-4} associated with random reentry of Titan IIIC debris is acceptable.

The exit conference was held at SAMSO on November 16, 1977.

Two days after the exit conference, SAMSO provided formal comments. Applicable portions of their letter follow:

"Mr. ALBERT L. BUSSEY,
U.S. General Accounting Office.

DEAR MR. BUSSEY: This office received your "Items for Discussion" relating to assignment code 952181.

Generally, the statements of fact presented are accurate and complete. However, we feel that it is strongly implied in your statement that some/most/all DOD payloads could be launched from Kennedy Space Center (KSC). This is not a viable option without violation of Range safety constraints and extremely sensitive foreign country overflight policies. It is our belief that such a violation is neither rational nor reasonable.

The following comments are addressed to specific statements of fact and are presented in order to assure accuracy and mutual understanding.

* * * * *

V. C. Casualty expectation figures cited are specifically for launches into a 97° orbit, although launches into a 90° orbit are substantially the same.

Sincerely,

WILLIAM J. SPARKMAN, Colonel, USAF
Deputy for Launch Vehicles."

This letter accepted GAO's range safety comments as being generally "accurate and complete". Such acceptance includes the figures at issue—the .9999 reliability goal for the Shuttle as well as the $.6 \times 10^{-5}$ (or 1 in 166,667) and the 1.6×10^{-4} (or 1 in 6,250) casualty expectation figures for the Shuttle and Titan, respectively. SAMSO's letter raised no objection to the comparison made at paragraph V.G. of our "Items for Discussion at GAO Exit Conference."

Following is a point-by-point response to a March 14, 1978 critique (see attachment I) performed by Aerospace Corporation (Aerospace), of the Draft GAO Report Review-Launch Hazards Analysis.

(paragraph 2.a) GAO does not imply that approval of high inclination launches from KSC " * * * will more or less be automatic if VAFB is not available." GAO understands that there are many factors that have to be considered by range safety personnel when approving flight plans. One of these is the availability of "Any alternate flight plan which will accomplish the program objectives."

The widespread public opposition to the proposed overland flight of the Minuteman (a specific weapon system which is not man-rated and which uses an expendable launch vehicle) mentioned by Aerospace could possibly have been caused just by the fact of what it is, a weapon system. Any implication that the Shuttle will be denied high inclination launches from KSC because of Minuteman experiences is unfounded at this time.

(paragraph 2.b) Aerospace bases their response on a typographical error in the GAO draft report. In fact, the GAO used the reliability figure of 0.9999 which Aerospace admits was a baseline value used in several studies and " * * * resulted from a review of generic reliability characteristics for other systems * * * ." Using this reliability figure the resulting failure rates show that "safety reliability" of the Shuttle is better than that of either Saturn SIC or SII operation. Aerospace officials agreed to this in a meeting held in Los Angeles on March 30, 1978.

(paragraph 2.c) Aerospace continues their "critique" of a typographical error. The propellant dispersion system assumption mentioned by Aerospace had previously been discussed between SAMSO, Aerospace and GAO and it was mutually agreeable that this would be the best assumption for northerly KSC launches.

(paragraph 2.d) the Aerospace has pulled a number from one of their 1971 studies, in particular, a study of Los Angeles International Airport ground hazards. The figure (i.e., 1×10^{-6}) is not located in the study, but rather is a rounded approximation of several values appearing on one page of the study.

(paragraph 2.e) Aerospace says that other "conditional hazards" should be considered along with casualty expectations to provide a better insight into the difference between the Titan III C random reentry hazard and the Shuttle launch hazard. This type of data would probably be of value to range safety. However, the GAO report is not based on the assumption that a Shuttle catastrophe occurs as suggested by Aerospace but rather, based on the best available data, what is the reliability of the system and as a result of this reliability what magnitude of casualty expectation results can be calculated for nominal northerly KSC launches. In this light, the probability of a Titan impact is far greater than that for Shuttle resulting in a higher casualty expectation for Titan.

(paragraph 2.f) Aerospace suggests another hazard parameter to be considered; the individual risk. This parameter only considers a single person and the probability of harm to that individual rather than the total population. The only study of individual risk for shuttle was performed in 1969. In that study Aerospace concluded, following a specified set of assumptions, that the individual risk for shuttle was less than that for many daily activities the population was involved in. Other studies mentioned by Aerospace were not provided to GAO although all Shuttle related studies were requested from SAMSO and Aerospace.

(paragraph 2.g) Aerospace says that there is always the probability of some catastrophic failures and that these failures would likely preclude successful abort of the Shuttle. The GAO understands that NASA's Safety and Reliability procedures are intended to identify failure modes and "close out" the modes prior to vehicle certification. Any failure modes not identified would be reflected in the systems reliability and thereby be accounted for in risk assessments.

Based on these responses, the GAO is of the opinion that the Aerospace Corporation Conclusion is unfounded. The GAO report brought to light the best and perhaps only data available to date for Shuttle launch hazards to high inclination orbits.

Notwithstanding the length of the preceding chronology, much too much emphasis is being placed on these particular figures. We think the figures do provide at least *one* risk assessment perspective. However, the case for land overflight—that is, post-critical phase, very high altitudinal overflight—rests on many factors.

THE AEROSPACE CORPORATION



Post Office Box 92957, Los Angeles, California 90009, Telephone: (213) 648-5000
 78-2610.2-039
 14 March 1978

Subject: Draft GAO Report Review - Launch Hazards Analysis Portion

To: SAMSO (LVG/Col J. Herriott)
 P. O. Box 92960
 Worldway Postal Center
 Los Angeles, California 90009

1. In response to Maj J. Wormington's request, the results of the Aerospace Corporation review of the launch hazards analysis portion of the January 1978 draft GAO Report are formally transmitted. The GAO report was primarily based upon Aerospace Report A76-5434.4-15 dated 23 June 1976 and discussions with its author, Mr. O. A. Refling and myself.

2. The following critique of the GAO report was prepared by Mr. Refling and approved by me prior to your use of it.

a. The GAO report states on page iii that "Range Safety officials have acknowledged that approval of high inclination launches from KSC depends basically on whether or not STS facilities are built at VAFB". This implies that approval will more or less be automatic if VAFB is not available. In view of the widespread public opposition to the proposed over-land flights of vehicles such as Minuteman from operational sites, it cannot be assumed that over flight of major populated land masses in the U. S. will be routinely accepted. This is especially true for a continuing flight program such as that of the Shuttle. It should also be pointed out that range safety approval has always involved need vs risk considerations. If the need is high enough and if there are no alternative approaches, the chance of approval are obviously enhanced.

b. The reference to the fact that "contractor studies have continually cited a reliability factor of 0.999" implies a high level of confidence in this value and a more extensive examination of the reliability than actually was the case. The value of 0.999 quoted in the report was used in range safety analyses to show the increase in hazard for a lower reliability than the baseline value of 0.9999. The baseline value of 0.9999, which was considered only as a reliability goal, resulted from a review of generic reliability characteristics for other systems including aircraft and space vehicles and was not developed from a reliability study of the Shuttle itself. The necessary

reliability analyses had not been performed at that time and are still not available to our knowledge. A value of 0.999 yields a failure rate of 2.7×10^{-6} failures/second from SRB jettison to ET tank jettison; this compares to vehicle loss failure rates for the Saturn of 6.3×10^{-6} and 1.6×10^{-6} during SIC operation and S II operation respectively. Differences in vehicle external configuration, redundancy, and the reuse aspect of the Shuttle are the basis for concern that the safety reliability of the Shuttle may actually be lower rather than higher than that for the Saturn vehicle.

c. The "one in 166,667", value indicated as a predicted hazard level in contractor studies was probably based on a casualty expectation of 0.6×10^{-5} (1/166,667) from a study which was an extension of studies made for launch site evaluations some years ago. This particular value was based on a reliability goal of 0.9999 and assumes that a propellant dispersion system would be used. The GAO implies that the one in 166,667 value is based on a reliability of 0.999. The predicted casualty expectation for a 0.999 would be 0.6×10^{-4} (1/16,667).

d. The GAO statement that the Shuttle "would pose fewer problems than commercial airlines" is very misleading. The average probability of a takeoff or landing accident for commercial aircraft is approximately 1×10^{-6} which is certainly lower than predicted for the Shuttle. On the other hand, the comparison may be on a yearly basis, with the hazard based on the estimated number of Shuttle flights per year versus the several million commercial aircraft flights per year. However, it is our opinion that putting the Shuttle in the same safety category as commercial aircraft is completely unbased at this time point.

e. The treatment of the comparison between the Shuttle ascent hazards and the Titan IIIC orbital debris reentry hazards is equally misleading. The use of the casualty expectation as a hazard parameter should be supplemented with other hazard parameters to provide more of an insight into the differences in the two situations. Another hazard parameter of interest in ascent analyses is the "conditional hazards", that is, the casualty expectation if a catastrophic failure occurs during ascent flight. In the case of the Shuttle, the area on the surface of the earth that would be affected by impacting debris would be several orders of magnitude larger than for the Titan orbital debris. Thus the consequences of a catastrophic failure of the Shuttle during ascent could be many times more serious than for the impact of Titan space debris in an area of similar demography.

f. Another hazard parameter that should be considered is the individual risk (i. e., the probability that a specific person would be harmed). In the case of the Shuttle ascent hazards, the risk is to a relatively small number of people along the ground track compared to the billions of people that might be exposed to a risk from the reentry of Titan space debris.

Other studies have shown that the average individual risk associated with the proposed Shuttle ascent flight plan is at least several orders of magnitude higher than the average individual risk associated with the reentry of Titan debris. It is our opinion that all these factors should be considered in evaluating the real risk that is being imposed on people. This is especially true of the "conditional hazard" mentioned above since Shuttle safety reliability data, which is unavailable, is not considered in this hazard parameter. Based on these hazard parameters the risk for Shuttle flight is considerably higher than for reentry of Titan orbital debris.

g. The reference that the Shuttle system "could most likely ditch in the ocean or be blown up with pieces falling into the ocean" is an oversimplification of the problem in that it assumes that an RTLS abort or abort to orbit is possible in most cases. As with all types of complicated mechanisms involving large quantities of explosive materials and operating in adverse environments, there is always the probability that catastrophic failures such as explosions, tank ruptures, nozzle burn-thru, structural and control failures may occur. These failures would likely preclude successful abort of the Shuttle and impact of the ET on land would occur with a high risk of casualties occurring.

3. Based on these points, it is our opinion that safety considerations in the GAO report were handled in a superficial manner and that the report lacks an appreciation of the many technical and non-technical factors that are considered in the range safety decision making process relative to flight plan approval.



J. H. Ashmore, Director
Systems Engineering Analysis
Space Transportation Directorate
Vehicle Systems Division

JHA:la

cc: LTC C. Essmeier/LVRE
Maj J. Wormington/LVGR

VANDENBERG LAUNCH CRITERIA

Mr. SIKES. Do I take it that OSD feels that safety is the primary consideration for the use of the Vandenberg site?

Dr. PERRY. Mr. Sikes, I wouldn't put it that way. Let me answer the question, if I may. Our primary consideration is maintaining with a high confidence our ability to launch these vehicles to get our space programs into orbit.

Mr. SIKES. Can you do that equally well from either site?

Dr. PERRY. What we are describing to you is a belief that if we go ahead with the alternative plan and we are limited to Kennedy, that we will have low confidence in being able to get our space vehicles in orbit on the schedules predicted.

Mr. SIKES. Why is that?

Dr. PERRY. OSD's point of view is that if we do not have a Vandenberg facility, that we will then propose to maintain the expendable launch vehicles for high priority satellites from Vandenberg.

Mr. SIKES. What are the reasons that you do not feel that you can launch properly from Kennedy, other than safety?

Dr. PERRY. First of all, if the dog leg launch is taken into account, which we judge would be required, the drop in performance in the Shuttle is significant enough that it reduces the weight which the Shuttle can carry to a value which is sufficient for most of our payloads but not for our most critical ones, and we do not believe it makes sense to take actions to reduce the weight on those payloads.

Our alternative proposal, if we did not have a Vandenberg Shuttle facility, would be to put those payloads on expendable launch vehicles and continue to launch them that way.

That means then we would have two programs going on simultaneously, the Shuttle program and an expendable launch program.

Mr. SIKES. What would be the additional cost?

Dr. PERRY. We can supply that for the record. It depends on what set of assumptions you take into account, but we have gone through that computation in several different ways.

Mr. SIKES. Would it be less than the amount of the cost of the Vandenberg site?

Dr. PERRY. The net cost as we see it, the net difference, is no savings in doing that, but again it depends on the assumptions, and I would rather supply the detail on that for the record than make a casual answer to the question.

[DOD information follows:]

We have estimated the costs of this alternative using the following groundrules: Vandenberg AFB STS facilities are deleted.

All currently manifested Vandenberg STS flights are moved to Kennedy and flown as manifested except two DOD payloads per year which will be flown on upgraded Titans from Vandenberg.

Based on these assumptions, we estimate the cost of this alternative to be approximately \$100 million more than the two site baseline.

[GAO information follows:]

GAO's position is that maintaining expendables at Vandenberg is not required since the Shuttle capability from Kennedy appears adequate to accommodate DOD's heaviest payloads. However, our analysis of the cost of this alternative of not building and operating Vandenberg shuttle facilities, but launching heavy DOD payloads on expendables from Vandenberg is as follows.

COST ADVANTAGES OF NOT BUILDING AND OPERATING VANDENBERG, BUT LAUNCHING HEAVY DOD PAYLOADS
ON EXPENDABLES FROM VANDENBERG

[In billions of real year dollars]

Launch rate from KSC	Cost savings of not building and operating Vandenberg	Cost of 2 expend- able launches per year from Vandenberg for heavy DOD payloads	Net cost advan- tages of reduced Vandenberg Shuttle facilities
40	3.5	2.3	1.2
60	2.3	2.3

Details and sources for the \$2.3 billion cost figure launching the heavy DOD payloads on expendables from Vandenberg are given in the following table:

COST COMPUTATION OF LAUNCHING HEAVY
DOD - PAYLOADS ON EXPENDABLE LAUNCH VEHICLES
FROM VANDENBERG AFB
(MILLIONS)

Nature of Costs (in FY 1979 dollars) <u>Incurred</u>	<u>CY-1979</u>	<u>1980</u>	<u>1981</u>	<u>1982</u>	<u>1983</u>	<u>1984</u>	<u>1985</u>
Research and Development ^a Upgrade Titan Launch Vehicle (note a)	\$198.00						
Titan 34D Launch Vehicle (2 per year at \$58 million each) (note b)					\$116.00	\$116.00	\$116.00
Titan III 7 Launch Vehicle (2 per year at \$59 million each) (note c)							
Launch Operations Support (for 2 flights per year) (note d)					\$116.00	\$116.00	\$116.00
Totals (in FY 1979 Dollars)	<u>\$198.00</u>				<u>\$116.00</u>	<u>\$116.00</u>	<u>\$116.00</u>
Conversion Factors (at 7 percent)	1.0000	1.0700	1.1449	1.2250	1.3108	1.4026	1.5007
Totals (in Real Year Dollars)	<u>\$198.00</u>				<u>\$152.05</u>	<u>\$162.70</u>	<u>\$174.08</u>

<u>1986</u>	<u>1987</u>	<u>1988</u>	<u>1989</u>	<u>1990</u>	<u>1991</u>	<u>Totals</u>
						\$ 198.00
						348.00
\$118.00	\$118.00	\$118.00	\$118.00	\$118.00	\$118.00	708.00
<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>26.00</u>	<u>156.00</u>
<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$144.00</u>	<u>\$1,410.00</u>
1.6058	1.7182	1.8385	1.9672	2.1049	2.2522	
<u>\$231.24</u>	<u>247.42</u>	<u>\$264.74</u>	<u>\$283.28</u>	<u>\$303.11</u>	<u>\$324.32</u>	<u>\$2,340.94</u>
						or
						<u>\$2.3 billion</u>

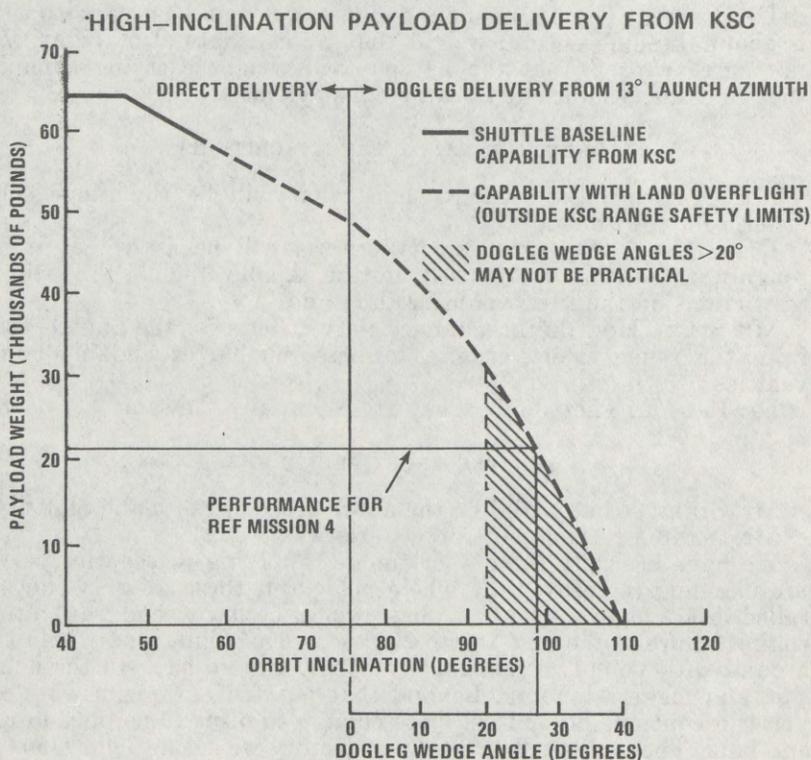
Notes:

- a/This cost, provided by Headquarters USAF/RDS, is the estimated cost required to upgrade the Titan launch vehicle from its present 5-1/2 segments to 7 segments. A 7-segment vehicle would be required if the payload weight growth projected after 1985 materializes.
- b/The unit cost of this 5-1/2 segment launch vehicle (\$58 million in FY 1979 dollars) was provided by Headquarters USAF/RDS and is based on a production rate of two per year. The Titan 34D costs shown here may be somewhat overstated in terms of the option under study. For example, even under current planning DOD will procure several of these vehicles, in varying stages of completion, to provide a Shuttle backup posture for defense payloads at Vandenberg through 1985. Thus, part of these costs will be incurred in either alternative-- Shuttle at Vandenberg or expendables at Vandenberg; the option under study should exclude common costs and analyze only additional costs.
- c/The unit cost of the Titan III (\$59 million in FY 1979 dollars) was provided by Headquarters USAF/RDS and is based on a production rate of two per year. If DOD's payloads do not experience the projected weight growth, this 7-segment launch vehicle would not be required.
- d/The \$26 million (FY 1979 dollars) cost for launching 2 expendable vehicles per year from Vandenberg was provided by Headquarters USAF/RDS. Under the proposed 2 Shuttle sites/5 orbiter fleet scenario, expendable launch vehicle support costs will be incurred at Vandenberg through 1985. Our analysis here included only those additional costs which would be incurred to fly the heavy DOD payloads on expendables from Vandenberg if Shuttle facilities were not built; thus, the additional launch support costs begin in 1986.

PAYLOAD LOSS CAPABILITY FOR KSC POLAR LAUNCHES

Mr. SIKES. What percentage of effectiveness do you lose on a dog leg flight?

Dr. PERRY. That can be probably best described in terms of the loss in payload capability as a function of how many degrees of dog leg you have to take. We have a graph which gives that complete set of data, and we will put that in the record. It is very significant. [DOD information follows:]



Mr. SIKES. You are not in a position to give a rough estimate?

Dr. PERRY. Yes, sir, about one-third.

Mr. SIKES. That much.

Do all of you agree with that?

Mr. TOLER. We can give an estimate. Our calculations show, of course it depends upon what your destination is, but for a 98-degree inclination orbit, there would be an approximate 10,000-pound payload loss between Vandenberg and KSC. The key though is not how much loss you have but will the remaining capability be sufficient to handle the DOD heavy payloads, and, of course, we have concluded that it is.

Mr. SIKES. You think that it would be sufficient from the Kennedy launch site?

Mr. TOLER. Yes, sir.

Mr. SIKES. Using the dog leg launch?

Mr. TOLER. Yes, sir, sufficient to handle DOD heavy payloads. All of the DOD and civil payloads can be handled out of the Kennedy Space Center if you accept the risks involved in land overflight.

Mr. SIKES. Something prompts me to want to accept your testimony.

Dr. PERRY. Mr. Sikes, may I comment on that?

Mr. SIKES. Of course.

Dr. PERRY. The 10,000-pound figure we would agree with. That is about the difference in weight that we calculate also. What we do not agree with is that the net payload weight carrying capability that remains is sufficient to carry our payloads.

SHUTTLE RANGE SAFETY CRITERIA

Mr. SIKES. Under current plans what will be the range safety criteria for the Shuttle?

Dr. FROSCH. The range safety criteria will be as we see it now roughly those that were used in the Apollo flight, the azimuth restrictions on the sites would be the same.

Mr. SIKES. How do these range safety criteria for the Shuttle differ from the range safety criteria for less reliable expendable launch vehicles?

Dr. FROSCH. They don't. They are essentially the same.

SHUTTLE ABORT PROCEDURES

Mr. SIKES. What would be the abort procedures for the Shuttle?

Mr. YARDLEY. The abort procedures?

We have basically three abort modes applying to the Shuttle. We are planning to recover the whole vehicle in these aborts. They are called intact aborts. The first phase would be if you had, say, a main engine failure in the first 180 to 200 seconds of flight, you would turn around with your two remaining engines, and go back to the launch site, and make a landing. Beyond that point, if an engine goes out, you can continue on and get close enough to orbit to go once around and land. Then a little later in the trajectory we get into our abort-to-orbit mode, where if an engine goes out, you can continue on into orbit, and then select your time for landing.

Mr. SIKES. What changes in abort procedure would be required to accommodate northerly launches over land from Kennedy?

Mr. YARDLEY. As stated in the Aerospace Report, the return to launch site abort, if you did it just exactly the same as we are doing it on easterly launches, would drop the external tank on land masses. so we would have to adjust that to swing out over the ocean to drop that tank at some probable loss in abort capability, which would mean perhaps some performance loss. We are reevaluating this area.

Mr. TOLER. May I make a comment on that?

Mr. SIKES. Yes, of course.

Mr. TOLER. Again we have a difference here in terms of interpreting the data or what data is available. The data that we have shows that a

return-to-launch-site abort could be safely executed, that the external tank would be dropped in water approximately 100 miles from the launch site, and that there would be no abort changes required, or if, any, very minimal.

Mr. YARDLEY. You have completely run all of those return to launch site trajectories I assume, for those curved launches, because we haven't.

Mr. TOLER. We simply took your RTLS data, and took the maximum cutoff point for initiating RTLS, that is I think 170 seconds, I forget the exact figure, and then looked at your profiles to see where that external tank would be. The closest it would get to land, would be somewhere around 320 or 330 miles down range, and it is 345 miles before you get to the coast, of course. Then in your return phase you would drop the external tank approximately 100 miles from the launch site over water.

The two other abort modes that NASA is planning for, that is abort to orbit and abort once around, the splashdown point of the external tank would be in approximately the same area that it would be for a normal mission. So there would be no danger to land masses.

Mr. SIKES. Mr. Chairman, I have some additional questions I would like to have answered for the record.

[CLERK'S NOTE: The questions submitted by Mr. Sikes and the answers thereto follow:]

RANGE SAFETY CRITERIA

QUESTION. Range safety criteria are another important variable in considering various Shuttle options. This is particularly true in regard to the question as to whether or not flight over inhabited areas should be permitted, as would be required under the GAO proposal to conduct polar launching from Kennedy in lieu of building Vandenberg. Under current plans, what will be the range safety criteria for the Shuttle?

DOD ANSWER: Current plans call for Shuttle launch from KSC between launch azimuths of 35 and 120 degrees. Launch at these azimuths, when complemented by VAFB launch between azimuths of 158 and 201, will satisfy the mission model requirements without posing problems of range safety or foreign overflight. Additionally, launch at these azimuths is conducive to Shuttle ascent sonic boom alleviation and solid rocket booster recovery. Comprehensive range safety analyses have not yet been performed and some variation in the above launch azimuths may prove advisable.

QUESTION. How do these safety range criteria for the Shuttle differ from the range safety criteria for the less reliable expendable launch vehicles?

DOD ANSWER: Range safety criteria for the initial Shuttle launches vary little from current ELV criteria. A destruct package will be carried on both the solid rocket boosters and the external tank thus providing protection to populated land masses similar to current ELV practice if the vehicle malfunctions and exceeds range safety limits.

Range safety criteria for the Shuttle operational phase have not yet been determined. The necessity of retaining the destruct packages

has yet to be determined as does the selection of specific launch azimuth constraints for the two launch sites.

CASUALTY EXPECTATIONS

QUESTION: The GAO testimony cites a study by a DOD contractor that states there is a 1 in 166,667 chance of an individual on the ground being harmed during a northerly Shuttle launch from KSC. This is much less than the 1 in 6,250 chance of harm from a Titan launch using current expendable launch vehicles. If these estimates are true, why isn't a northerly Shuttle launch an acceptable risk?

DOD ANSWER: The GAO treatment of the comparison between the Shuttle ascent hazards and the Titan IIIC orbital debris reentry hazards is misleading. The use of the casualty expectation as a hazard parameter should be supplemented with other hazard parameters to provide more of an insight into the differences in the two situations. Another hazard parameter of interest in ascent analyses is the "conditional hazards", that is, the casualty expectation if a catastrophic failure occurs during ascent flight. In the case of the Shuttle, the area on the surface of the earth that would be affected by impacting debris would be several orders of magnitude larger than for the Titan orbital debris. Thus the consequences of a catastrophic failure of the Shuttle during ascent could be many times more serious than the impact of Titan space debris in an area of similar demography.

It is significant that the reliability factor of .9999 which was considered only as a reliability goal, resulted from a review of generic reliability characteristics for other systems including aircraft and space vehicles and was not developed from a reliability study of the Shuttle itself. A value of .9999 yields a failure rate of 0.27×10^{-6} failures/second from SRB jettison to ET tank jettison; this compares to vehicle loss failure rates for the Saturn of 6.3×10^{-6} and 1.6×10^{-6} during SIC and SII operation respectively. Differences in vehicle external configuration, redundancy, and the reuse aspect of the Shuttle are a basis for concern that the safety reliability of the Shuttle may not offer such an improvement over that of the Saturn.

In summary, the data contained in the Aerospace report does not provide the comprehensive treatment of the technical and non-technical factors that are fundamental to a range safety decision for northerly launch from KSC. Data which must be available prior to performance of such an analysis are: (1) The Shuttle's malfunction characteristics and probability of occurrence and (2) debris characteristics and probability of occurrence and (2) debris characteristics of the Shuttle if a malfunction occurs.

[GAO Information follows:]

Aerospace, the Contractor that did the DOD study, says that other "conditional hazards" should be considered along with casualty expectations to provide a better insight into the difference between the Titan III C random reentry hazard and the Shuttle launch hazard. This type of data would probably be of value to range safety. However, the GAO report is not based on the assumption that a Shuttle catastrophe occurs as suggested by Aerospace but rather, based on the best available data, what is the reliability of the system and as a result of this reliability what magnitude of casualty expectation results can be calculated for nominal northerly KSC launches. In this light, the probability of a Titan impact is far greater than that for Shuttle resulting in a higher casualty expectation for Titan.

The GAO used the reliability figure of 0.9999 which Aerospace used as a baseline value in several studies and " * * * resulted from a review of generic reliability characteristics for other systems * * * " Using this reliability figure the resulting failure rates show that "safety reliability" of the Shuttle is better than that of either Saturn SIC or SII operation. Aerospace officials agreed to this in a meeting held in Los Angeles on March 30, 1978.

QUESTION. What will be the abort procedures for the Shuttle?

NASA ANSWER. There are two categories of aborts for the Space Shuttle:

1. Intact aborts. Intact aborts result in the safe return of the Orbiter to a runway. There are three intact abort modes: Return to Launch Site (RTL), Abort Once Around (AOA), and Abort to Orbit (ATO). At least one of these three abort modes is available throughout the ascent profile and are designed to recover from selected propulsion system failures.

2. Contingency aborts. Contingency aborts may result in either safe return of the Orbiter or downrange ditching in the ocean. Contingency aborts provide some protection against multiple failures.

QUESTION. What changes in abort procedures would be required to accommodate northerly launches over land from Kennedy?

NASA ANSWER. Intact abort procedures would not change, provided that the launch azimuth would be initially constrained to avoid dropping the Solid Rocket Boosters on land and oil/gas offshore drilling equipment. Some contingency aborts would be a problem. If multiple failures should occur under a set of conditions which would have resulted in a downrange ditching in the ocean on a normal launch azimuth, both the External Tank and the Orbiter would impact on land. The probability of a safe landing of the Orbiter would be remote. We know of no way to avoid the increased risk to the crew and the risk to the population on the ground track of the ascent profile. The added risk cannot be quantified. We consider it to be very small, but obviously finite.

TRACKING AND DATA RELAY SATELLITE SYSTEM

QUESTION. Explain briefly the purposes of the Tracking and Data Relay Satellite System, and when it will become operational.

NASA ANSWER. The Tracking and Data Relay Satellite System is planned as a system consisting of a ground terminal in New Mexico and two operational telecommunications relay satellites in earth synchronous orbits. The satellites will be used to track space vehicles in trajectories below 12,000 Km altitude and to relay data, commands, and voice and television communications between these space vehicles and the ground terminal for distribution to and from various flight control facilities. These TDRSS capabilities are being obtained by NASA on a long-term leased-service contract, under which the contractor is designing and building the system and will operate it to provide the service to NASA over a 10-year period. The system is planned to be operational in the 4th quarter, CY 1980 and will then be used to provide the majority of tracking and data acquisition support for NASA's automated and manned space vehicles.

QUESTION. Will the Tracking and Data Relay Satellite System be capable of tracking northerly launches from Kennedy and determining an abort on the first orbit?

NASA ANSWER. The Tracking and Data Relay Satellite System will be capable of tracking and providing required communications to and from the Space Shuttle during and following launches from Cape Canaveral at all feasible launch azimuths. System coverage is such that virtually continuous contact can be maintained throughout the flight (including almost any abort event) except over a small area centered along 74°E longitude.

NORTHERLY LAUNCHES FROM KSC

QUESTION. Northerly launches from Kennedy would require sub-orbital flight over Russia on the initial orbit. Describe in more detail how the Shuttle would overfly Russia and why this is potentially troubling.

DOD ANSWER. Northerly launches from Kennedy Space Center would require overflight of the USSR during the initial orbit of the Shuttle. To enable disposal of the solid rocket boosters (SRBs) in the Atlantic Ocean and restrict sonic boom(s) to areas outside Florida, the vehicle starts its mission with an initial 19° azimuth heading. After SRB safe impact is assured, the vehicle performs a "dog-leg" flight maneuver into the planned mission trajectory/mission inclination. If launched northward from KSC, the present defined missions would follow the trajectories illustrated on Figure 1. These flight paths cover a major portion of the USSR during suborbital flight, as shown on the figure. Although the flight mechanics of these mission trajectories are physically feasible, they have been declared unacceptable by NASA, DOD, and the State Department. The State Department letter dated November 11, 1977, to Mr. Conahan of GAO summarized the basic concerns as follows: (a) The ascent maneuvers would reduce payload capability and undercut the STS potential to support systems essential to national security, (b) polar launches from KSC will require notification to USSR of the impending event. However, there isn't any assurance that, even with notification being sent early enough, Soviet reaction to the sudden appearance of the STS, including the external tank, could be averted, and (c) unsuccessful orbital insertions could necessitate mission aborts into Canada and the USSR. (deleted.)

NASA ANSWER. Northerly launches from Kennedy Space Center would require overflight of the USSR during the initial orbit of the Shuttle. To enable disposal of the solid rocket boosters (SRBs) in the Atlantic Ocean and restrict sonic boom(s) to areas outside Florida, the vehicle starts its mission with an initial 19° azimuth heading. After SRB safe impact is assured, the vehicle performs a "dog-leg" flight maneuver into the planned mission trajectory/mission inclination. If launched northward from KSC, the present defined missions would follow the trajectories illustrated on Figure 1. These flight paths cover a major portion of the USSR during flight, as shown on the figure. Although the flight mechanics of these mission trajectories are physically feasible, they have been declared unacceptable by NASA, DOD and the State Department. The State Department letter dated November 11, 1977, to Mr. Conahan of GAO summarized the basic concerns as follows: (a) the ascent maneuvers would reduce payload capability and undercut the STS potential to support systems essential

ENVELOPE OF TRAJECTORIES FOR NORTHERLY LAUNCHES FROM KSC



to national security, (b) polar launches from KSC will require notification to USSR of the impending event. However, there isn't any assurance, that even with notification being sent early enough, Soviet reaction to the sudden appearance of the STS, including the external tank, could be averted, and (c) unsuccessful orbital insertion could necessitate mission aborts into Canada and the USSR. These concerns were reiterated in a second letter from the State Department to the GAO on February 28, 1978.

GAO answer. According to NASA, during a normal high inclination KSC flight the external tank, after separating from the orbiter/over the Great Lakes region at an altitude of about 70 miles, would continue halfway around the world and splashdown in the Indian Ocean. Before splashdown occurred, the tank would have passed over part of Russia, but at an altitude of from 80 to 100 miles. The orbiter, after separating from the external tank, would be injected into a low earth orbit by its orbital maneuvering system engines before reaching the Soviet Union.

At our request, the Department of State officially reviewed the subject of polar launches from KSC. The agency formally responded in November 1977 with a position paper, listing seven reasons why such launches would be unacceptable. The first and second reasons given by the State Department for its position were:

"The ascent maneuvers required at KSC would result in substantial loss of payload capability. This would undercut the capability of STS to provide launch support for systems essential to national security * * *"

"The loss of payload capability would hamper our important programs of international cooperation in space activities."

As we have previously noted, the payload delivery capability from KSC would be substantial; it would allow performance of all the Space-lab or international cooperation missions and all of the defense related missions projected for the Space Shuttle.

The third reason given was:

"Polar launches from KSC would require passage over the USSR on the initial portion of the first orbit. The 1971 Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics anticipates the need for notification in situations where unidentified objects on early warning systems raise the risk of nuclear war; but we have no knowledge of whether such notification, even if given in timely fashion, would avert Soviet reaction to the sudden appearance of the STS, including its separated external tank."

The Department's concern is how the Russians will react to the orbiter and external tank coming over the North Pole's horizon, a region which is strategically important. Strategic importance derives from the fact that the Arctic offers the shortest air route between the United States and the Soviet Union. With the development of long-range weaponry, such as intercontinental ballistic missiles (ICBMs) and strategic bombers, the Arctic became a prime area for detecting the approach of hostile elements. During the 1950s, both the United States and the Soviet Union built radar detection systems facing northwards to give an early warning system.

Aside from performance or weight-carrying capability, the possibility of adverse Soviet reaction to northerly Shuttle launches from

KSC is the international aspect of most concern to the Department of State. Basically, this seems to be a question of radar misinterpretation. There are several factors which should help to mitigate concern on this issue. For example, all Shuttle launches will be announced beforehand, a step necessary to clear ships from ocean areas where solid rocket boosters will splash down. For northerly civil and defense launches from KSC, special prior notification could be given to the Soviet Union; the 1971 U.S.-Soviet agreement, mentioned above, provides a mechanism for such notification.

The 1971 agreement contains the following provisions:

"Article 4: Each Party undertakes to notify the other Party in advance of any planned missile launches if such launches will extend beyond its national territory in the direction of the other Party."

"Article 6: For transmission of urgent information, notifications and requests for information in situations requiring prompt clarification, the Parties shall make primary use of the Direct Communication Link between the Governments of the United States of America and the Union of Soviet Socialist Republics.

For transmission of other information, notifications and requests for information, the Parties, at their own discretion, may use any communications facilities, including diplomatic channels, depending on the degree of urgency."

Article 7: The Parties undertake to hold consultations, as mutually agreed, to consider questions relating to implementation of the provisions of this Agreement, as well as to discuss possible amendments thereto aimed at further implementation of the purposes of this Agreement."

We have asked the State Department for a history of the 1971 U.S.-Soviet Agreement, i.e., whether the notification procedures have ever been used in regard to aircraft, missile, or spacecraft activity. A response has not been received, however, State officials have acknowledged that their November 1977 letter was drafted without inquiring into post-agreement experience. While the Arctic area is undoubtedly of strategic importance and sensitivity, "interference" with early-warning systems may be somewhat of an ambiguous concern. The orbiter and external tank will obviously be picked up on Soviet radar, especially if prior launch notification is given, Soviet radar systems should be sophisticated enough to distinguish the Shuttle elements from ICBMs. U.S. radar is quite sophisticated. For example, the U.S. Air Force's Cobra Dane radar can detect a basketball-sized object at a range of 2,000 miles and track simultaneously more than 100 objects.

Also, the external tank is much larger than a missile. The dimensions of the Shuttle's external tank in comparison to silo-based missiles are as follows:

	Length (feet)	Diameter (feet)
External tank.....	154.0	28.6
Titan II.....	103.0	10.0
Minuteman III.....	59.8	6.0
Minuteman II.....	57.6	6.0

Moreover, since only a few polar Shuttle launches a year are planned (14 or less), it is difficult to see how these could be of significantly more concern than polar crossings by aircraft, which may resemble strategic bombers. During 1977, Trans World Airlines alone flew more than 1,000 polar crossings.

The Department of State has not voiced a "hostile missile" concern about other Shuttle launches from Kennedy and Vandenberg which could similarly raise radar misinterpretation issues. For example, KSC launches presently planned to 57 degrees inclination orbits, the separated external tank will pass over the Black Sea, several Soviet Block countries, and the edge of Russia. One has to assume that this trajectory is detectable by Soviet radar. Whether this flightpath is as sensitive as polar launches from KSC is another question—perhaps best addressed by DOD. State Department officials have commented informally that concern over 57 degree launches is minimal compared with the sensitivity of launching over the North Pole. In addition, the Soviets have experimented with Fractional Orbit Bombardment Systems (FOBS) which is fired on a southerly hemispheric trajectory, thus avoiding detection by major U.S. radar installations. Similarly, who is to say that Shuttle launches south from Vandenberg could not be interpreted as a FOB-type firing. A FOBS-type attack may be difficult to detect, even with sufficient radar coverage, because the deorbiting maneuver which would distinguish a missile from a satellite occurs only a few minutes before arrival at the target.

It may also be that space programs and other technological developments since the 1950s have lessened the sensitivity of the Arctic area. Now, submarine-launched ballistic missiles can be fired by either the U.S. or the U.S.S.R. from near the other's coasts or from unknown spots in distant oceans. In his testimony, Dr. Perry said:

"A fundamental point from the Defense Department's point of view is that during the last decade we have made a very significant commitment to space; we have been gradually transferring important missions in defense to space systems, and during the next decade we plan to continue that.

"As a consequence, we have a major dependence today in the fields of * * * ballistic missile warning systems. More and more the capability in Defense to perform those functions is dependent on space."

Given space technology, or over-the-horizon radar, we question whether northerly Shuttle launches from KSC will present "sudden appearance problems."

The State Department's fourth reason against northerly launches from KSC was:

"Launching of STS in the direction of populated areas could be expected to bring shuttle more centrally into international debate, especially in the UN Outer Space Committee. This would abet arguments raised by countries opposed to our position on such issues as the delimitation or boundary of outer space."

Regarding this concern over international debate, it is probably inevitable that the Shuttle will eventually be the focus of discussions on the extent of sovereign air space. This is because such issues are not associated simply with northerly launches from KSC. The pres-

ently planned easterly launches from KSC post similar questions—for land areas such as Africa, Europe, Middle East, a portion of Russia, and Soviet Block Countries—as the external tank completes its trajectory and comes down in the Indian Ocean. Additionally, the orbiter's atmospheric reentry and landing approach after each mission may focus the issue.

However, State Department officials have commented that the air space/outer space boundary issue is a very low priority item on the agenda of the United Nation's Outer Space Committee, and U.S. policy is to keep it that way. They explained that the U.S. really does not fully understand its interests yet and thus does not want to focus on this issue in the United Nations. Nevertheless, we think the concern about possible international debate over delimiting outer space may not be a substantive reason for precluding northerly launches from KSC. Generally, about 60 to 65 miles has been the upper limit in most discussions on the extent of sovereign air space. The separated external tank's passage over Russia would be higher than 65 miles; at no time would it be less than 80 miles high. The external tank's overflight at this altitude may not provoke the Russians, into pushing for extending air space and delimiting outer space. After all, their space programs would be reciprocally hindered by too-stringent delimitations.

The fifth and sixth reasons given by the State Department for its position were:

"The Department is informed that while range safety calculations have not yet been made in detail for such launches, the likelihood of an accident leading to injuries is greater for the polar launch from KSC than was deemed acceptable for such launches from VAFB. If this is confirmed by detailed range safety calculations it would, of course, be unacceptable to the Department of State."

"Many factors can make launch or insertion into orbit unsuccessful. A number of these would require bringing portions of the system to earth nearly underneath the planned flight trajectory. Both Canada and the Soviet Union could be thus affected by a mission abort."

Basically, these reasons may be categorized as land overflight or range safety considerations.

Finally, the seventh reason presented was:

"The United States, Canada, and the USSR are signatories to the Convention on International Liability for Damage Caused by Space Objectives. This Convention provides for "absolute liability" for damages on the earth's surface. The Department of State believes that all reasonable measures should be taken to avoid situations putting the U.S. in such a position of liability, especially those involving populated areas under the ascent phase of a launch."

Here, the Department's specific import seems to be that the United States, as a signatory to the Convention, will be absolutely liable (i.e., liable despite the absence of any negligence) for any damages caused by Shuttle operations. This consideration applies, of course, to Shuttle launches in any direction; thus, we feel it is not a point upon which the Vandenberg question will be decided.

Essentially, of the seven subject areas presented by the State Department, we think only one may be substantively sufficient to

warrant further congressional inquiry—the possibility of adverse Soviet reaction. On February 28, 1978, the Department provided official comments on the GAO draft report on “Space Transportation System: An Analysis of Launch Site and Fleet Size Requirements.” Some of their comments were:

“* * * your report greatly understates the importance of the 1971 ‘Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics’ and the spirit in which that agreement was negotiated and concluded.”

“Your readers should be cautioned that your interpretation (of the 1971 Measures Agreement) is not authoritative and should not be construed as the U.S. position on the matter.”

“The Department of State does not discount, summarily or otherwise, the 1971 Measures Agreement. This Agreement is one of the few milestones we have been able to erect along the path toward reducing the risk of nuclear war. It would be impossible to put a price tag on efforts such as these.”

“The mission agencies should be consulted on the question of notification. It may be improvident to assume that notification is possible or practicable.”

“The capability of Soviet detection and discrimination systems should be explored further.”

“* * * we do assume that the Soviet Union would take all reasonable steps to implement the Agreement.”

Noticeably, this issue relates to foreign policy and/or national security considerations, areas traditionally felt to be within the nearly-exclusive purview of the executive branch. However, the Congress obviously has a role to play in these areas. Its function as a critic serves to promote serious discussion of national issues, thus providing multiple perspectives and a testing of policy options. There are few formal legislative enactments for guidance where foreign policy is concerned; therefore, congressional oversight is especially important. Similarly, concerning national security, President Carter has said: “If national security is involved on some special issue and it is therefore inadvisable to publicize details, at least congress must be kept informed.” In this spirit, we think the Congress should have complete information regarding the need for a second launch site. To ensure that presidential and congressional perspectives on the need for Vandenberg interact, we think the Congress should take the initiative in obtaining all pertinent information from the executive branch, particularly the National Security Council.

RUSSIAN FLIGHTS OVERLAND

Mr. SIKES. Let me ask this question.

The Russian launch sites require flight over land. Tell us how the Russians handle these problems which accompany flights over land.

Why is the Shuttle situation different than the current Russian situation?

Dr. FROSCH. I am not sure exactly how they handle them or whether they simply don't worry about them, but if I recall where their launch sites are, they have the option of launching over an area of the Soviet

Union which has almost no population in it. Launching north out of Kennedy we don't have that option. That is where most of the U.S. population is concentrated.

Mr. SIKES. What about northern Canada?

Dr. FROSCHE. In the figures we have looked at we have included the population that would be under the footprint of Quebec, Ontario, and part of Manitoba. That is a significant population. North of there, there is a very, very sparse population, of course, and then you are out over the Arctic Ocean.

Mr. SIKES. I think we will have to suspend again, gentlemen. I am very sorry. We will be back as soon as we can.

(Recess.)

Mr. SIKES. Please provide for the record the answers to the following questions.

(Clerk's note: The questions submitted by Mr. Sikes and the answers thereto follow.)

NORTHERLY LAUNCHES FROM KSC

QUESTION. How many shuttle flights per year would be required over Russia if northerly launches were made from Kennedy?

DOD ANSWER. Assuming some single-launch scheme to launch heavy DOD payloads from KSC, a total of 138 launches would be required over Russia in the FY 83 to first quarter FY 92 time period. Alternatively, if dual shuttle launches were required for heavy lift northerly launches from KSC, 155 Russia overflights would occur. If the heavy payload launches were retained at VAFB, the flights over Russia would be reduced to 121.

GAO ANSWER. We believe fewer than 14 Shuttle flights per year would be launched north from KSC. The national mission model, revised in October 1977, projects 487 Shuttle flights during 1980-92. This total includes an average of 14 high inclination launches per year from Vandenberg; all of these missions would not necessarily require launching toward Russia if accommodated from KSC. For example, NASA has indicated that some Spacelab missions, now planned for polar or near-polar orbits, could be accommodated at lower inclinations. Also, some of the 14 missions per year involve free-flying satellites which are small enough to permit on-orbit launches using upper propulsion stages for inclination changes.

GIANT PATRIOT

QUESTION. In 1974 the Air Force requested funds for the "Giant Patriot" Minuteman II Operational Base Launch program. This program provided for eight Minuteman II missiles to be launched from their operational silos in Montana and South Dakota, across the northwestern United States, to target areas in the Pacific. Dr. Perry, your statement explains that polar launches from Kennedy are unacceptable because the shuttle would overfly populated areas. This appears inconsistent with the past justification of the Giant Patriot program. Would you comment?

Dr. PERRY. The Giant Patriot program was designed to operationally test the Minuteman II system. Certain restrictions were however placed upon the operational realism of the proposed tests.

The operational reentry vehicles were to be replaced with inert, test reentry vehicles. A destruct system was to be added to the missile so that inflight destruct could be ordered. The missile trajectory was planned to cross the lowest population density path in an already sparsely populated region. Finally the population living in the areas where debris from an aborted, destructed missile might impact were to be evacuated. The program estimated the probability of casualties at 3 chances in 100,000,000. These considerations differ vastly from those associated with shuttle launch over the heavily populated eastern United States. Finally, the Giant Patriot (now called operation base launch) program has never been approved due to Congressional opposition for environmental reasons.

QUESTION. Are any joint U.S./Soviet launches using the Shuttle being planned? If yes, why would the Soviets oppose overflights of the Soviet Union?

NASA ANSWER. There are no joint U.S./Soviet launches using the Shuttle currently being planned. There have, however, been preliminary exploratory discussions under the cooperation treaty to assess the potential and value of possible cooperative operations with Shuttle and SALYUT.

There is no basis for expecting Soviet acceptance of overflight of many flights with unknown missions because of an isolated joint space activity flight of which they would have full knowledge.

GAO ANSWER: NASA and the U.S.S.R. Academy of Sciences have held several meetings. One meeting, held in Moscow, November 14-17, 1977, concerned possible cooperative scientific experiments using the U.S. Shuttle and the Soviet Salyut spacecraft. At other meetings, held at Wallops Island, Virginia, November 19-25 and in Bethesda, Maryland, November 16-18, experiments flown on a recent Soviet biosatellite as well as proposals for future biosatellite missions and medical results of manned space flight were discussed.

In Moscow the two agencies discussed preliminary scientific proposals and scientific experimental areas that might benefit from a long duration station of the Salyut type and a reusable Shuttle spacecraft. The joint working groups agreed to meet in the United States in late March or early April, in Moscow in July and again in the U.S. in October 1978.

The Bethesda and Wallops Island meetings discussed information on experience gained in manned space flight programs, in particular, the Salyut 5/Soyuz 21 and 24 missions. Also discussed were preliminary results from U.S. and Soviet experiments flown on Cosmos 936 in August 1977. The U.S.S.R. also invited the U.S. to participate in Soviet biosatellite flights in 1980 and 1981.

A ninth meeting of the space biology and medicine working group will be held in the U.S.S.R. in the second half of 1978.

The talks are being held as part of ongoing activities under the U.S.-Soviet Space Cooperation Agreement.

NORTHERLY LAUNCHES FROM KSC

QUESTION: If northerly launches from Kennedy were not feasible, how many expendable launch vehicles would be required until all payloads could be redesigned to fly within the constraints of the Kennedy launch site?

DOD ANSWER: It is not feasible to redesign the DOD heavy lift payloads in such a manner to achieve a KSC launch capability without overflight and still satisfy the mission requirements.

GAO ANSWER: The question anticipates that payloads destined for polar (90°) or near polar (98°) orbits would be launched to a 57° inclination (achievable by a KSC shuttle without land overflight) and an upper propulsion stage would be used to transfer the payload to its final destination. According to NASA Headquarters' and DOD officials, the IUS is the only upper stage now envisioned that could feasibly accommodate this transfer—but only to the extent that roughly 4,000 pounds of payload could be sent to a 98° inclination. This Shuttle/IUS capability may be insufficient to accommodate certain civil and defense payloads:

CIVIL-AUTOMATED PAYLOADS

The October 1977 STS Mission Model shows 42 automated payloads (civil) whose weights exceed the IUS' transfer capability to polar or near-polar inclinations:

1983	3
1984	2
1985	6
1986	6
1987	4
1988	7
1989	4
1990	7
1991	3
Total	42

Because the first of these payloads is not projected for Shuttle launch until 1983, it is possible that some could be changed to meet the KSC-only Shuttle/IUS capability; if this were the case, no expendable launch vehicles would be required. However, given that these projected payloads range in weight from 6,300 to 9,700 pounds, redesigns reducing the weights to 4,000 pounds may be technologically infeasible; we have insufficient data to determine this.

CIVIL-SPACELAB PAYLOADS

The October 1977 mission model also projects 57 Spacelab payloads from Vandenberg to high inclinations:

1984	7
1985	11
1986	7
1987	8
1988	7
1989	5
1990	5
1991	7
Total	57

The IUS, of course, is not applicable to these payloads; the Spacelab remains attached to the orbiter throughout the mission. Some of these missions probably could be flown at lower inclinations (i.e., within the KSC constraints posed in the question) without significant

degradation of the experiments; how many Spacelab flights fall into this category is an open question. One factor to note is that Spacelab flights are the least firm in the mission model and are often referred to as "fillers". In any reduced mission model study, Spacelab flights are always the first category adjusted. Also, the Spacelab payloads can be thought of as relatively "Shuttle-unique". That is, the Spacelab obviously cannot be launched by an ELV. Moreover, it is unlikely that many of the payloads on dedicated Spacelab flights would be reinstrumented for accomplishment by automated satellites because several ELVs could be required to duplicate the capability of one dedicated Spacelab mission.

DEFENSE PAYLOADS

The DOD has at least two payloads a year (a total of 18) which could not be accommodated under the KSC-only Shuttle/IUS scenario.

SUMMARY

We cannot say with certainty how many ELVs would be required under the scenario posed in the basic question. Many factors should be considered. For example, the frequent use of IUSs to perform on-orbit inclination changes would directly impact both the cost and scheduling of Shuttle operations from KSC. Cargo integration, the method by which a single Shuttle flight carries several payloads and thus reduces individual user's transportation costs, would certainly be minimized. The IUS is so large that a dedicated Shuttle flight would probably be required for each payload destined for a polar or near-polar orbit. In addition, NASA has said that benefits derived from retrieving these payloads would be lost if the orbiter itself could not rendezvous with the payloads. On the other hand, any computation of payload benefits lost is, at best, a rough estimate. There has as yet been no demonstration of benefits associated with retrieval and reuse, and the payloads involved are only projections, not firm mission requirements. Also, it is well to emphasize that payloads are designed in reference to available capacity.

We asked NASA and DOD in September 1977 questions similar to the one posed here. Our inquiries and their responses are provided below for the record.



UNITED STATES GENERAL ACCOUNTING OFFICE
 WASHINGTON, D.C. 20548

260a-4

PROCUREMENT AND SYSTEMS
 ACQUISITION DIVISION

SEP 19 1977

The Honorable Robert A. Frosch
 Administrator, National Aeronautics
 and Space Administration

Dear Dr. Frosch:

As you know, the General Accounting Office has been tasked with providing the Congress timely information for their consideration in evaluating the Space Transportation System (STS). Present concerns center on the number of orbiters and launch/landing sites needed to support a balanced space program in the 1980-1991 timeframe. Accordingly, there is much interest in the planned utilization of the STS, particularly the launches proposed for the Vandenberg Air Force Base launch/landing site which is yet to be developed.

According to the 1976 National Payload Model, NASA plans to launch Spacelab and automated payloads from Vandenberg. To fully evaluate the need for this planned launch site, we believe that NASA and other civil Federal agencies' payloads planned for Vandenberg launch should be analyzed in relation to two separate assumptions regarding orbiter capability from the Kennedy Space Center (KSC). These assumptions are: (1) the orbiter would be limited to orbit inclinations from 28.5 to 57 degrees, as is presently planned; and (2) a KSC-launched orbiter could also achieve orbit inclinations of 70 to 75 degrees.

We would appreciate receiving your response to the questions that follow, keeping in mind these assumptions. We recognize there may be range safety considerations and environmental impact factors related to achieving the higher inclinations from KSC. However, please respond to these questions based on the given assumptions and comment separately, if you so desire, on the safety/environmental factors.

Spacelab payloads

NASA's current payload projections for the STS show 31 Solar Terrestrial payloads planned for high inclination Spacelab flights in the 1983-1991 timeframe from Vandenberg. These payloads are in the following specific areas: Solar/Stellar Infrared; Advanced Solar Physics; and Atmosphere, Magnetosphere, and Plasmas-in-Space.

- A. How would NASA accomplish the objectives of these projected Spacelab payloads with the STS if the orbit inclinations achievable by the orbiter did not exceed 75 degrees:
1. Could these payloads remain on a Spacelab flight at this lower inclination with little or no degradation in their mission? If not, exactly how would the mission be affected?
 2. Or, would these payloads be flown on free flyers? How would this affect the particular mission objectives? Would an upper stage be required to kick the payload to a higher inclination? If so, what size upper stage would be necessary?
- B. Similarly, how would NASA accomplish these projected Spacelab payloads using the STS if the orbiter were limited to inclinations of 28.5 to 57 degrees? The questions in A-1 and A-2 should also be addressed for this analysis.

Automated payloads

The 1976 National Payload Model projects 24 NASA automated payloads for polar or sun synchronous orbits. These payloads include: some Space Science Explorer series satellites; Gravity Probe B; Advanced Relativity Experiment; Landsat; Earth Survey Satellite; Gravsat; and Environmental Monitoring. In addition, a total of 28 other civil Federal agencies' payloads are projected for the ITOS Follow-on; Operational Seasat; and Earth Resources-Low programs.

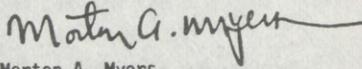
For each of the above payload programs, please respond individually to the following sets of questions.

- A. How would these payloads be accommodated on the STS if the orbiter could not achieve inclinations exceeding 75 degrees:
1. Would these payloads be flown at orbit inclinations achievable by the orbiter?
 2. Or, would an upper stage be used to kick the payloads into a higher inclination orbit thus making them unavailable for retrieval? If this were the case, please provide information on the cost tradeoffs associated with procuring a new satellite as opposed to retrieving and refurbishing existing satellites for those payloads which are now planned for retrieval from Vandenberg AFB.
- B. Similarly, how would these payloads be accommodated on the STS if the orbiter could achieve inclinations of only 28.5 to 57 degrees? Again, please address the questions presented in A-1 and A-2 for this analysis.

NASA's responses to the above questions should be sufficiently detailed so as to allow independent analysis by payload experts in the appropriate scientific disciplines. An early reply, preferably on or before September 30, 1977, would be greatly appreciated.

If you have any questions or desire additional information, please contact Chester S. Daniels, Assistant Director, on 275-3191.

Sincerely yours,

A handwritten signature in cursive script that reads "Morton A. Myers". The signature is written in dark ink and has a long, sweeping horizontal line extending to the right.

Morton A. Myers
Deputy Director

NASANational Aeronautics and
Space AdministrationWashington, D.C.
20546*1/11. 1977*
200
Mr. Jones EES
File 952181

2600-7

NOV 11 1977

Reply to Attn of MOI

Mr. R. W. Gutmann
Director
Procurement and Systems
Acquisition Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Gutmann:

The Administrator has asked me to provide a final response to Mr. Myers' letter of September 19.

If the Shuttle were limited to inclinations of 28.5 to 57 degrees, NASA would continue to fly the Western Test Range (WTR) science Spacelab payloads currently identified in the 1976 National Payload Model at the lower inclinations. For solar Spacelab payloads, the on-orbit observing time of the sun would be reduced. The Atmosphere, Magnetosphere, and Plasma-in-Space (AMPS) payloads would not have access to observations and measurements of the unique geophysics which occur between the Earth's geographic and magnetic axis. High energy astrophysics payloads would not be able to conduct low energy cosmic ray investigations because the Earth's magnetic field deflects low energy cosmic rays except at the poles where the field is weakest.

With respect to applications Spacelab payloads, current NASA thinking envisions two WTR missions per year. Many of the techniques involved in acquiring remotely sensed data are amenable to general verification in lower inclination orbits. However, high inclination orbits will be necessary to accomplish full verification of systems, sensors, or techniques and to acquire special periodic or calibrative data.

In regard to automated applications payloads, both R&D and operational, high inclination (sun-synchronous) orbits are critical to achieving mission objectives.

Sun-synchronous orbits are also critical to achieving the objectives of automated science payloads which measure the "drag" effect of the Earth's rotating gravitational field on a spinning gyroscope. For scientific survey-type automated payloads, these orbits are desirable because accessi-

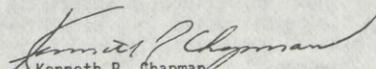
bility to them minimizes design requirements on explorer spacecraft by allowing comprehensive surveys of the celestial sphere to be completed in less time than would be possible at lower inclinations.

In the event that WTR were not available to the Shuttle, NASA might choose to accomplish the objectives of those automated payloads which must fly at high inclinations by launching them on expendables from WTR. Disregarding the question of performance capability of various payload/upper stage configurations to effect plane changes from 57 degrees to near polar inclinations, simple cost analyses indicate that there are cases where expendable launches of spacecraft from WTR are more cost effective than dedicated STS flights from KSC in the accomplishment of the same missions. The fundamental data contributing to this conclusion have been provided to the GAO in the analysis entitled, VAFB Shuttle Capability, Justification and Impact of Program Delays (December 1976), where both transportation and payload cost impacts were addressed.

In the case of the Spacelab payloads which must fly at high inclinations, it is impractical to design most of the proposed Spacelab instrumentation to fly on automated spacecraft. Therefore, the current mission objectives of these Spacelab payloads could only partially be achieved by launching compatible instrumentation on expendable launch vehicles.

You have asked for an analysis based on the assumption that a KSC launched orbiter will be permitted to achieve orbit inclinations of 70 to 75 degrees. The task involved falls under paragraph 6.h. of NASA Management Instruction (NMI) 1325.3. Unless the GAO has information that current launch restrictions can be relaxed, it would be fruitless to make an analysis based on such an assumption.

Sincerely,


Kenneth R. Chapman
Acting Associate Administrator
for External Relations



UNITED STATES GENERAL ACCOUNTING OFFICE

WASHINGTON, D.C. 20548

 PROCUREMENT AND SYSTEMS
ACQUISITION DIVISION

2600-9

SEP 19 1977

Major General Edwin A. Coy
Director of Space
Headquarters, USAF/RDS
Washington, D.C. 20330

Dear General Coy:

As you know, since 1972 when the decision was made to develop a reusable Space Transportation System (STS), the General Accounting Office has been tasked with providing the Congress timely information on shuttle-related issues. Present concerns involve the number of orbiters needed, the timing of their production, and their utilization.

Orbiter utilization plans affect, of course, fleet size requirements as well as launch facility needs. Due to national security considerations, DOD's payloads planned for the STS have not been subjected to open review and reporting. We believe, however, that DOD's payload/launch requirements can be discussed in general terms. For instance, we understand that many of DOD's satellites will require high-inclination orbits--56 to 104 degrees.

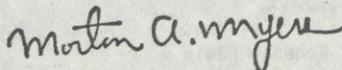
Along this line, we need to know what the minimum acceptable orbit inclinations are for DOD's space missions. That is, assuming shuttle launches into pure polar and higher inclination orbits were not available, would shuttle launches in the 70 to 75 degree range and less substantially accomplish DOD's program objectives represented in the current mission model? If not, please explain; i.e., how many payloads would be adversely affected and to what extent?

Note that we are not soliciting classified information in your response, but would expect the response to be sufficiently detailed or descriptive to permit independent evaluation by payload experts. Such evaluations may be made, we believe, even if based on general parameters and not on specific payload data. As a case in point, Earth observation missions can be evaluated in relation to orbital inclination. For example, if a 75-degree orbit will give near-total coverage of the Earth, is or isn't this inclination sufficient for mission accomplishment?

These kinds of sensitivity analyses--relating orbital inclinations to general programs--will be useful in our current review of the STS. Your early reply, preferably on or before September 30, 1977, will be greatly appreciated.

If you have any questions concerning this request, please contact Chester S. Daniels, Assistant Director, on 275-3191.

Sincerely yours,



Morton A. Myers
Deputy Director

bc: Mr. Day (PSAD/ST)
Mr. Gutmann (PSAD)
Mr. Daniels (PSAD/ST)
Mr. Lewis (PSAD/ST)

DEPARTMENT OF THE AIR FORCE
 HEADQUARTERS UNITED STATES AIR FORCE
 WASHINGTON, D. C.
 20330



30 SEP 1977

Mr. Morton A. Myers
 Deputy Director
 United States General
 Accounting Office
 Washington, DC 20548

Handwritten:
 1. Mr. Myers
 2. Mr. Ray
 3. Mr. [unclear]
 4. Mr. Lewis

Dear Mr. Myers

The DOD Space Shuttle Transition Plan dated 20 July 1977 (SECRET) based on the Space Mission Model Revision 6 reflects forty-four high inclination Shuttle launches from Vandenberg Air Force Base (VAFB). These missions require orbits which can be directly achieved only from VAFB. Many of these missions could not be launched from Kennedy Space Center because ETR range safety launch azimuth restrictions prohibit direct injection into final mission orbit inclinations, and spacecraft size and weight preclude use of upper stages for inclination changes.

As noted in your letter, earth observation missions can be evaluated in relation to orbital inclination with respect to sensor coverage. However, an equally important consideration is lighting conditions in the viewing area. In this regard, the sun-synchronous orbit must be used for most earth observation missions. While the inclination of sun-synchronous orbits is a function of altitude, the inclination of this orbit lies near 90 degrees for low altitude orbits where the resolution of earth viewing sensors is most acute.

I hope this reply is sufficiently comprehensive to assist in your deliberations. Please note that a more detailed discussion will involve classified information due to mission objective and orbital parameter correlation considerations.

Sincerely

John C. Bricker

JOHN C. BRICKER, Colonel, USAF
 Deputy Director of Space
 DCS/Research and Development

EXPENDABLE LAUNCH VEHICLE COSTS

QUESTION: What would be the cost of the expendable launch vehicles for these flights?

DOD ANSWER: As the payload cannot be designed for KSC launch compatibility it would be necessary to keep the payload on the Titan at VAFB with launch vehicle upgrading required after the mid-1980's. The transportation cost of these 17 missions (FY 1983 through 1st quarter of FY 1992) would be \$1.360 billion (\$0.2 billion non-recurring and \$1.16 billion recurring in FY 1979 \$).

GAO ANSWER: As indicated in our response to the preceding question we do not have sufficient data to state with confidence exactly how many projected payloads would require expendable launch vehicles from Vandenberg if a KSC shuttle could not be launched to a polar or nearpolar orbit. If however, the 18 heavy DOD payloads are the only ones requiring expendable launch vehicles from Vandenberg the cost would be roughly \$2.3 billion (real year dollars).

Details and sources of the \$2.3 billion cost figure for expendables at Vandenberg are given in the following table:

PAYLOAD REDESIGN

QUESTION. Could existing payloads be redesigned so Northerly launch from Kennedy would not be required? What would this cost?

DOD ANSWER. No, DOD payloads could not be redesigned and meet the mission requirements since accomplishment of mission is dependent on orbital inclination.

RUSSIAN FLIGHTS OVER U.S.

Mr. BOLAND. Let me ask a question. Do any of the Russian launchers fly over the United States in a suborbital fashion similar to the way the Shuttle would fly over Russia?

Dr. FROSCHE. I do not think so.

SHUTTLE FLIGHTS OVER RUSSIA

Mr. BOLAND. The GAO testimony suggests that any potential problems with launches over Russia could be negotiated under the 1971 U.S.-Soviet agreement entitled: "1971 Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War between the United States of America and the Union of Soviet Socialist Republics." Do you agree that any problems with northerly launches could be resolved through negotiations under the terms of this treaty? Has either DOD or NASA actually asked the Soviet Union if they would object to Shuttle flights over their country?

[DOD information follows:]

The DOD has not initiated action to seek such an opinion from the Soviet Union.

We consider prior notification unacceptable from a mission viewpoint. Further, we recognize the potentially precarious position that could result from any negotiated overflight agreement which has implicit the consideration that overflight in space is contingent upon approval of the country over which the Shuttle passes. Denial of overflight could place the United States in an untenable position with respect to the performance of missions critical to national security. The question of reciprocity and the acceptability of routine suborbital overflight by the Soviet Union over the continental United States must also be considered.

Dr. FROSCHE. We have not asked the Soviet Union in any case. The State Department would presumably do that, but we have not asked them to do that. It is possible for the NASA launches that we could give such notice and whether the Soviets would accept it or not I do not know. I believe there may be a question as to whether DOD would be willing to give that kind of prior notice in all cases.

JOINT US/USSR LAUNCHES USING SHUTTLE

Mr. BOLAND. Are any joint United States-Soviet launches using the Shuttle being planned?

Dr. FROSCHE. Some discussion has gone on under the cooperation treaty with regard to the possibility of cooperating operations with Shuttle and Salyut, but the discussions are only in the early stages to determine whether there is anything worth doing in such a mode.

Mr. BOLAND. Mr. McEwen?

Mr. McEWEN. Thank you, Mr. Chairman.

IMPACT ON DOD IF VANDENBERG FACILITY IS DELAYED

Dr. Perry, what would be the impact on the DOD program if Vandenberg were delayed, the military construction, for one or two years?

Dr. PERRY. That would delay by that same amount of time our ability to launch our polar vehicles on the Shuttle and what that would mean then is that we would have to procure more expendable launch vehicles and use them during that period of time.

Mr. McEWEN. How many more vehicles are you talking about?

Dr. PERRY. The answer to that question is a little complicated.

The minimum we would have to do would be two per year; in other words, accommodate our heaviest systems, I will give you more—another way of looking at that, though.

We have 11 DOD launches planned out of Vandenberg on the Shuttle from the time it starts into 1985, from 1983 to 1985. So you might consider that all 11 of those would have to go on expendable launch vehicles, but we would have the alternative of only launching the 4 heaviest on expendable launch vehicles and having the lightest launched from Kennedy.

Mr. McEWEN. How many vehicles do you have?

Dr. PERRY. In addition to the ones which are already scheduled we are planning to procure 3 complete back-up vehicles plus 4 partially assembled back-up vehicles, plus long lead items for 4 more.

Mr. McEWEN. In other words, you would have the vehicles to perform the missions?

Dr. PERRY. If Vandenberg were delayed I imagine what we would do, Mr. McEwen, is procure more expendable launch vehicles and probably adjust our backup procurement of TITAN vehicles as circumstances at the time would dictate.

Mr. McEWEN. What drives the DOD date for the first launch from Vandenberg?

Dr. PERRY. The sooner we start launching from Vandenberg, the sooner we begin to achieve the economic benefits the Shuttle would accrue to us, that is the sooner we can stop buying expendable launch vehicles.

Mr. McEWEN. Is that the only reason?

Dr. PERRY. We project that there will be a payload that will come in about 1985 or 1986, that is heavier than we can put on the expendable launch vehicles. So up until 1985 or 1986 it just is a question of buying more expendable launch vehicles.

After 1985 or 1986, if we are not going to have Vandenberg, then we will have to upgrade the performance of these vehicles to handle the heavier payload.

VANDENBERG LAUNCH RELIABILITY

Mr. McEWEN. Dr. Perry, would you for the record provide what the weather conditions are at the Vandenberg site and how many times during the past 3 years have scheduled launches from Vandenberg been postponed or canceled because of weather, and how many days out of the year are not suitable for launch or recovery of the Space Shuttle orbiter?

Dr. PERRY. Be happy to do that.

[DOD information follows:]

During the past three years three launches have been delayed at VAFB because of winds. In 1975, a T III B launch vehicle experienced two delays of one day each; in 1976, a Scout vehicle was delayed one day; and in 1977, an Atlas E/F vehicle had two delays of one day each. The weather conditions most significant to shuttle operation at VAFB are ground winds, upper atmosphere winds, landing field visibility and landing field wind (landing field conditions are pertinent because of the possibility of an aborted launch returning to base). Other considerations which are less significant are precipitation, thunder showers, train operations, and sea-state for SRB recovery. Preliminary studies have identified a launch probability of approximately 92 percent at VAFB and 94 percent at KSC. On this basis approximately 29 days out of a year would not be suitable for launch at VAFB. These estimates are preliminary and will be updated as shuttle performance characteristics are better understood through analysis and operational experience.

ESTIMATED COSTS FOR OPERATIONS AND MAINTENANCE AT VANDENBERG

Mr. McEWEN. What are the estimated annual O&M costs?

Dr. PERRY. General Coy?

General COY. \$160 million a year in 1979 dollars.

Mr. McEWEN. What is the total cost for construction of all facilities at Vandenberg in then-year dollars?

Dr. PERRY. Let me answer that, Mr. McEwen, and then have General Coy correct me.

We are budgeting about \$900 million for Vandenberg acquisition. The Air Force is also doing contingency planning, trying to estimate what the maximum cost might be. Their outside figure of what it might go to is \$1.2 billion.

General Coy, would you comment on that?

General COY. That is correct.

Mr. McEWEN. Is that two launch pads or one launch pad?

General COY. That is one launch pad.

General GILBERT. That is total cost of everything, Mr. McEwen. If you are talking about just the facility, that is \$245 million plus or minus 5 percent.

COST OF CONSTRUCTION FOR VANDENBERG FACILITY

Mr. McEWEN. Provide the same figures of construction funds if construction funds are approved in fiscal year 1980 or fiscal year 1981.

Dr. PERRY. We will provide that for the record, Mr. McEwen.

[DOD information follows:]

If construction funds for Vandenberg were approved in 1980 and 1981 versus 1979 and 1980 as currently planned, the total construction funds required would be approximately \$262.1 million as a result of escalation.

VANDENBERG COSTS RECOVERED THROUGH USER CHARGES

Mr. McEWEN. Will all or a portion of these capital costs for Vandenberg be recovered through user charges to non-DOD government agencies or private sector users?

Dr. PERRY. We do not plan to keep the books that way, Mr. McEwen. The DOD investment in the Shuttle program was building the Vandenberg facility and building the Inertial Upper Stage; that is our contribution to the investment, it is a small portion of the total investment NASA is making.

In return for that, we get the benefit of the investment NASA is making, but we make available to the non-DOD users the IUS and the Vandenberg facility.

Do you have anything else to add on that?

Mr. YARDLEY. Yes. Let me just add one thing. In our user charge to commercial or foreign customers are put in what we call a use charge, which is analogous to depreciation.

Now the charge per flight will be something like \$4 million. Part of that is for let's say depreciation of launch facilities. When a commercial or foreign user goes out of Vandenberg, that portion of that charge will be refunded to the Air Force. I do not know if you knew that.

Dr. PERRY. No. It is good news.

STATUS OF VANDENBERG SPACE SHUTTLE COMPLEX

Mr. McEWEN. What is the current status of design on the Vandenberg Space Shuttle complex?

General COY. Sir, we are under contract with the Martin Company for facility definition. That contract, the results of it will be available to us in June of this year.

General GILBERT. You are addressing the facility aspect, Mr. McEwen.

Mr. McEWEN. I am sorry; the facility aspect?

General GILBERT. Yes, sir. The airfield is 100 percent designed now, the airfield extension in this year's program, the launch pad is 30 percent designed, and the payload processing room is 10 percent designed at this point in time.

Mr. McEWEN. What percentage of the total will be completed by October 1?

General GILBERT. By October 1, I have the schedule here; just the landing strip and the mate/de-mate facility will be completed by 1 October, Mr. McEwen. Completion of the remaining should occur shortly thereafter.

For instance, the launch control facility modification is due for completion by 31 October 1978; then the horizontal and vertical facilities associated with the launch pad modification are due for completion by the end of April of 1979.

That represents the total facilities in the current program for Vandenberg.

Mr. McEWEN. It will be complete then in April of 1979?

General GILBERT. Yes, sir, the last one.

COSTS FOR VANDENBERG FACILITY

Mr. McEWEN. General Coy, what again was the total figure you gave for the Vandenberg complex?

General COY. \$900 million, sir, with our uppermost estimate being \$1.2 billion in fiscal year 1979 dollars.

I am sorry, those are in then-year dollars.

Mr. McEWEN. Then-year dollars?

General COY. Yes.

Mr. McEWEN. What portion of this is available in existing appropriations?

General COY. Through our 5-year defense program we have a total of \$877.6 million for Vandenberg through FY 83.

Mr. McEWEN. What portion is required then in fiscal years 1979, 1980, and 1981?

General COY. Fiscal 1979, we need a total of \$252.3 million. This is all appropriations?

Mr. McEWEN. Yes.

General COY. At the present time we are building our program objective for fiscal year 1980, but at the present time it is in there at \$283.8 million. I believe you mentioned 1981, also; \$132.2 million, that includes RDT&E, procurement and other procurement.

Mr. McEWEN. Yes. Would you for the record break that out by account?

General COY. Yes, sir.

Mr. McEWEN. Those same figures for those years.

[DOD information follows:]

	Fiscal year 1979	Fiscal year 1980	Fiscal year 1981
R.D.T. & E. (3600).....	39.9	51.0	73.3
MPAF (3020).....	60.4	127.0	58.9
OPAF (3080).....	15.2	16.3	0
Milcon (3300).....	136.8	89.5	0
Total.....	252.3	283.8	132.2

IMPACT OF B-1 CANCELLATION ON ORBITER COST

Mr. BOLAND. Thank you.

Is there any possibility that Rockwell might increase the unit cost of the orbiter occasioned by the transfer of some overhead costs from the defunct B-1 program to the Shuttle program?

Mr. YARDLEY. We have discussed that with Rockwell. There is not much cross-talk at all between the two divisions.

Mr. BOLAND. There is not what?

Mr. YARDLEY. Not much cross-talk between the two divisions. They are separate, autonomous centers. The effect of the B-1 cancellation on the corporate overhead structure will tend to increase the Space Division overhead a little bit. The fact is that the B-1 division is building some parts for the Shuttle. The price of those parts will increase because of their overhead problem. So there will be some modest impact.

SEPARATE MISSION CONTROL CENTER FOR DOD LAUNCHES

Mr. BOLAND. There have been discussions in the past about a separate mission control center for DOD-classified launches. A separate mission control center would run between \$200 and \$300 million.

I understand that in your statement you indicate that DOD and NASA are currently negotiating to make modifications to the Johnson Mission Control Center so that a separate DOD mission control center will not be required.

Let me ask whether or not the 1979 budget assumes there will be a joint DOD-NASA use of the Johnson Center in lieu of a separate mission control center?

Dr. PERRY. That is correct.

Mr. Chairman, I will say that it is—negotiation perhaps does not describe it adequately. We have come to an agreement on the principle that we will operate out of Johnson. We are only now working out the details of how that joint operation will take place.

Mr. BOLAND. I take it that the Johnson Control Center will be used both for Kennedy and Vandenberg launches, is that correct?

Dr. PERRY. That is correct.

IMPACT ON COSTS AT JSC WITHOUT VANDENBERG FACILITY

Mr. BOLAND. If Vandenberg were not built, would any economies or extra costs be incurred at the Johnson Space Center?

Dr. FROSCHE. Not as far as we know.

Mr. YARDLEY. They have some communication line leases between the West Coast and Johnson that could be dropped, that sort of thing.

INCREASE IN SPACE ACTIVITY

Mr. BOLAND. Now the GAO testimony states that the current mission model would require a threefold increase in space activity.

Is that analysis accurate?

Mr. YARDLEY. I guess it is a matter of interpretation. I wouldn't say it is three. I would say it is probably two or two-plus.

Dr. FROSCHE. That is at the extreme end of the mission model.

General COY. From the DOD aspect it is inaccurate. We are currently, as I showed you in my briefing this morning, continuing at the launch rate that we are experiencing at the present time. In other words, our portion of the mission model we feel is quite conservative and it does not necessarily have in it any sort of full utilization of the Shuttle capabilities.

Mr. BOLAND. Now, there is a trend for payloads to be increasingly reliable, for example, early communications satellites had lifetimes measured in months. Communications satellites being designed for flight in the early 1980's have design lives from 7 to 10 years. In addition, those communication satellites will have significantly greater capacity per satellite so that fewer satellites will be required to achieve any given level of communications capability. The trend in communications satellites are generally true for other classes of satellites as well.

Given these trends of longer lives and higher capacity, you couldn't justify a threefold increase in space activity, could you?

Dr. FROSCHE. Those statements are true of communication satellites. They don't take into account the fact that the traffic load is growing and the prospect is for an increase in circuit requirements. Working that out into satellites is complicated because there is some increase coming in circuit capacity but still an expected increase in the number of satellites. What we have been using on communications satellites is data, partly at least, from the industry, with their prospects for launches built into our expectations. While it is true that reliability of satellites is increasing, the number of uses that we are putting them to is also increasing. It is not at all clear that the number of application satellites for specific useful purposes is not going to grow in spite of the increase in reliability.

Mr. BOLAND. If the GAO analysis is accurate in that the analysis indicated that the current mission model would require a threefold

increase in space activity, what would be the cost of the payloads if there were a threefold increase?

Dr. FROSCHE. It is almost impossible to say precisely, because we don't know. We haven't made that hypothesis. The hypothesis that we are making with regard to the mission model, and the NASA planning is for planning purposes essentially within a level-of-effort budget. So essentially we are planning the use within our budget.

Mr. BOLAND. Has GAO made an analysis of this?

Mr. TOLER. Yes, sir. I think we obtained some calculations again from NASA as to the—

Dr. FROSCHE. From someplace in NASA.

Mr. TOLER. From someplace in NASA, a reliable source—

Dr. FROSCHE. Usually reliable.

Mr. TOLER [continuing]. That the Government costs, for just the payload portion, would be around \$30 billion for their 560 flight mission model. Now this doesn't include DOD payloads. I think some of that is classified information which we were unable to get. There is an additional cost for the operations which would bring the total to about \$53 billion.

Dr. FROSCHE. I will be fascinated to see those numbers.

Mr. YARDLEY. That is over a 12-year period.

Mr. BOLAND. We will give you the opportunity. Supply them for the record.

[GAO information follows:]

The following table (with minor subsequent revisions) was provided to NASA on January 5, 1978, as part of GAO's draft report, "Space Transportation System: An Analysis of Launch Site and Fleet Size Requirements." During a meeting with NASA Headquarters officials later that month, we discussed the table and indicated to the NASA representatives that supporting data, which was originally obtained from NASA Headquarters personnel was available for their review.

Estimated costs to U.S. government (note a) for 1980-92 operations in space (note b)

Payloads (note c):

NASA:	<i>Billions</i>
Spacelab.....	\$4.7
Space industrialization (note d).....	13.7
Free-flying satellites.....	10.8
Subtotal.....	29.2
Other U.S. Government civil agencies: Free-flying satellites.....	2.6
Department of Defense: (not provided) (note e).....	-----
Total payloads.....	31.8
Transportation (note f):	
Standard services (note g):	
Spacelab.....	9.3
Space industrialization.....	1.4
Free-flying satellites.....	5.5
Projected reflights (note h).....	.9
Subtotal.....	17.1
Optional services (note i):	
Spacelab hardware usage (note j).....	2.5
Upper stages (note k).....	1.7
Subtotal.....	4.2
Total transportation.....	21.3
Grand total.....	\$53.1

NOTES

(a) Cost data incorporated herein was provided primarily by NASA and has not been verified or analyzed in depth by GAO. All costs are expressed in real year dollars.

(b) Costs shown are for the U.S. Government's portion of the 560 Shuttle flights/1,091 payloads in the 1976 mission model. We have not prepared a similar cost breakdown of the 1977 mission model, which projects 552 flights/1,000 payloads.

(c) The source of the payload cost data is the Office of payload Analysis and Mission Planning, NASA Headquarters. It was provided in August-September 1977 and was presented on a yearly basis, by payload. Payload costs include development of the experiment/mission, procurement of mission spacecraft and scientific hardware, and subsequent analysis of data derived from the mission.

(d) According to NASA this program includes activities ranging from materials processing in space to constructing large structures in space. While we did not analyze these projected activities, they seem to reflect NASA's perceived need for permanent manned occupancy of space. It should be noted that, although relatively few Shuttle flights are shown, the Space Industrialization program represents a substantial portion of the mission model's total payload cost.

(e) DOD would not provide the estimated costs of its payloads projected for the 1980-92 timeframe.

(f) Transportation costs shown are for U.S. Government Shuttle flights only, although a total of 83 expendable launch vehicles were projected for use during the Shuttle era. Most of these vehicles will be flown while users are transitioning to the Shuttle. The remainder provides a backup posture for launching critical satellites in the event of a Shuttle anomaly. NASA and DOD have estimated the costs for these 83 vehicles to be about \$3.0 billion.

(g) These costs are based on data presented in the October 1976 "Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues." Standard Shuttle transportation services include such support as: two standard mission destinations (28.5 degree and 56 degree orbit inclinations); one-day mission duration; Orbiter flight planning services; a three-person flight crew (commander, pilot, and mission specialist); and on-orbit payload handling. Additional (optional) services are explained in note i. Several steps were required to arrive at the figures presented in this table, and are briefly outlined below:

(1) Average Cost per Flight (in FY 1978 dollars) = \$22.5 million.

Computation:	<i>Billions</i>
Civil Shuttle operations cost.....	\$10.1
DOD Shuttle operations cost.....	2.5
Total.....	12.6

\$12.6 billion minus 560 flights equals \$22.5 million per flight.

(2) Shuttle Operating Costs for U.S. Government Flights (in FY 1978 dollars) = \$9,090 million.

Computation:	<i>Flights</i>
NASA.....	267
DOD.....	109
Other U.S. Government.....	28
Total.....	404

404 flights times \$22.5 million equals \$9,090 million.

(3) The \$9,090 million (FY 1978 dollars) was then broken down by the year the flights would occur. These yearly costs were spread over a three-year period (20 percent 2 years before flight, 34 percent 1 year before flight, and the remaining 46 percent in the year of flight) in accordance with NASA User Charge Policy specified in NASA Management Instruction 8610.9, dated February 11, 1977.

(4) The \$9,090 million (FY 1978 dollars) spread costs were then adjusted to reflect real year dollars using an annual inflation rate of 7 percent. The total cost for scheduled U.S. Government flights (which does not include reflights) is \$16.2 billion.

(5) To separate this \$16.2 billion total by nature of the flight (i.e., Spacelab, Space Industrialization and free-flying satellites), an analysis similar to that delineated in steps 2 through 4 was performed. The results are:

	<i>Billions</i>
Spacelab	\$9.3
Space industrialization	1.4
Free-flying satellites	5.5
Total	16.2

(6) To determine the cost of projected reflights for the U.S. Government, we calculated the cost (in real year dollars) of all *projected* reflights (31) and assigned 71 percent (a figure indicated in the above-named 1976 study) of this to the U.S. Government.

Calculation:

Total cost (million real year dollars)	\$1,258
Times (percent)	71
Equals (million)	893

(h) A total of 404 Shuttle flights were projected for U.S. Government missions; 22 of these, however, are for reflights of missions not successfully accomplished. Mission failure may result from occurrences such as: Shuttle cargo bay doors failing to open; upper propulsion stage failing to ignite; satellite not checking out properly prior to deployment; and Shuttle failure causing return to Earth before mission accomplishment.

(i) Optional Shuttle transportation services will, in many cases, be required to tailor flights to the user's needs. Optional services include such items as: use of Spacelab hardware; revisit and retrieval of satellites; use of upper stages; additional time on orbit; payload data processing; and use of extra fuel to take the Orbiter to an altitude higher than 160 nautical miles. The estimated costs for these services, however, were provided for only two items—Spacelab hardware usage and upper stages.

(j) The average cost per flight of using Spacelab hardware is \$3.6 million (FY 1978 dollars) according to information provided by NASA Headquarters to the Congressional Budget Office. The data was furnished during CBO's analysis of shuttle budgetary implications, requested by the Senate Budget Committee. This \$3.6 million average cost was applied to each of the 394 projected U.S. Government (all NASA) Spacelab payloads, by year of flight, giving a total cost of \$1,418 million (FY 1978 dollars). The annual costs were then spread (see note g, step 3) and adjusted to reflect real year dollars using an annual inflation rate of 7 percent. This resulted in a total cost of \$2.5 billion for Spacelab hardware usage.

(k) Upper stage costs were computed using (1) the upper stage requirements listed in the October 1976 "Joint NASA/USAF study on Space Shuttle Orbiter Procurement and Related Issues," (2) cost data provided by the Office of Space Flight, NASA Headquarters and by Headquarters USAF/RDS.

Upper stages	Requirements	Unit cost
IUS: 2 stage	90	\$8,000,000 (fiscal year 1979 dollars).
IUS: 3 stage	9	\$11,000,000 (fiscal year 1979 dollars).
IUS: 4 stage	4	\$14,000,000 (fiscal year 1979 dollars).
SSUS-A	7	\$3,000,000 (fiscal year 1975 dollars).
SSUS-D	35	\$2,000,000 (fiscal year 1975 dollars).

Costs were scheduled out by year of flight and adjusted to reflect real year dollars using an inflation factor of 7 percent, resulting in a total cost of \$1.7 billion.

Mr. BOLAND. Mr. McKay?

MANNED ORBITING LABORATORIES

Mr. MCKAY. Mr. Chairman, the Air Force in 1969 had the manned orbiting laboratory program that was to use as a launch pad the Vandenberg site. All of a sudden you stopped that program after spending a billion dollars.

What happened? Was that premature spending or did you just decide you didn't need it any more?

Dr. PERRY. Mr. McKay, I hate to make a flip answer, but that didn't happen on my watch. Maybe I can find somebody here who was around at that time and can come to a judgment on it.

General Coy. No, sir, I can't provide the reason.

Mr. MCKAY. Provide for the record what the other watch might have done. I think incidents like this constantly put us on the alert.

Why did we spend a billion dollars for a program that didn't get off the ground? Was it premature or was it intended to be part of a program whose time had not yet come? All of those factors play as we start talking about this whole thing. That is why some of my previous questions included: Why do you have to do it now? Do you have other alternatives? Will you get down the road to another 1969 situation and decide you don't need it after we have a few billion dollars in it?

The public gets very upset when we spend a billion dollars as though we were buying an ice cream cone and it really didn't matter. People can't conceive what that is, nor \$1 million, nor \$100,000 can they conceive, when they relate it to what they do daily.

Provide that information for the record.

[DOD information follows:]

In June 1969, the Secretary of Defense with the concurrence of the President cancelled the MOL program. In making the determination to cancel the Air Force Manned Orbiting Laboratory program, the Department of Defense carefully evaluated that program in relation to other priority defense requirements, as well as the urgent need to reduce defense spending in FY 1970 and in future years.

The primary objectives of the MOL program were to develop and test advanced equipment for both manned and unmanned space flight and to determine the extent of man's utility in space for national defense purposes.

Several factors contributed to the decision to cancel MOL:

1. In order to further reduce the FY 1970 defense budget significantly, it was necessary either to drastically cut back or terminate numerous small but important efforts, or one of the larger, more costly programs, DoD had the choice of going forward with cuts all through various research and development items, or finding one of the larger and more costly programs in order to make a budget reduction.

2. The development status of the MOL program was such that large annual investments were necessary to realize reasonable progress. Further, fiscal year 1970 reductions of any significance, beyond those already made, would have reduced MOL activity to a sustaining level and would still have required several hundred million dollars.

3. The potential worth of the unique experiments planned for MOL plus the information expected on man's utility in space for military purposes was not as valuable to Defense as the aggregate of other priority programs.

4. Since the initiation of the MOL program, major advances had been made by both NASA and DoD in automated techniques for unmanned satellite systems. In the same period, DoD had accumulated much experience and operational capability in unmanned satellite operations for such purposes as communications, navigation, and meteorology.

The experiences as far as unmanned satellites were concerned gave confidence that the most essential Department of Defense space missions could be accomplished with lower cost unmanned spacecraft.

General Coy. I would like the record to reflect that in my briefing this morning, those facilities that we are modifying, that I showed were facilities that had been built for the MOL program. So we are equally conscientious about being stewards of the taxpayers' money and are trying to minimize the cost of Vandenberg by modifying existing facilities insofar as we can.

Mr. MCKAY. If you can work out retroactively what can be re-couped somewhere. Provide it for the record so we have some answers.

General Coy. We will, sir.

[The information follows:]

We estimate that we will derive approximately \$300M benefit by modifying the MOL facilities rather than beginning from "bare ground."

Mr. McKAY. At some point, somebody came in here very vehemently and told us you just have to have it right now or else the country will collapse and \$50 million will be——

Well, that is enough.

Mr. BOLAND. Or \$200 million additional for a delay.

Mr. McDade.

Mr. McDade. Not right now, Mr. Chairman.

Mr. BOLAND. Larry?

Mr. COUGHLIN. Do you want to go into closed session?

Mr. BOLAND. Is there some classified material that we should be informed of in closed session that any of you are aware of?

Mr. GUTMANN. Yes, there is. I would urge that the committee obtain this classified information directly from Dr. Mark.

Mr. BOLAND. Is that agreeable to you?

Mr. COUGHLIN. Can we get that and have it available to us?

Mr. BOLAND. I presume since he is the source of the classified material, I suppose we ought to go right to the source, right to the head.

It seems to me the problem we have here is what Mr. Gutmann is going to report on, which are conversations with Dr. Mark; is that correct? Is that what you were referring to? Is that the classified material you were going to indicate to us?

Mr. GUTMANN. Well, I don't feel I am in a position to indicate it to you and I think that Dr. Mark is, really, the man that the information should come from.

Mr. BOLAND. Very well. Why don't we have him later?

Mr. COUGHLIN. Fine.

CLOSING STATEMENT

Mr. BOLAND. If there are no more questions, I want to thank all of you, Dr. Frosch, Dr. Perry, Mr. Gutmann, and all the backup team. It has been a very pleasant and very persuasive and very happy gathering. I think you have supplied this committee with enough information to keep us going through the next election.

There will be a number of questions which we will supply to all three of you which have not been answered and we would appreciate your answering them for the record. But the most important ones have been answered. In any event, we will have a complete record after all of you have looked at these questions and responded to them.

Mr. ADDABBO. Please provide answers for the record for the following questions.

(Clerk's note: The questions submitted by Mr. Addabbo and the answers thereto follow:)

GAO STUDY

Question. Much of today's hearing will be based upon the findings of the GAO study of the Space Shuttle program.

Please describe why GAO conducted this study, how long the study has been underway, the level of effort assigned to this study and the qualifications of the analysts conducting the study?

GAO answer. The GAO conducted this study of the Space Transportation System at the specific request of the Chairman, Subcommittee on HUD-Independent Agencies, Senate Committee on Appropriations.

This particular study effort began in May 1977; it is preceded, however, by other GAO studies on the STS dating to 1972.

Approximately 1,050 staff-days have been expended through March 1978. Review work was performed at NASA Headquarters, Washington, D.C.; Department of Defense, the Pentagon; Johnson Space Center, Houston, Texas; Marshall Space Flight Center, Huntsville, Alabama; Kennedy Space Flight Center, Cape Canaveral, Florida; USAF Space and Missile Systems Organization, Los Angeles, California and the Aerospace Corporation, El Segundo, California.

This effort was performed by our Dallas staff in conjunction with our headquarters staff in Washington, D.C. Dr. Marshall Kaplan, consultant to GAO on this review, provided technical assistance. Dr. Kaplan's credentials were described by Mr. Gutmann in his statement. Biographical sketches of GAO witnesses have been furnished for the record.

Over the past few years, GAO's professional expertise has been increased by the addition of engineers, economists, mathematicians and scientists to its staff. Backgrounds of staff members on this assignment include accounting, auditing, economics, mathematics, physics, and computer science.

Question. Have DOD and NASA had an opportunity to comment to GAO on these findings prior to today's hearing?

DOD answer. The DOD responded to the draft GAO report by letter dated 17 February 1978. We have not been provided insight into the proposed content of the final report by GAO.

NASA answer. NASA was furnished a copy of the initial GAO draft report in early January 1978. This report was reviewed extensively within NASA and comments regarding the GAO findings were reviewed with GAO representatives on a page by page basis on January 31, 1978. On the more important issues, GAO was furnished analyses to substantiate NASA views. Subsequent to that meeting at least six additional meetings and numerous phone conversations were conducted to review NASA's data concerning the proposals in the GAO report.

Significant disagreement with the issues of the report and supportive data to corroborate NASA's disagreement were discussed and provided to the GAO. There was never any indication that the technical or economic facts provided by NASA were accepted by the GAO.

TECHNICAL FEASIBILITY OF GAO REPORT

Question. Are the GAO proposals technically feasible if the United States is willing to accept flight over land and a level of space activity which is higher than current activity but lower than currently projected in the NASA/DOD model?

DOD answer. The GAO proposal is technically feasible with no launch azimuth constraints, but not practical. The most recent NASA analysis indicates that launch azimuth constraints, imposed to preclude damage from sonic boom impingement or solid rocket booster impact, result in Shuttle performance degradation to the point where the critical missions cannot be accomplished without ignoring significant damage potential.

[GAO information follows:]

A KSC-launched Space Shuttle can carry over 32,000 pounds to 98-degree inclination orbits. To accomplish northerly launches from KSC to polar and near-polar orbits, the Space Shuttle must change its launch trajectory in flight. (See Figure 1)

A KSC-based STS can accommodate all of the payloads, civil and military, projected for the 1989-91 period, including those projected for high inclination orbits.

Pursuant to the Chairman's directive that GAO, NASA, and DOD get together after the hearings and reconcile their differences on payload carrying capabilities, a meeting was held at Johnson Space Center on March 17, 1978. Headquarters' representatives from all agencies were present. At this meeting, tentative agreement was reached on the following performance figures:

Shuttle performance capability for northerly launches from KSC (assuming initial launch ascent azimuths of 8, 10, 13, and 19 degrees, with a subsequent dog leg maneuver to obtain a 98 degree—150 nautical miles orbit)

Initial launch ascent azimuth (degrees):	Weight-carrying capability (pounds)
8	34,922
10	33,512
13	31,148
19	25,729

Backup details and explanations of these figures are given in attached charts 1 through 4.

The figures shown above do not reflect the less severe wind conditions that exist at KSC as compared to Vandenberg which could result in additional performance capability, perhaps ranging from 750 to 2,100 pounds depending on actual winds at time of launch. Additionally, NASA has underway several studies involving ways to modify the Shuttle's design to give additional performance capability ranging from 2,000 to 20,000 pounds. One of the studies involves adding a catalyst to the SRB propellant, which could improve the Shuttle's capability by 5,000 pounds. The studies, are targeted for completion in June 1978.

As a point of understanding for the record, we note that the performance figures discussed at the March 17th meeting are *not* based on system changes which affect abort procedures or in any way compromise orbiter and crew safety. The figures do *not* include any deployment manifest deletions from the orbiter, that is, *no* items were off-loaded from the standard delivery configuration even though it was generally recognized that certain non-safety items (televisions, cameras etc.) were not mission-essential. The participants agreed to discuss at a future meeting those items which could possibly be off-loaded, thus giving additional payload capability.

Two other issues were raised by NASA at the March 17th meeting as possible constraints against northerly launches from KSC—(1) potential sonic booms on Florida coastal areas and (2) oil and gas leases in possible SRB splashdown areas. These two issues are addressed following this discussion on performance capability.

Headquarters representatives of the three agencies met again on March 23-24, 1978, in Washington, D.C. There was no indication at that meeting that substantive changes would be made to the payload carrying capability tentatively agreed to a week earlier at Johnson Space Center. However, the DOD representative stated that the payload question was still being studied while we met.

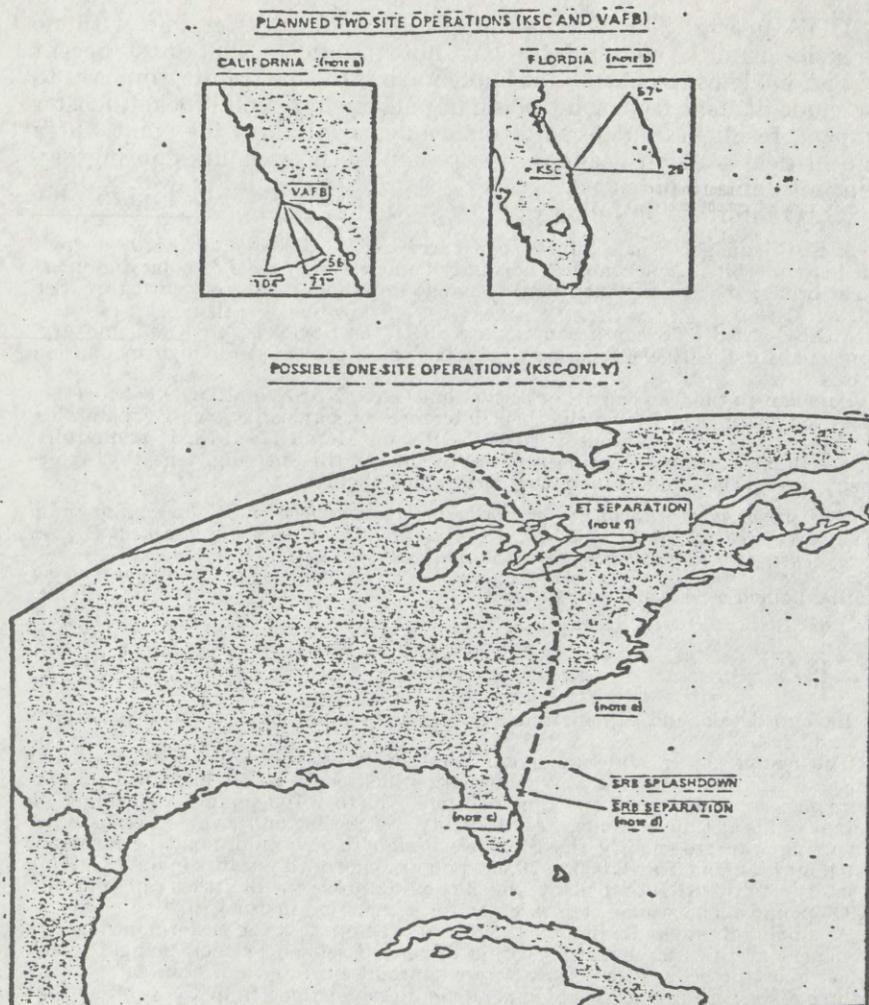


FIGURE 1.—Comparison of STS Launch Operations: Planned Two-site versus Possible One-Site

Notes to Figure 1:

^a Shuttle launches to high inclination orbits (56 to 104 degrees) are planned from Vandenberg Air Force Base, which is not scheduled for operations until June 1983. Polar (90 degrees) and sunsynchronous (about 98 degrees) orbits are popular high inclination orbits and are especially useful for Earth observation missions. Although present plans show that Vandenberg will be used to launch the Shuttle to inclinations ranging from 56 to 104 degrees, it is probable that sonic boom and external tank (ET) impact considerations will not permit direct Shuttle ascent into inclination of 56 to 71 degrees. If so, a dogleg maneuver (similar to that discussed in note c) will have to be used if these inclinations are to be achieved from Vandenberg.

^b The primary site, KSC, is expected to be operational in mid-1980 and will be used to launch the orbiter to low inclination orbits ranging from 28.5 to 57 degrees. According to NASA, inclinations above 57 degrees are not achievable from KSC due to land overflight considerations. However, KSC-only operations are possible (see note c) and offer significant cost savings. For a number of reasons, we feel that an absolute constraint on Shuttle overflight of land may be unwarranted.

CHART 1—SHUTTLE PERFORMANCE CAPABILITY FOR NORTHERLY LAUNCHES FROM KSC (ASSUMING INITIAL LAUNCH ASCENT AZIMUTHS OF 8°, 10°, 13°, AND 19°, WITH A SUBSEQUENT DOGLEG MANEUVER TO OBTAIN A 98°, 150-NAUTICAL-MILE ORBIT)

Mission/operating profile	Weight-carrying capability (pounds) at various launch azimuths ¹			
	8°	10°	13°	19°
Basic deployment and retrieval ²	27,499	26,089	23,725	18,306
Less management reserve ³	1,270	1,270	1,270	1,270
Subtotal.....	26,229	24,819	22,455	17,036
Add capability gained by—				
Offloading SRB recovery system ⁴	1,259	1,259	1,259	1,259
Deploying but not retrieving on same mission ⁵	7,434	7,434	7,434	7,434
Total ⁶	34,922	33,512	31,148	25,729

¹ Weight-carrying capability decreases as the various launch azimuths increase because the Shuttle requires a "dog-leg" maneuver to achieve a 98° inclination orbit (angle at which the orbit crosses the Earth's equator). For example, a 13° azimuth would place the Shuttle in a 74° inclination orbit. To achieve a more northerly inclination (such as 98°) from this same azimuth, an in-flight direction change maneuver (requiring additional energy) must be performed. Thus, the greater the direction change, more fuel is required and the payload carrying capability is decreased.

² This basic deployment/retrieval capability is based on ground rules established by NASA and DOD. (See chart 2.)

³ This management reserve is part of the Shuttle's overall payload carrying capability; however, NASA management holds 1,270 lb aside in reserve status to cushion the effects of unforeseen system weight anomalies.

⁴ The solid rocket boosters will separate from the Shuttle system at an altitude of about 150,000 ft. After separation, the boosters will parachute into the ocean some 150 nautical miles downrange for recovery and reuse. Deleting this recovery system (parachutes, etc.) reduces system weight by 1,259 lb and increases weight-carrying capability by the same amount. For further explanation, see chart 3.

⁵ Missions calling for satellite delivery and retrieval on 1 flight require more fuel, time, and crew than do delivery-only missions. The latter category of missions allows 7,434 lb of additional weight-carrying capability. For further explanation, see chart 4.

⁶ These totals, and the preceding figures, were agreed to during a reconciliation meeting on Mar. 17, 1978, attended by headquarters' representatives from NASA, DOD, and GAO.

CHART 2

EXPLANATION OF GROUNDRULES AND ASSUMPTIONS UNDERLYING THE "BASIC DEPLOYMENT AND RETRIEVAL" CAPABILITY SHOWN IN CHART 1

a. The basic deployment and retrieval capability is in reference to DOD's heaviest or most demanding mission. The mission calls for a 32,000 pounds delivery capability to a 98 degree inclination-150 nautical miles orbit, plus a retrieval capability of 25,000 pounds from the same orbit. As presently planned, the deployment/retrieval mission will require a four-person crew, seven days in space, and full fuel for the Reaction Control System (RCS) and the Orbital Maneuvering System (OMS).

b. Under the groundrules discussed above, a KSC-launched Shuttle cannot meet the reference mission of 32,000 pounds delivery/25,000 pounds retrieval. For example, the performance at an 8 degrees launch azimuth is 27,499 pounds delivery/25,000 pounds retrieval. However, by adjusting the mission/operating profile (for example, as indicated on chart 1, notes 4 and 5), it is possible to achieve a 32,000 pounds delivery capability.

c. Achieving the 32,000 pounds delivery capability does result in not having same-flight retrieval capability for this mission. We feel this is an acceptable trade-off because DOD, as mentioned by Dr. Perry, plans only two missions per year involving delivery weights greater than 22,000 pounds.

^e Southerly launches from KSC are not feasible due primarily to sonic boom considerations. Similarly, for the same reason plus solid rocket booster splashdown requirements, *direct* northerly launches from KSC to polar (90 degrees) and near-polar (98 degrees) orbits are not feasible. However, these orbits are obtainable from KSC by using an initial launch ascent azimuth which is less than true north and then subsequently using a dogleg (orbiter yaw steering) maneuver to change trajectory in flight. This maneuver is done immediately after SRB separation.

^d About 2 minutes after the integrated Shuttle vehicle ascends from the launch pad, the SRBs are jettisoned at an altitude of about 26 miles. The system is 31 miles downrange, over the ocean. At this point the most critical phase of a Shuttle launch, regardless of launch direction, has been completed.

^e After SRB separation, the orbiter and ET continue ascending and are about 70 miles high when they reach the coastline.

^f The orbiter separates from the ET about 845 miles downrange from the launch site. The orbiter continues into orbit while the ET, in a suborbital trajectory, falls into a remote part of the Indian Ocean.

CHART 3

EXPLANATION OF THE "CAPABILITY GAINED BY OFF-LOADING SRB RECOVERY SYSTEM" SHOWN IN CHART 1

a. *SRB splashdown*

If the SRBs are to be recovered and reused 19 times as planned, NASA estimates that 180 feet is the minimum ocean depth acceptable for parachute-splashdown of the 140 feet long boosters. Off-loading the SRB recovery system (parachutes, etc.) for DOD's two heavy missions per year means that the boosters will not be reusable after splashdown, regardless of ocean depth. For these missions, water depths in the estimated splashdown area range from about 100 to 180 feet, depending upon the Shuttle's launch azimuth. The splashdown water depth associated with a 13 degrees launch azimuth is about 180 feet. According to NASA, this depth is sufficient to preclude the free-fall boosters' impacting and lodging on the ocean floor. However, more northerly launch azimuths (such as 10 or 8 degrees) may have splashdown depths below 120 feet, perhaps necessitating booster salvage operations instead of a normal tow recovery.

b. *SRB costs*

NASA has estimated that each SRB will have an average cost of \$7.4 million (FY 1979 dollars) over the 12-year Shuttle era (FY 1980-91). Off-loading the SRB recovery system should not be construed as advocating throw-away boosters. The growth versions of DOD's heavy payloads are not expected until after 1985. By that time, many recovered/reworked boosters should be available. With proper planning, those boosters having limited remaining launch lives could be used for the few missions under consideration.

CHART 4

EXPLANATION OF THE "CAPABILITY GAINED BY DEPLOYING BUT NOT RETRIEVING ON THE SAME MISSION" AS SHOWN IN CHART 1

a. *Weights associated with satellite retrieval capability*

Compared to a deployment/retrieval mission, a deployment-only mission has greater delivery capability because the latter requires:

	<i>Pounds</i>
2 less crew members and 3 fewer days in space.....	1, 179
1 less cryogenic tank set.....	1, 608
No rendezvous radar.....	337
Less OMS fuel.....	936
Less RCS fuel.....	3, 374
Total.....	7, 434

b. *No increased risk*

According to NASA, none of the adjustments above will adversely affect abort procedures or compromise orbiter and crew safety.

We met again with NASA officials in Washington on March 29. DOD representatives were not present. We were informed that non-safety related manifest items totalling 359 pounds could be off-loaded. The NASA representatives also stated that the performance capability as previously discussed was in error; they said that capability gained by deploying but not retrieving on the same mission was over-stated by 1,050 pounds—that is, the figure should be 6,384 and not 7,434. We have not analyzed this new data.

At this meeting, the NASA representatives also stated that DOD had refigured its mission requirements (i.e., capability needed for its heaviest payloads) and, thus, several thousand pounds should be deducted from the figures tentatively agreed upon earlier. Stated in its simplest terms, it seems that what NASA was saying was that DOD's payload could be greater than the 32,000 pounds requirement previously cited.

During the March 29th meeting, NASA's Associate Administrator for Space Transportation Systems commented that the hazards of land overflight was the real issue regarding northerly launches from KSC. He said potential constraints due to sonic boom considerations or oil and gas leases could be overcome. Moreover, he added that if for some reason the total performance capability was now not enough for DOD's heavy payloads, sufficient system improvements could be made at an additional cost. The Associate Administrator indicated, that assuming

land overflight was acceptable, it would be more cost-effective than building Shuttle facilities at Vandenberg.

SONIC BOOM CONSIDERATIONS—KSC

During the March 17, 1978, meeting at Johnson Space Center, NASA Headquarters and Johnson Space Center officials expressed the concern that a 13 degree launch azimuth could cause sonic boom overpressures in excess of 2.0 pounds per square foot (psf) on Florida land areas during launch. (For a delineation of the relative behavior effects caused by sonic boom overpressures, see table 1.)

TABLE 1.—Behavioral effects of sonic boom

Sonic boom overpressures (psf):	Behavioral effects
0.3-----	Orienting, but no startle response, Eyeblink response in 10 percent of subjects. No arm/hand movement.
0.6 to 2.3-----	Mixed pattern of orienting and startle responses. Eyeblink in about half of subjects. Arm/hand movements in about a quarter of subjects; no gross bodily movements.
2.7 to 6.5-----	Predominant pattern of startle responses. Eyeblink response in 90 percent of subjects. Arm/hand movements in more than half of subjects; gross body flexion in about a fourth of subjects.
7.1 to 13.4-----	Arm/hand movements in more than 90 percent of subjects.

SOURCE.—“Environmental Impact Statement,” Space Shuttle Program, Draft, July 1977.

IS THE RECENT DATA ACCURATE?

The data provided us on March 17th indicates that overpressures exceeding 2 psf may impact on Florida land areas during a KSC Shuttle launch to the 13 degree azimuth (see figure 2). This data differs significantly from sonic boom overpressure charts developed by NASA previously. For example, the October 1976 NASA/USAF report to OMB indicated that an 8 degree launch azimuth was sufficient to preclude overpressures of more than 0.5 psf from impacting on land areas (see figure 3). An earlier report prepared by NASA's Marshall Space Flight Center had reached this same conclusion. Although the Marshall Center's estimate was qualified as being preliminary and awaiting detailed definitions of flight control systems and other variable factors, it was recognized as being representative of the Shuttle system and deviations from the results predicted were expected to be minimal. Moreover, the Center's study was a relatively detailed effort and made use of a sonic boom computer program.

In contrast, the recently supplied data is only a generalized estimate—no detailed study was performed to support it. For example, the assumption was made that the trajectory for a 13 degree launch azimuth from KSC (northerly) would not be significantly different than the trajectory for a 70 degree orbit inclination from Vandenberg (southerly). The Vandenberg sonic boom footprint was thus merely overlaid on a Florida coastline map. Scientific reports, however, point out that there is sufficient difference between northerly and southerly launch trajectories to warrant separate analyses of the sonic boom overpressure footprints. We have therefore requested that NASA perform a detailed computer-supported study of the overpressure footprint for a 13 degree launch azimuth; NASA has estimated that this effort will require several weeks to complete. We suggest that similar studies should be considered for launches at 10 degrees and 8 degrees.

In addition, there are other factors which should be taken into consideration before a final estimate of sonic boom overpressure is made. These factors include wind effects, atmospheric conditions, payload variations, aerodynamic uncertainties, azimuth and inclination effect, etc. Some of these factors (e.g., wind effects) can be estimated and taken into consideration now, but some may require actual flight data before final sonic boom predictions can be made.

It should also be noted that, under presently planned reentry and landing profiles at KSC, the Shuttle will cause sonic boom overpressures ranging up to 2.1 psf. The land area impacted by sonic boom overpressures stretches across the entire peninsula from Tampa to KSC in a path approximately 27 miles wide and 75 miles long (see figure 4). About 500,000 people and such cities as Orlando, St. Petersburg, Lakeland, and Winter Haven will experience some degree of overpressures, ranging up to 2.0 psf. The region impacted by the maximum over

pressures—those in the range of 2.0 to 2.1 psf.—is, however, relatively small and sparsely populated.

SONIC BOOM CONSIDERATIONS—VANDENBERG

Sonic boom overpressures impacting on land during Shuttle launch are not limited to northerly launches from KSC. A 70 degree launch inclination now planned for a Vandenberg Shuttle could result in overpressures as high as 30 psf impacting off the California coast on the Channel Islands (see figure 5). Some marine scientists have stated that the force of such severe sonic booms (up to 30 psf) could disrupt critical wildlife colonies on these islands. The Channel Islands serve as the habitat for several rare or endangered species, including the brown pelican, and also provide the most diverse seal and sea lion rookery in North America. At present, 16,000 to 17,000 sea lions use one of these islands as a breeding ground and the only other breeding area is an island off the Alaska coast. Marine scientists are concerned that severe sonic booms could startle adult birds and marine mammals into abandoning their breeding areas, thus leaving the young subject to predators or starvation. Also, it is believed that the sonic booms could crush delicate seabird eggs and damage the eardrums of a variety of animals.

USAF officials are not unaware of this potential problem. A series of studies to examine the possible harm from this degree of overpressure are planned, partly in response to the growing concern among marine scientists. To move the most intense booms from these islands, changes in launch velocities and inclination are being considered.

The reentry boom at Vandenberg is expected to affect a few thousand people and subject the Channel Islands to overpressures up to 2.0 psf (see figure 6).

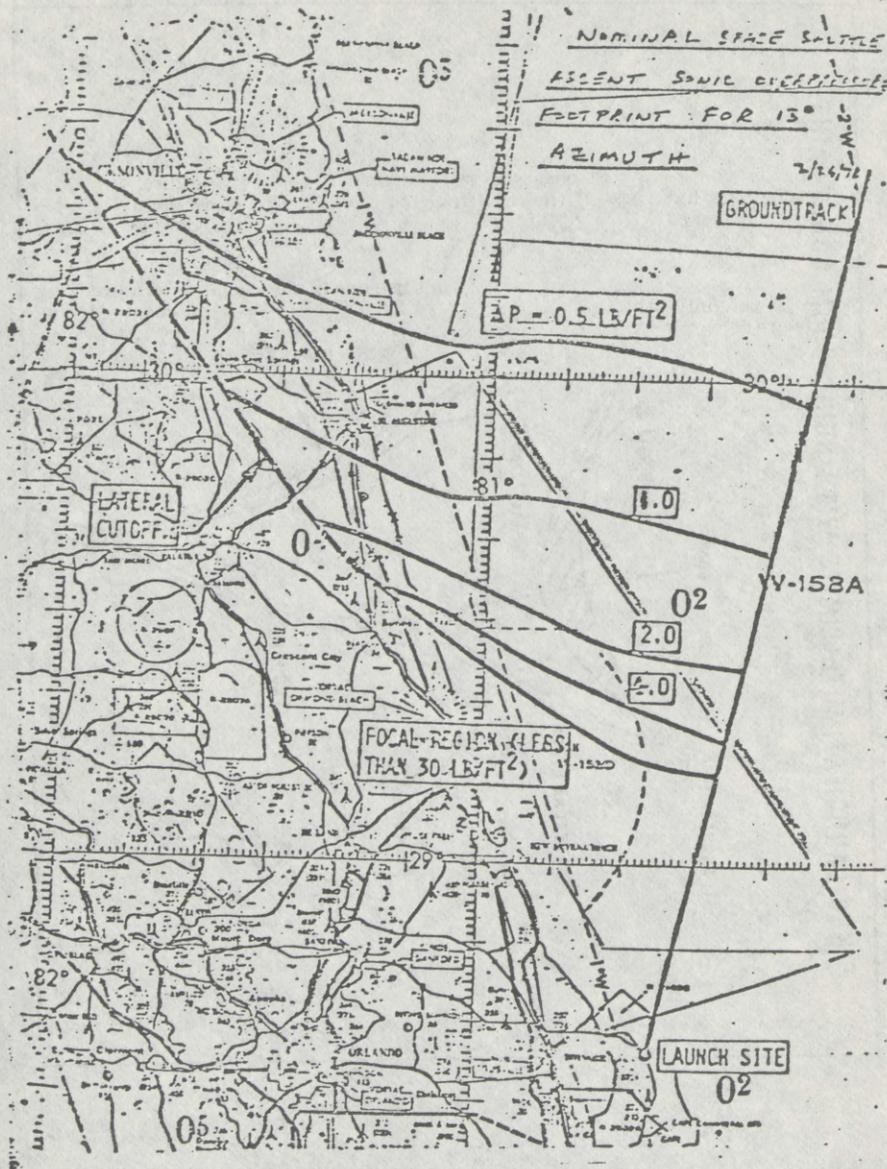
SUMMARY AND CONCLUSIONS

We believe that insufficient data has been developed to allow an accurate determination of what degree of sonic boom overpressure would impact Florida land areas with a northerly KSC launch. Detailed analysis of appropriate trajectory data and other variable factors may provide sufficient basis to make sound decisions.

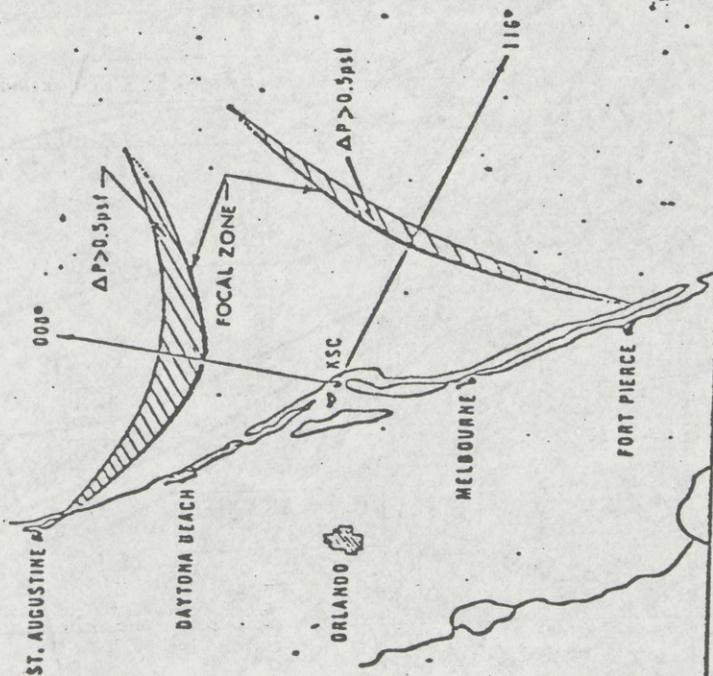
OIL AND GAS LEASE CONSIDERATIONS

During the March 17, 1978, meeting at Johnson Space Center in Houston, NASA Headquarters and JSC representatives expressed the concern that northerly Shuttle launches from Kennedy Space Center could be constrained by oil and gas lease tracts on the outer continental shelf (OCS). Basically, NASA's specific concern involves several lease tracts, located in waters which are a small portion of the estimated splashdown area for the Shuttle's solid rocket boosters. These tracts were recently leased to commercial interests by the Department of the Interior as part of OSC Sale Number 43.

We question whether offshore oil and gas leases would be as constraining against northerly launches as indicated by NASA. If such leases are a constraint, then all easterly launches from KSC will be similarly affected. To explain, another planned sale by the Interior Department, OCS Sale Number 54, contains about 160 lease tracts which could be affected by Shuttle launches within the presently-planned azimuth range. See figure 7.

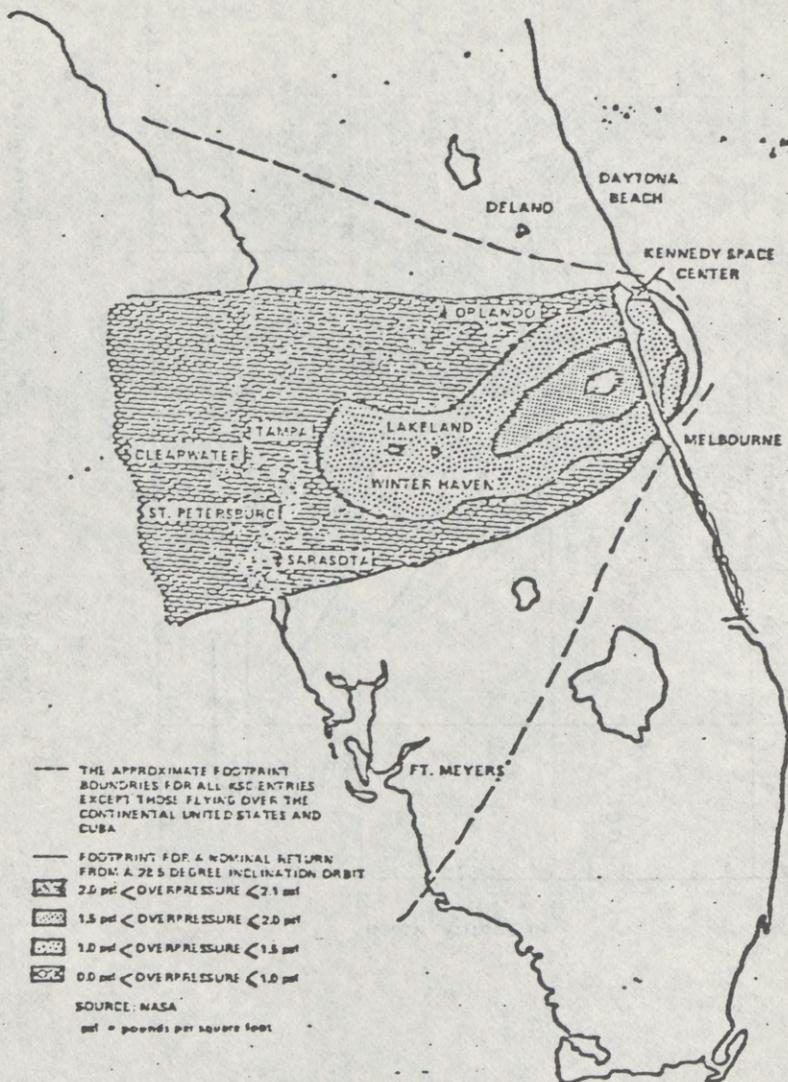


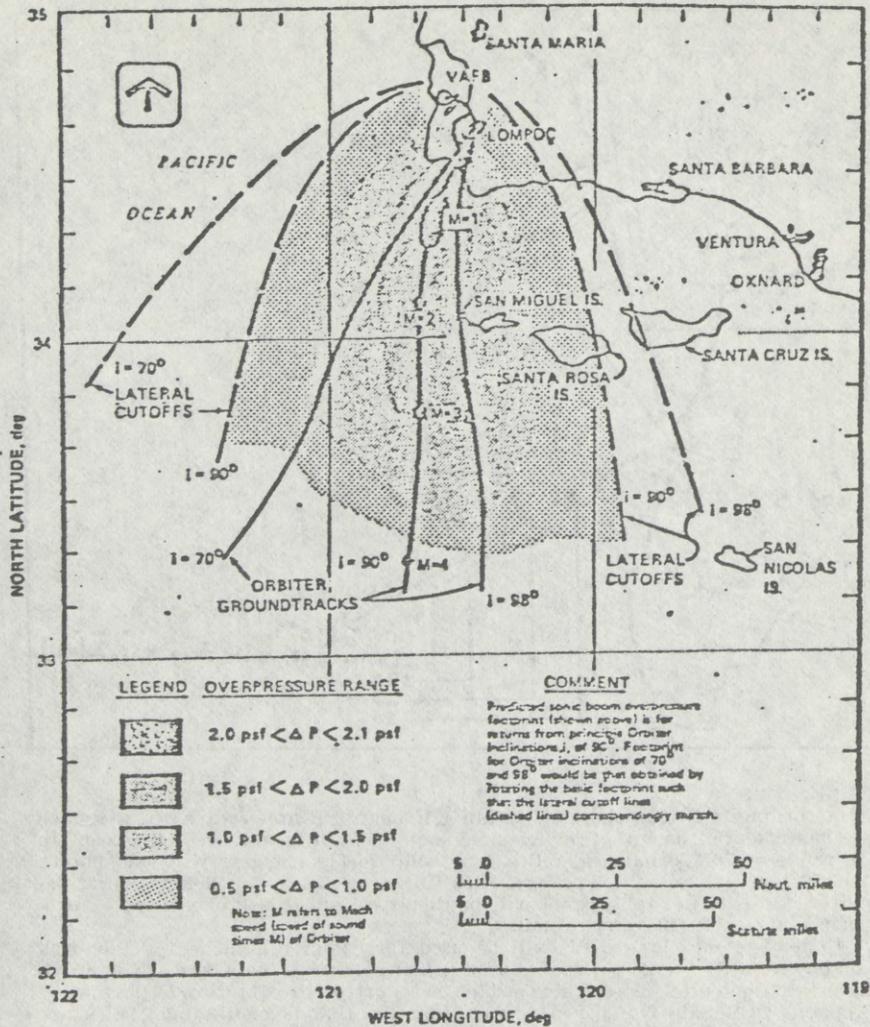
KSC LAUNCH AZIMUTH LIMITS WITH SONIC BOOM CONSTRAINT



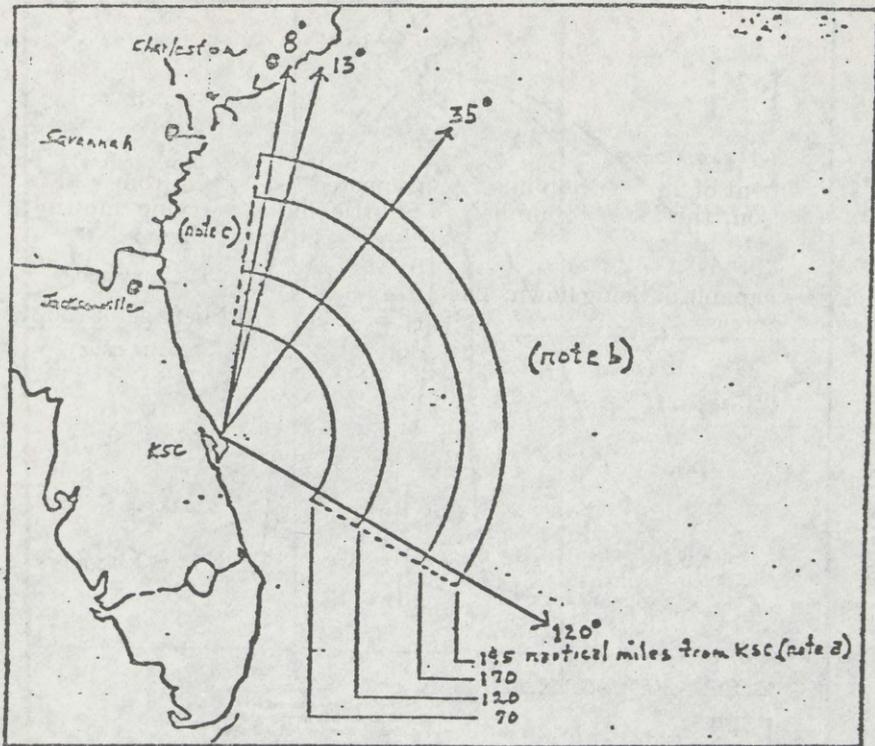
SPACE SHUTTLE SORIC BOOK

OVERPRESSURES PREDICTED FOR KENNEDY SPACE CENTER APPROACHES





Predicted footprint of sonic boom overpressures resulting from dorsal end-of-mission return of Orbiter to Vandenberg Air Force Base.



Notes:

^a According to NASA, the area within a 195-nautical mile-radius of the launch site has potential hazards. For example sonic boom overpressures may focus in the range of 70-120 nautical miles. The solid rocket boosters will splashdown 120-170 nautical miles downrange. Also, for a return-to-launch-site abort maneuver, the external tank's fuel will be dispersed and the tank dropped downrange at about 170-195 nautical miles.

^b Under present plans, KSC will be used for easterly launches at azimuths ranging from 35 to 120 degrees. Located between these azimuths are approximately 160 potential lease tracts, which are part of the Interior Department's Proposed OCS Sale Number 54. Tract identification is continuing; sales are tentatively scheduled to begin in late 1979.

^c Located within the azimuth range of 8 to 13 degrees are approximately 7 tracts, which are part of OCS Sale Number 43. Tract identification has been completed and several lease bids have been made. For example, along the 13 degrees azimuth, ten lease bids have been submitted—five of the tracts under bid are located in waters which are a very small portion of the estimated SRB splashdown area.

FIGURE 7.—Oil and Gas Lease Considerations

NASA response. The technical feasibility of the GAO proposal that all Civil and Military payloads currently projected thru 1992 should be accommodated by the Shuttle with northerly launches out of KSC (overflying the U.S., Canada and U.S.S.R.) is contingent upon three major considerations: Sonic boom impingement during ascent; Solid Rocket Booster impact; and Shuttle capability with yaw steering during ascent.

NASA considers that acceptable limits for the first two require a launch azimuth of no less than 19 degrees east of north. Under this condition, Shuttle capability with yaw steering after booster separation is not adequate to perform at least one high priority DOD program of 17 flights between 1984 and the end of CY 1991. The Shuttle capability also is inadequate to satisfy the high inclination orbit requirement of 28 Spacelab missions projected for launch from VAFB. In addition, there are a number of Shuttle flight carrying multiple payloads to high inclination orbits which exceed the performance of the Shuttle. These payloads would have to be regrouped into different cargoes capable of being flown. This less efficient packaging of payloads would increase the number of Shuttle flights and add between \$150M and \$200M in transportation costs.

In view of the fact that the DOD missions cannot be accommodated as GAO proposes, some alternative means of satisfying these missions is needed. In their draft report provided to NASA in early January 1977, GAO suggested three possible options which might be considered if the DOD mission requirements could not be met as they proposed. These options were:

1. Dual KSC Shuttle launches of the payload and an upper stage followed by on-orbit assembly.
2. Retain limited STS facilities at VAFB for the DOD heavy payloads.
3. Retain ELV capability at VAFB to launch the DOD heavy payloads.

Analyses performed by NASA of these GAO options using the 487 mission model from the 1977 OMB Study Update were reviewed with GAO representatives on a number of occasions. The more critical issues and impacts are given below:

NASA does not consider any of the three options proposed by the GAO to accommodate the few demanding high inclination DOD missions as acceptable. All remaining traffic currently planned for launch at VAFB would require overflight of the U.S., Canada and Russia to achieve the required orbit. The NASA and the DOD consider that the risk, international implications and security considerations preclude this type of launch for STS missions. However, even if the political and safety aspects of these overflight missions are overlooked, the costs associated with the options proposed by GAO would be as great or more expensive when compared to a two site STS operation.

Considering the option which proposes on-orbit assembly, dependence on this concept erodes most of the cost benefits of a single site by requirements for development of on-orbit assembly capability for the applicable upper stage and/or the spacecraft and by requiring multiple Shuttle launches for single missions. In addition, if the Inertial Upper Stage is considered for such missions, a new configuration would have to be developed to meet polar orbit delta-velocity requirements and Shuttle high inclination lift constraints. This operation may be unacceptable for certain payloads.

Additional costs would be incurred to procure extra stages, and payload benefits associated with payload retrieval would be lost. NASA estimates that this option would result in about \$150M cost increase.

The retention of limited Shuttle capability at VAFB would be even less cost effective and NASA analyses show that it would result in a cost increase of \$0.4 to \$0.5 billion. Since VAFB is planned with a "single line flow," most of the facilities currently planned would still be needed. The launch pad, payload handling facility and accommodations for ET's and SRB handling would still be required. The runway would be needed to allow for aborted flights. Considerable check-out and refurbishment equipment would be necessary to take care of anomalies which might occur during the launch sequence even if the Orbiter were checked out prior to delivery to VAFB. Shuttle ferry flights would incur additional costs as well as increase the timelines for Orbiter turnaround. Finally, even though operational manpower could be reduced, a minimum operations crew would have to be maintained. It is doubtful if the manpower level could be reduced much below one-half of the planned complement and still support a launch.

In addition, much of the savings in VAFB development would be off-set by increased investment costs at KSC if the projected traffic model is to be supported. This could run as high as about \$250M.

Retention of limited ELV capability at VAFB, is also unattractive and would result in a cost increase of about \$0.1 billion compared to a full STS two-site operation. A principal objective of the Shuttle program was to permit early replacement of ELV's with the STS. Retention of both on ELV and STS capability has been shown in numerous studies to be more expensive than Shuttle only. NASA estimates show that combining the cost of ELV operation, augmentation of KSC facilities, loss of payload benefits and funds already expended about offset the savings achieved by elimination of VAFB as a Shuttle launch site.

If the level of space activity were reduced to approximately the number of flights that could be supported out of KSC without additional facilities (approximately 400 flights), the cost reduction would be relatively small—on the order of \$0.3 to \$0.4 billion. About one-half of these reductions results from not having to expand KSC facilities. The remainder results from a reduction in total transportation cost, even though the individual Shuttle cost/flight increases about 10%.

SAVINGS IF GAO REPORT IMPLEMENTED

Question. What would be the savings between now and 1992, if the GAO proposals not to buy Vandenberg AFB and to have a three orbiter fleet were accepted rather than the current DOD/NASA proposals?

DOD answer. With consideration for orbiter attrition, the three orbiter GAO proposal will provide a total of 249 Shuttle flights. It will therefore require an additional 311 ELV flights or a total of 560 flights to satisfy the requirements of the baseline 487 Shuttle flight model. This alternative was examined in support of the 1977 OMB study and found to result in an increased cost of \$6.4 billion.

NASA answer. The results of the joint NASA-DOD analysis of orbiter fleet production options prepared for OMB in October 1977 show no economic advantage for the three orbiter, single site option

when equivalent missions are performed using either a five or four orbiter fleet operating from two sites. The cost comparisons displayed below show that for a 487 flight mission model, a five orbiter fleet with attrition is over six billion dollars more cost effective than the three orbiter single site alternative. Even at a much lower flight rate, e.g., a 360 flight mission model, the five orbiter fleet is less costly by about two billion dollars than the three orbiter option. These results indicate that the projected savings due to reduced production costs with fewer orbiters and elimination of VAFB construction costs are more than offset by increased costs of expendable launch vehicles, and loss of payload benefits without Shuttle retrieval and reuse.

[In billions of fiscal year 1979 dollars]

Mission model	Number of orbiters		
	2 sites		1 site 3 flights
	5 flights	4 flights	
487	29.7	34.1	36.1
425	28.8	30.7	31.0
360	27.7	28.0	29.9
300	26.7	26.9	27.5

GAO answer. As shown below, a single-site STS program could save the Government from \$2.3 billion to \$3.5 billion, depending upon the annual launch rate from KSC.

COST ADVANTAGES OF 1-SITE (KSC) SHUTTLE PROGRAM

[Dollar amounts in billions]

Annual launch rate from KSC	Cost savings of not modifying Vandenberg to accommodate Shuttle operations (real year dollars)		
	Facilities	Manpower (fiscal year 1983-92)	Total
40	\$1.0	\$2.5	\$3.5
60	.8	1.5	2.3

Savings accrue from single-site operations because Vandenberg Facilities would not be built and manpower to operate the site would not be needed (see charts 1 and 2). These savings, however, must be offset by the additional facilities and manpower required at KSC to handle any additional workload. Planned facilities and manpower at KSC can handle over 40 Shuttle flights a year. However, additional facilities (costing about \$0.2 billion—see chart 3 below, note 4) and manpower (costing about \$1.0 billion—see chart 4 below, note 2) would be needed at KSC to support 60 or more yearly launches, thus slightly reducing overall facility savings to \$0.8 billion (\$1.0 billion minus \$0.2 billion) and overall operations savings to \$1.5 billion (\$2.5 billion minus \$1.0 billion). Based upon present and past levels of about 26 to 35 expendable launch vehicle flights per year, 40 Shuttle launches a year is a more realistic level of activity than 60; thus, KSC-only STS operations could save the Government up to \$3.5 billion over the next

decade. It is important to note that the \$3.5 billion establishes the maximum savings due to elimination of Vandenberg. Under certain circumstances, a portion of the \$3.5 billion savings could be achieved by simply reducing the flight level of a two site operation from 60 to 40 flights per year.

The detail and sources of the \$2.3 billion to \$3.5 billion potential savings are given in the following five charts:

CHART 1. Vandenberg facilities investment

Category	[Millions of real year dollars]	Amount
Research and development	-----	¹ \$338. 0
Support equipment	-----	¹ 269. 0
Communications equipment	-----	¹ 44. 0
Military construction	-----	¹ 226. 0
Subtotal	-----	² 877. 0
Launch pad No. 2	-----	³ 175. 7
Total	-----	1, 052. 7
Costs incurred through fiscal year 1978	-----	⁴ (80. 9)
Vandenberg facilities savings	-----	⁵ 971. 8

¹ These are the estimated amounts through fiscal year 1983. The figures are as presented by General Coy in his testimony.

² According to General Coy's testimony the upper bound of this estimate is \$1,200,000,000. Therefore, potential facilities savings could be higher than shown on this chart.

³ This estimate was provided us by the Air Force's Space and Missile Systems Organization (SAMSO).

⁴ See chart 5.

⁵ This figure rounds to \$1,000,000,000.

CHART 2.—Vandenberg manpower costs (direct and indirect)

Fiscal year:	[Millions of real year dollars]	Amount
1983	-----	¹ \$168. 5
1984	-----	¹ 241. 8
1985	-----	¹ 258. 9
1986	-----	¹ 265. 0
1987	-----	¹ 276. 6
1988	-----	¹ 295. 9
1989	-----	¹ 316. 7
1990	-----	¹ 338. 8
1991	-----	¹ 362. 5
1992	-----	¹ 96. 8
Subtotal	-----	2, 621. 5
Minus overhead	-----	² (100. 0)
Total	-----	³ 2, 521. 5

¹ The source of these costs, is the Space/Shuttle preliminary cost data base, dated June 1977, prepared by the Operations Resources Analysis Office, Johnson Space Center. The figures were given in fiscal year 1975 dollars; we converted them to real year dollars, using an annual inflation factor of 7 percent. The source document contained the following introductory comments: "The resources data contained within this document covers all those costs and associated manpower (direct and indirect) to provide the standard Shuttle services * * * for the current STS Flight Traffic Model."

² According to NASA Headquarters and DOD (Pentagon) officials, the manpower estimates for Vandenberg include about \$1,000,000,000 of overhead costs which may not disappear if Shuttle operations do not materialize at Vandenberg.

³ This rounds to \$2,500,000,000.

CHART 3.—*Single-site Shuttle program: additional facilities costs at KSC if launch rate increases from 40 flights per year to 60*

[Millions of real year dollars]

Shuttle research and development:	
Launch processing system	-----
Equipment	-----
Equipment surcharge for non-Government furnished equipment	-----
Site activation	-----
Design support	-----
Subtotal	69
Payload research and development:	
Ground support equipment	-----
Launch processing system	-----
Design support	-----
Subtotal	24
Construction of facilities:	
Mobile launch platform No. 3	-----
SRB disassembly workstands	-----
Orbiter processing facility	-----
Subtotal	¹ 88
Additional mobile launch platform No. 4	25
Other:	
Program ground support equipment	-----
Spares	-----
Propellants	-----
Payload support	-----
Shop capability	-----
Subtotal	² 40
Total	³ 246

¹ Present planning, which anticipates 40 flights a year at KSC, calls for three mobile launch platforms. Therefore, this figure (\$88,000,000) is overstated by \$25,000,000.

² We disagree with these costs; they appear to be operations costs which would not represent "additional" facilities costs associated with single-site operations.

³ This total, and the detailed breakdown given above, were provided us by Mission Analysis and Integration, NASA Headquarters; adjusted per footnotes 1 and 2, is \$181,000,000, which rounds to \$200,000,000.

CHART 4.—*Single-site Shuttle program: Additional manpower costs at KSC if launch rate increases from 40 flights per year to 60*

[Millions of real year dollars]

Fiscal year:	Amount
1983	¹ \$282.6
1984	¹ 277.7
1985	¹ 297.2
1986	¹ 318.0
1987	¹ 340.2
1988	¹ 364.0
1989	¹ 389.5
1990	¹ 416.8
1991	¹ 446.0
1992	¹ 422.7
Subtotal	3,254.7
Times (percent)	.30
Total	² 976.4

¹ The source of these costs is the document indicated in chart 2, footnote 1.

² Kennedy Space Center, as currently planned, will support 40 Shuttle flights per year. Based upon discussions with officials at NASA Headquarters, Johnson Space Center (JSC), and KSC, apparently no studies have been made of how much additional manpower would be required at KSC to support up to 60 Shuttle flights a year (a 50 percent increase in the currently planned flight activity). However, JSC and KSC representatives have commented informally that any increase in manpower requirements would be minimal but could approach 30 percent. On Mar. 30, 1978, officials in NASA Headquarter's Space Transportation System Operations Office stated that 60 launches a year from KSC might require slightly more than a 30 percent increase in the proposed shuttle manpower level at KSC. However, as stated above, this information was not based on any detailed evaluation.

CHART 5.—VANDENBERG FACILITIES COSTS INCURRED THROUGH FISCAL YEAR 1978

[In millions of real year dollars]

Category	Prior years	Fiscal year 1978	Totals through fiscal year 1978
Research and development.....	\$31.2	\$24.3	\$55.5
Support equipment.....		17.2	17.2
Communications equipment.....		8.2	8.2
Military construction.....			
Total.....	31.2	49.7	80.9

Note: The figures are as presented by General Coy in his testimony.

TITAN 34D VEHICLE

Question. The DOD expendable launch vehicle will be the Titan 34D which is a modification of existing launch vehicles.

Why was a new design required?

DOD answer. The integration of the Inertial Upper Stage and its redundant avionics into the Titan III family will correct current Titan III reliability deficiencies, reduce unit production costs, increase Space Shuttle transition flexibility, and reduce Space Shuttle backup capability costs. The principal benefits are the 6-7% increase in reliability and the reduction from four to one in the number of Titan configurations in use during the Space Shuttle transition period. This basic Titan III(34)D can be used with the IUS for high altitude missions from Cape Canaveral AFS, FL or without the IUS for low altitude missions from Vandenberg AFB, CA.

Question. What will be the cost of developing a Titan III(34)D?

DOD answer. The development of the Titan III(34)D is expected to result in a net savings of between \$50 and \$110 million. The range of savings is a function of the quantity of backup vehicles procured and the launch date of the last Titan III(24)B. To achieve these net savings, an investment of \$74.2 million is required, \$25.4 million in FY 79 and \$17.2 million in FY 80, with \$31.6 million prior year funding.

Question. When will the Titan III(34)D have sufficient flight experience to be certified as an acceptable backup launch vehicle in case of Shuttle grounding or other problems?

DOD answer. The initial Titan III(34)D/IUS launch will place an operational payload in orbit. Therefore, the Titan III(34)D will be a certified vehicle concurrent with the first launch in 1980.

Question. Why is a new configuration of the Titan being used as a backup vehicle? Doesn't this add additional risk to the backup strategy?

DOD answer. The Titan III(34)D/IUS configuration minimizes the DOD transition costs while providing a projected 6-7 percent increase in launch reliability for high altitude missions. Rather than add risk, this new configuration, with its redundant avionics, will enhance mission success.

PERFORMANCE, SCHEDULE PROBLEMS

Question. Potential performance and schedule problems are also of concern to some planners. Are there any major degradations in Shuttle performance?

NASA answer. NASA's current projections and commitments for Space Shuttle performance at the initiation of the *operational* use of each Orbiter are that Orbiters 103 and 104 will have the full required capability, the STA 099 vehicle will be about 2000 pounds low in capability, and Orbiter 102 will be about 3000 pounds low in capability.

Question. How reliable are the current estimates as to the payloads which can be placed in orbit?

NASA answer. NASA planning to date has found no technical reason why all the payloads currently scheduled for Shuttle launch through mid-1982 (the extent of the early planning phase) cannot be accommodated with the Shuttle. Twenty-three launches being planned through January 1982, including some development flights, have payloads assigned. Among these are twelve commercial payloads for which NASA has received advance payment or progress payments, eleven government payloads (one DOD, two NOAA, eight NASA) for which funding has been approved, and one dedicated ESA Spacelab mission.

As for the Shuttle schedule, there is no major problem anticipated by Shuttle today that would cause a schedule slip beyond the time required to launch important commercial or NASA payloads.

Question. Are there some payloads which may not be able to go on Shuttle if the full thrust requirements are not met?

DOD answer. If the operational Shuttle were to be limited to the 100% thrust level planned for Orbital Flight Test (versus 109% required for operations) the DOD would not be able to launch the VAFB Reference Mission 4 without compensating weight reductions. It is planned to launch two of these payloads per year or 17 within the FY 1983 to first quarter FY 1992 time period.

NASA answer. There are some high priority DOD payloads that are scheduled which would be impacted by a reduction in full Shuttle performance capability. These missions, as well as the NASA Planetary and Spacelab missions, were used in the Shuttle's preliminary design phase as the basis for payload requirements. A ten percent reduction in payload-delivery performance could seriously affect the accommodation of these planned missions. In addition, current flight manifests would require reassessment to assure that envisioned mixed cargo missions were consistent with the degraded performance of the Shuttle.

Question. What is the role of the Inertial Upper Stage and is its development proceeding on schedule?

DOD Answer. The Shuttle is performance constrained to low earth orbits of less than approximately 400 nautical miles. The purpose of the upper stage is to carry the spacecraft from low earth orbit to the high energy orbits—namely, synchronous equatorial and

12-hour orbits and planetary trajectories. The IUS completed a major review by the Defense Systems Acquisition Review Council on 23 March thus enabling initiation of Full Scale Development as scheduled. The IUS is planned to be available for first launch on both the Shuttle and Titan III (34)D in mid-1980.

Question. Would launches requiring use of the Inertail Upper Stage be limited in any way if Kennedy rather than Vandenberg were used?

DOD answer. The Inertial Upper Stage is planned to be used at KSC only; no plans exist for its launch from VAFB. The decision to use KSC only would have no impact on IUS use providing provisions are made to handle the resulting increased KSC traffic.

Question. The Air Force RDT&E budget requests \$32,600,000 for the Space Booster program. How much of this is for development of the Titan III(34)D/IUS? How much will be required in FY 1980 to complete development?

DOD answer. The Titan III(34)D/IUS development is projected to require \$25.4 million in FY 1979 and \$17.2 million in FY 1980.

Question. If the Titan III D/IUS has not completed development, why have procurement funds been requested in fiscal year 1978 and 1979? When were the FY 1978 procurement funds obligated?

DOD answer. The changes to integrate the Inertial Upper Stage and its technology into the Titan III family are straight forward. The structural and avionics portions will be completed in time to avoid any production impact. Analytical and software portions are time phased to provide outputs before the launch vehicle is delivered. The initial contracts for the Titan III portion of the vehicle were begun in Dec 1977; the Inertial Upper Stage (IUS) production portion will be conducted in two steps: material procurement in Apr 1978, and fabrication go-ahead in Apr 1979. All flights of the Titan III D/IUS will carry operational payloads with the first flight scheduled for mid-1980.

Question. A total of \$87.6 million is requested for continued development of the Inertial Upper Stage in the FY 1979 Space Shuttle program. The IUS is scheduled to enter Full Scale Development this month. How can procurement of two additional IUS vehicles be justified in FY 1979?

DOD answer. There are nine initial production vehicles to be procured; four for DOD, and five for NASA. The number of initial production vehicles to be procured was a function of the mission needs for the IUS, the 30 month production lead time, and the maturity of the IUS. Long lead items for the first follow-on production lot will be procured through PE 35171F, Space Launch Support, funding in FY 1979. Assembly of the first follow-on lot and procurement of subsequent vehicles will follow Milestone III production phase approval given by the Defense Systems Acquisition Review Council. The vehicle delivery requirements are determined by the approved DOD space mission model and the NASA statement of need for IUS vehicles.

VULNERABILITY

Question. The physical vulnerability of a single launch site is a possible objection to the selection of a single site as recommended by GAO. What redundancy will exist at Kennedy under current plans?

NASA answer. The level of redundancy at the Kennedy Space

Shuttle launch and landing site which exists under current plans is related to that which is built-in due to a dual line capability and multiple facility and support elements. The level of redundancy as related to risk varies widely from a high level such as exists with two remotely located launch pads to a lower level where there are two processing flows within a single building. During the operational era, for example, there will be two launch pads, two Mobile Launch Platforms, two Orbiter processing bays in the same building, two vehicle assembly cells in the same building, and two firing rooms in the same building.

A variety of support facilities are located around the NASA Center and the Air Force areas.

Question. What additional redundancy could be added to Kennedy if it were decided not to build Vandenberg? What would be the cost of adding extra redundancy to the Kennedy launch site?

NASA answer. If it were decided not to build the Vandenberg AFB Space Shuttle launch and landing capability, and an equivalent level of national space activity were maintained, certain additions would be required at the Kennedy site which would constitute some level of added redundancy. These include addition of the third firing room and the third and fourth Mobile Launch Platforms, and augmentation of a number of other facilities, for an estimated total additional cost of about \$250 million. Since most hazardous operations are conducted at the launch pad, addition of a third pad would provide for extra redundancy in that area. A third pad has not been designed or costed, but a new pad for the 1983-84 time period could cost up to \$150 million depending upon the criteria to which it would be designed.

All these modifications at KSC to provide some redundancy cannot, however, economically replace the redundancy and cost advantages afforded by a west coast Shuttle launch site for polar and near-polar missions.

Question. What is the vulnerability of current launch sites using expendable vehicles?

DOD answer. Current expendable launch vehicles are essentially single string operations from manufacture, through transportation, processing, build-up, and launch. The multiple types of ELVs provide some measure of redundancy since each has its own facilities. The current DOD payloads are, however, designed to the characteristics of a specific ELV. It would be, therefore, expensive and time consuming to move a specific payload to another ELV.

Question. How would the vulnerability of the Kennedy site compare to the current vulnerability of facilities using ELVs?

DOD answer. They are equally vulnerable.

GAO answer. KSC-only operations, using the two launch pads planned, may provide more responsive backup than the Nation is currently experiencing with existing expendable launch vehicles (ELVs). For instance, the planned two-week turn-around time for the Shuttle is much faster than for ELVs. At KSC, 17 weeks (without overtime work) are needed to ready a replacement Titan III. At Vandenberg, ELVs are assembled on the pad, and turnaround time for a replacement ELV is about 4 to 6 months (without overtime). These turnaround times are lengthy because, under current operations, ELV launches are not "backed-up" with a standby ELV; the production pipeline must provide replacements.

It should also be noted that the Space Shuttle Launch and Recovery Site Review Board, established by NASA in April 1971 to evaluate candidate sites, established the technical feasibility of single-site Shuttle operations. Actually, the primary thrust of the Board's effort was selection of a single-site-vulnerability was not a source of overwhelming concern.

Question. If Vandenberg were built, what would be the backup for a catastrophic accident at Vandenberg, and, would northerly launches from Kennedy be authorized if Vandenberg were damaged?

DOD answer. Given an absolute overriding operational necessity and loss of Vandenberg launch capability, polar launches might be conducted from KSC for such limited time required to regenerate the Vandenberg capability. We do not recommend that mode of operation as the normal for planned operations. It is, however, a logical use of the redundancy offered by identical systems operating from two sites. We believe that such a contingency operation must be forced by the highest operational necessity and would probably require Presidential approval for each launch due to critical national security versus safety considerations.

NASA answer. NASA, alone, could not grant such authorization. Both NASA and DOD have stated their unwillingness to accept responsibility for polar launches from KSC.

Question. Would northerly launches from Kennedy be authorized if Vandenberg were damaged?

GAO answer. Range Safety personnel have not established maximum or minimum allowable risk for either the Shuttle or for expendable launch vehicles. Generally, Air Force range safety personnel evaluate each flight's acceptability based on factors such as casualty expectations and importance of the payload to national security. According to the Aerospace Corporation, a DOD contractor, launches of expendable vehicles have been permitted with casualty expectations as great as 1 in 12,500; but, more characteristically the acceptable limit has been 1 in 100,000. In comparison, the Aerospace estimate of casualty expectations for a Shuttle launched northerly from KSC was 1 in 166,667—well within the limits just mentioned.

The Aerospace Corporation's analysis is dated June 1976. In considering the population distribution under the Shuttle's northerly flight path, the study used 1970 census data which will be about 13 years old before the Shuttle is scheduled to begin polar launches. However, the Aerospace analysis is the most recent available and does provide some risk assessment perspective. An updated analysis might be in order if full consideration is given to northerly KSC launches.

According to NASA as well as Aerospace Corporation, land overflight has been permitted in the past, however, this has been the exception rather than the rule. The reason for very limited overflight derives from the design of the past space vehicles. Past launch vehicles were expendable, having one or more stages disposed of at various phases of launch ascent. Thus, it has not been feasible to overfly most land areas close to the launch site.

By contrast, the Shuttle's design offers more operational flexibility. The most critical phase of a Shuttle launch is from lift-off to solid rocket booster (SRB) separation. For northerly launches from KSC, the critical phase will be over the approximately 345 miles of ocean

between KSC and the coast of South Carolina; the SRBs, jettisoned early in the flight, would splashdown in the Atlantic. The external tank, which remains attached to the orbiter until just prior to orbital insertion, would splashdown in a remote part of the Indian Ocean.

Moreover, the Shuttle is expected to be highly reliable because it is a man-rated system with numerous safety features including redundant critical systems. It is expected to be more reliable by several orders of magnitude than expendable launch vehicles. This is because the Shuttle's design is an extension of technology developed from expendables. Based upon analysis of commercial and military aircraft, Aerospace concluded that a .9999 reliability (100 losses per million) would be a reasonable goal since the factor is not as high as for commercial airlines or as low as for military aircraft such as the F-84. In selecting this goal Aerospace Corporation noted that a reliability factor approaching .9999 would be necessary to provide a cost effective system with acceptable risks to the crew. Aerospace used this factor in estimating the 1 in 166,667 casualty expectation figure mentioned earlier.

Actual Space Shuttle reliability, of course, must be demonstrated. The exact number of Shuttle launches required to gain confidence in the Shuttle's performance reliability has not been determined. By June 1983, however, when polar Shuttle launches are scheduled to begin from Vandenberg, the STS will have had over 3 years' experience, entailing over 50 Shuttle flights. There is some logic in assuming that these flights should provide a sufficient "shake-down" period in which problems will be identified and corrected. If problems still exist after 3 or 4 years of operations, the entire Shuttle program may be in jeopardy. During his testimony today, Dr. Frosch stated, "I think we will have to get through the orbital flight test period before we would have sufficient confidence that we would be through with the expendable launch vehicles." The test period will consist of 6 flights. If 6 Shuttle flights provide enough confidence to phase out all expendables, then why should 50 or more flights not generate confidence to permit land overflight?

Regarding this question, a 1974 study conducted by NASA at the request of DOD stated: "* * * The nature of the space Shuttle (manned vehicle, redundant critical systems, intact abort capability, etc.) can be expected to result in a very high success probability (low probability of failure) to be assigned to the program. It should be expected that the resultant success probability will be higher than previous manned systems and considerably higher than expendable launch vehicle systems. Since expendable systems have been allowed to overfly land at relatively long distances from the launch site, a higher success probability for Shuttle should permit land overflight of areas closer to the launch site such as might be the case for at least some of the KSC launch azimuths required to provide a Shuttle high inclination orbit capability. As stated above, this logic represents only a probable outcome of the land overflight question; not a conclusion."

Actually, the term "land overflight" is somewhat of a misnomer. As discussed earlier, the most critical phase of launch is between lift-off and solid rocket booster separation. The SRBs are jettisoned after

about two minutes into flight, at an altitude of about 26 miles, while the Shuttle is 31 miles downrange. Over 300 miles of ocean will remain in which to take actions to avoid endangering populated areas. Also, the mated orbiter and external tank will be 67 miles high when the system reaches the South Carolina coast. At this height, the Shuttle is almost as much in "orbit" as it is in "flight" and should not even be perceptible, either visually or audibly, from the ground.

Basically, there are two categories of aborts planned for the Shuttle. The first category, intact aborts, is planned for those failures which have the highest probability of occurring (e.g., loss of one engine). There are three intact abort modes: (1) return-to-launch-site, (2) abort-once-around, and (3) abort-to-orbit. All three of the intact abort modes can be successfully accomplished during northerly KSC launches without danger to persons on the ground from either the external tank or the orbiter. The orbiter would in all instances return to the launch site and the external tank would be disposed of as follows. For the return-to-launch-site mode it would be dropped in the Atlantic Ocean approximately 100 miles from the launch site and, for the other two abort modes, it would splashdown in approximately the same area of the Indian Ocean as planned for normal missions.

The Second category is contingency aborts. This mode is planned for failures which are the least likely to occur (e.g., loss of thrust in two or all three main engines). The contingency abort mode consists of jettisoning the external tank and making a controlled landing wherever possible. For northerly KSC launches, whether the external tank could be dropped in the ocean depends on when the malfunction occurs. For instance, if the incident occurred soon after lift-off, it might be possible to maneuver the orbiter and external tank for both to land in the ocean. If the occurrence is later in flight, the external tank would have to be released and detonated to prevent its coming down intact on land. Additionally, maneuvering capabilities should allow for landing in an unpopulated area.

In summary, we feel that the case for northerly Shuttle launches from KSC rests on many factors, not just the casualty expectation figures estimated by Aerospace Corporation. To reiterate, some of these factors are:

The Shuttle is a man-rated system.

The Shuttle has been designed to have a very high degree of reliability.

The most critical phase of northerly launches would be over water.

There are various abort maneuvers planned for selected failures which have the highest probability of occurring.

In a worst case situation the external tank could be released and detonated.

The orbiter should still have some maneuverability even with loss of thrust in all three main engines.

Additionally, the Shuttle will have had over three years' experience before northerly KSC launches would be required. Any operational problems should have been identified and corrected during this period. The cost to replace an orbiter will be near a billion dollars. Thus, for the program to be viable, the Shuttle must be virtually 100 percent reliable.

Question. If an Orbiter were damaged or grounded for some reason, there might be insufficient remaining Orbiters to launch all payloads. Will DOD payloads have priority if insufficient Orbiters are available to accommodate all payloads?

DOD answer. Yes.

NASA response. The order of priority for Shuttle users in the event of a reduced operational fleet has been established. Space programs requiring urgent STS support to maintain national security mission capabilities would come first. These would be followed by (a) significant science and technology missions and/or missions with launch window constraints, (b) committed reimbursable missions, (c) routine science and technology and late request missions, and (d) space available requests.

SECURITY CONSIDERATIONS

Question. Security considerations may affect DOD participation in the Shuttle program. How will classified military space activities be conducted in the Shuttle era?

DOD answer. There are currently two options for conducting classified military operations in the Shuttle era: (1) joint DOD/NASA use of Johnson Space Center (JSC) in Houston, with security implemented in a "Controlled Mode", and (2) DOD planning and controlling its launches from a separate DOD Shuttle Operations and Planning Center (SOPC) facility. We have come to an agreement with NASA on the principle we will operate out of JSC. We are now working out the details of how "Controlled Mode" joint operations will be conducted.

In the "Controlled Mode," unclassified NASA missions and classified and unclassified DOD missions will both use the same facilities simultaneously. Several areas at JSC (including a DOD Flight Control Room) will be secured and access to these areas restricted. Certain large computer facilities will be shared; hardware isolation and switching techniques are being studied in an attempt to minimize the possibility of compromising classified data.

The "Controlled Mode" applies to the planning and real-time control of the Space Shuttle vehicle, or Orbiter, only. All planning for, and control of, the flight of the DOD Inertial Upper Stage (IUS) and spacecraft, will be done in secure DOD facilities. Mission Control in Houston will be responsible for launch, ascent, the deployment of the IUS/spacecraft (in some cases, the spacecraft only), and the safe return of the Orbiter. Once the IUS/spacecraft is outside the Orbiter bay, the responsibility for the remainder of the DOD mission will be assumed by the Air Force Satellite Control Facility (AFSCF) at Sunnyvale, CA.

Question. Will military crews be used for DOD missions?

DOD answer. Crews for DOD missions will hold the appropriate security clearances. No requirement has been levied that only military crews be used, but it is expected that military personnel detailed to NASA as part of the single overall flight crew pool will make a large proportion of the crews for DOD missions.

NASA answer. The NASA cadre of crew members for the Shuttle era is composed of both civilian and DOD astronauts. For DOD dedicated flights it is assumed by NASA that DOD would prefer to

man those flights with its own people. This would not impact our current planning.

Question. There have been discussions in the past that a separate mission control center would be required for classified DOD launches. A separate mission control center could cost \$200 to \$300 million. Page 10 of Dr. Perry's statement indicates that DOD and NASA are currently negotiating to make modifications to the Johnson Mission Control Center so that a separate DOD mission control center will not be required. Does the 1979 budget assume there will be joint DOD/NASA use of the Johnson center in lieu of a separate DOD facility?

DOD answer. Yes.

NASA answer. There is an agreement in principal between DOD and NASA to use the JSC Mission Control Center for classified DOD missions and a joint NASA/DOD validation study is underway. This study is to be completed by mid-April 1978 and will provide the basis for confirming the agreement. Necessary funds to modify the JSC for this capability are to be provided by the DOD. A very minimal funding level is required for FY 1979. The confirmation date of June 1978 is based on the requirement for obtaining funding for the 1980 budget.

Question. Will the Johnson Center be used for both Kennedy and Vandenberg launches?

DOD answer. Yes.

NASA answer. If the decision is made to perform Shuttle flight control for DOD classified missions at JSC, then launches from both Vandenberg and Kennedy will be accommodated at the JSC Mission Control Center. The JSC MCC has been designed to accommodate up to 60 flights per year.

Question. If Vandenberg were not built, would any economies or extra costs be incurred at Johnson?

DOD answer. None of any significance that have been identified. There may be minor savings associated with VAFB to JSC communications links that would not be required.

NASA answer. Johnson Space Center (JSC) costs are basically independent of the launch site from which a mission is launched. Therefore, for a given flight rate, the operations costs would be the same based on a single site (KSC) operation or a two-site (KSC and VAFB) operation. The DOD costs due to security would also be essentially the same, whether or not VAFB was built.

SHUTTLE TRANSITION

Question. The method of transitioning to the Shuttle era can have important cost implications. In its simplest form, the transition strategy which has been adopted for the Shuttle will have four stages. These stages are:

Stage 1: An all expendable launch vehicle fleet, with research and development launches of the Shuttle.

Stage 2: A hybrid fleet, with use of expendable launch vehicles for high priority time critical payloads which cannot be delayed, and use of the Shuttle for continued research and development launches and for launches of operational payloads which can be delayed.

Stage 3: An all Shuttle fleet, with most payloads optimized for Shuttle launch but with some critical payloads modified for Shuttle

launch but still capable of launch on expendable launch vehicles if trouble develops with the Shuttle.

Stage 4: An all Shuttle fleet, with all payloads optimized for Shuttle launch and with no expendable launch vehicles for backup.

Do the various witnesses concur that this four stage structure I have just outlined is an accurate summary of the transition strategy?

DOD answer. While no staged program for payload transition to the Shuttle has been developed, with exception of Stage 2, the DOD transition plan generally reflects the philosophy presented in the four stage plan. DOD payload transition is not tied to mission criticality as suggested in Stage 2. DOD payloads will be transitioned to the Shuttle in accordance with economic and operational constraints, with high priority payloads designed for both STS and ELV compatibility during the transition period to minimize risk should Shuttle problems develop early in the operational period. Payload transition may be concurrent with payload program block change, or in the case of new programs, concurrent with their development.

GAO answer. Our review effort did not include a detailed examination of the proposed method of transitioning payloads to the Shuttle. Although we agree that the strategy chosen will have important cost implications, we believe that NASA and DOD are in a better position to respond to these questions within the time permitted.

NASA answer. In the case of the civil program, the four stage scenario as set forth above is not an adequate description of the concept for transition of civil payloads to Shuttle. The civil transition concept can best be characterized by 3 stages:

Stage 1: An all expendable launch fleet, to support all civil launches until completion of the Shuttle Orbital Flight Test (OFT) program, currently expected to be completed in the second quarter of CY 1980.

Stage 2: Upon completion of Shuttle OFT, it is generally expected that all civil launches from KSC will be made by Shuttle. In any case NASA expects to phase out ELV launch capability at KSC by the end of CY 1980. Transition from ELV's to Shuttle is expected when the Shuttle becomes operational at VAFB now planned for June 1983.

In the case of NASA, all payloads planned for flight after mid-1980 at KSC will be flown on Shuttle. This is possible since NASA payloads are generally one of a kind; therefore, NASA payloads planned to fly on Shuttle are optimized for Shuttle, and skip Stage 2 completely.

In the case of other civil payloads, a number of programs span the transition period from ELV to Shuttle and must be designed to be compatible with both ELV's and Shuttle. Intelsat V is an example of this, where four payloads will fly on Atlas Centaur while the remainder are planned for Shuttle. Other payloads such as SBS and the Canadian Payload "ANIK" require a flight very close to the time Shuttle is expected to become operational (late CY 1980). To insure the capability to launch on time in case of a Shuttle slip, they too are designing dual compatibility.

NASA will provide a back-up capability for these civil users at KSC until after the First Manned Orbital Flight (FMOF). This will require procurement of long lead ELV hardware only and represents a minimum cost to NASA. Subsequent to successful completion of FMOF, costs for retention of an ELV back-up capability would be borne by the user.

Stage 3: Following completion of launches of payloads spanning the transition era (1980-1983) all civil payloads are expected to be Shuttle optimized and planned only for launch on Shuttle.

Question. What are the current estimates as to the time periods for each of these four stages?

DOD answer. DOD transition of existing programs to the Shuttle begins in FY 82 and with exception of a single program is completed at both launch sites in FY 84. The final payloads transition in FY 85 was determined by a scheduled payload program block change. New programs are transitioned to the Shuttle as they become available with a research and development payload scheduled for launch in FY 81. The periods associated with the four steps are generally reflected in Revision 6 of the DOD traffic model as follows:

Step 1—1980-1982.

Step 2—(Modified) and Step 3—1982-1985.

Step 4—After 1985.

NASA answer. For the civil program the time frame associated with the transition stages as defined in our earlier response is as follows:

Stage 1—prior to mid CY 1980.

Stage 2—mid CY 1980 to mid CY 1983.

Stage 3—Post CY 1983.

Question. Will the transition costs be higher if the transition period is stretched and lower if the transition period is compressed? Will the risks of launch failure be increased if the transition stages are compressed and lower if the transition schedule is stretched?

DOD answer. Compressing the transition period would both increase payload transition cost and risk. Delaying or stretching out the transition period far enough could eliminate the cost associated with the backup ELVs but incurs an increased cost offset through the use of ELVs for an extended period. It also has the disadvantage of delaying use of increased capabilities of the Shuttle for this period. In view of these considerations, the DOD payload transition plan as defined represents an expeditious, economical and low risk transition from ELVs to the Shuttle.

NASA answer. In the case of NASA payloads delay in transition is not planned as explained above. If the Shuttle schedule slips, it is planned to delay launch of NASA payloads until the Shuttle is available.

For other civil payload users, delay in transition will significantly increase the cost to the user. For Delta ELV users, launch cost for using a Delta ELV are approximately \$18M in 1979 dollars versus \$7.3M using the Shuttle. Users requiring an Atlas Centaur would pay \$43M in 1979 dollars versus \$20M using the Shuttle.

The above is true for payloads in the design or development stage. Other payloads in an on-going status would have to be examined on a case-by-case basis and transition costs may mitigate the transportation cost advantage provided by the Shuttle.

The risk of launch failure will be reduced by minimizing or compressing the transition period. The Shuttle is considered to be a much more reliable launch system than expendables. NASA currently estimates a Shuttle maximum abort probability is better than for any currently operational expendable system. Further, Shuttle is expected to abort *intact*, that is it will land safely and not damage the payload. In the

case of expendable launch systems a launch failure results in loss of the launch vehicle and the payload. Current expendable launch vehicle failures range from between 3 and 10 percent depending on the type of launch vehicle involved.

Question. How will the tradeoffs be made between cost savings from an accelerated transition strategy versus the risks of an accelerated strategy?

DOD answer. The current DOD plan transitions eight existing payload programs starting in FY 82 and ending in FY 84. The last existing payload program is transitioned in FY 85. Three new payload programs are integrated to the Shuttle during this four year period and an additional five research and development payloads are flown between FY 81 and FY 85. Payload program requirements are such that the need for reviewing specific payload transition plans may arise. These cases will be addressed as required but no overall revision of the plan to reflect an accelerated transition is contemplated.

NASA answer. For civil programs, cost benefits are derived by early transition both in terms of lower cost transportation and lower risks. Consequently all civil users plan to transition to Shuttle at the earliest possible time.

To allow for the possible delay in availability of Shuttle during the early phase of transition, non-NASA civil users are designing spacecraft that are compatible for launch on either Shuttle or a suitable ELV. These costs are estimated to add no more than 2 to 3 percent above that required to launch on ELV's only. These additional costs will be much less than would be incurred if transition to Shuttle were delayed.

Further, they insure that the user can make the decision to revert to an ELV launch should the Shuttle not be available in time to meet their launch requirements. In this case the cost to launch on an ELV would add substantially to the transportation cost which the user would have to bear.

Question. What are the current estimates of transition costs?

DOD answer. A sum of \$540 million will be spent in transitioning existing DOD payloads to the Shuttle. An additional \$395 million will be spent in providing common integration equipment and services for all DOD payloads and in integrating the new DOD payloads onto the Shuttle.

NASA answer. As mentioned above the added cost in spacecraft design to civil users is expected to be no more than 2-3 percent of total spacecraft program cost. The capability to provide long lead time ELV hardware is expected to be between one and one and one-half million dollars. NASA will provide this back-up capability thru first manned orbital flight (FMOF) currently planned during the 2nd quarter of FY 1979. At that point each user will decide whether or not to continue a back-up ELV capability. This would be at the users expense. Should he decide to use an ELV instead of Shuttle the payments furnished NASA for a Shuttle launch would be applied to the cost of an ELV launch. As mentioned earlier, the cost to launch on an ELV would be considerably greater than the cost for a Shuttle launch.

Question. Has any serious consideration been given to further acceleration of the transition period in order to reduce transition costs?

DOD answer. No acceleration of the plan to transition payloads to the Shuttle is planned. We feel such an acceleration would increase transition risk without offering a commensurate cost savings.

NASA answer. Transition of civil payloads to Shuttle is being planned for the earliest possible date which can be supported by the STS capability. No greater acceleration is possible.

Question. Is DOD in fact going in the opposite direction and stretching the transition period by slipping when it will modify payloads for Shuttle launch?

DOD answer. The current DOD transition plans offers an expeditious, economical and low risk program because it is keyed to the respective payload program status. No plans to extend this transition period exist. As noted above, should a specific program requirement necessitate review of its planned transition, this will be addressed as required.

PAYLOAD COSTS

Question. Payload costs will be another major component of the Shuttle program. There are three major issues concerning payload costs. These are:

1. The cost of transitioning existing payloads for the Shuttle.
2. The cost savings resulting from redesigning payloads to take advantage of the new capabilities of the Shuttle.
3. The number of payloads which will be launched. We'd like to discuss each of these subjects today.

Explain the various types of costs associated with transitioning existing payloads to the Shuttle, and give a total estimate of these costs.

DOD answer. The cost of transitioning existing DOD payloads to the Shuttle has been estimated at \$540 million. These costs entail the following:

- (1) Payload redesign for Shuttle compatibility, the primary considerations being Shuttle payload environments and caution and warning for manned operation.
- (2) Payload integration to the Shuttle. This includes the tests necessary to ensure payload/Shuttle physical and operational compatibility and preliminary mission analysis and flight planning.
- (3) Modification of existing payloads which have been built for ELV launch and now will be launched by the Shuttle.

NASA answer. In the case of civil payloads, there are no *existing* payloads which must be transitioned to Shuttle. NASA payloads planned to fly after Shuttle IOC are being designed specifically for Shuttle, other civil payloads which span the transition era (Intelsat V, SBS, Insat, etc.) are just entering the design phase. Consequently, the payloads can be designed and developed for flight on Shuttle.

Question. Are these costs solely for transitioning payloads to the Shuttle or do they also include improvements in payload capabilities?

DOD answer. These costs are for transition only. In those cases where transition is concurrent with a payload block change, an attempt has been made to segregate transition costs from modification costs. Integration of new payloads with Shuttle is not included.

NASA answer. In the case of civil payloads which span the transition era from ELV's to Shuttle, the costs involved with transitioning these payloads are associated with designing them to be dual com-

patible with ELV's and Shuttle. This is to allow the payload to fly on Shuttle if it is available, while retaining the option to fly on an ELV if the Shuttle is not available in time to meet their launch requirement. No costs are included to improve the payload capability.

Question. What can be done to minimize the cost of transitioning payloads to the Shuttle?

DOD answer. Transition of DOD payloads to the Shuttle has been encumbered by uncertainties in Shuttle design and operational characteristics. Since a four year period is required for payload integration, commitments on payload design must be made this year for payloads which will be launched in 1982. While propulsive and structural testing of the Shuttle will provide an improved understanding of the Shuttle environment this year, it will require OFT flights scheduled to begin in 1979 to provide confidence in these data. Consequently, payload design revisions made this year and next must be made on a conservative basis and thus will incur costs which may not be required. Payloads transitioning after a comprehensive understanding of Shuttle design and operational characteristics are understood will not face this uncertainty. Delay in transition could relax this uncertainty and associated payload costs but would incur additional costs associated with extended expendable launch vehicle operations. We believe that our current transition plan reflects a reasonable approach considering both risk and cost.

NASA answer. The most effective way to reduce payload transition cost is to incorporate payload modifications compatible with Shuttle as early in the design phase of the payload as possible. For payloads not yet designed, these modifications should be incorporated into the initial design. The case of existing payloads, these design changes have to be retrofitted with attendant higher payload transition costs.

If the payload is not planned for flight until after the transition period is complete, NASA believes that significant savings in payload costs can be realized by designing the payload specifically for Shuttle to take advantage of the many unique features the Shuttle offers for payload operation; i.e., Shuttle optimized designs.

Question. What is the difference between making a payload "Shuttle compatible" versus making a payload "Shuttle optimized?"

DOD answer. The term "Shuttle compatible" implies a payload design compatible with Shuttle launch: it may or may not be compatible with ELV launch. The term "Shuttle optimized" implies a payload designed to exploit the unique capabilities of the Shuttle—i.e., retrieval, on-orbit service, large weight and volume, etc. The "Shuttle optimized" payload is not likely to be compatible with existing ELV launch capability. The term "Shuttle optimized" does, however, have different connotations for different classes of payloads. For certain applications, the opportunities for "Shuttle optimization" may be limited, as in the case of high altitude payloads designed for high reliability and long life, so as to lessen the distinction from a "Shuttle compatible" payload.

NASA answer. The term "Shuttle Compatible" implies a payload is also compatible with other launch systems. It can be launched with either the Shuttle or expendable launch vehicles. The term "Shuttle Optimized" does not preclude the possibility of launching the payload

on expendable launch vehicles but implies the nature of the payload design and overall program strategies have been carefully considered to take maximum advantage of the most cost effective and unique features of the Shuttle to reduce payload costs.

Factors to consider for "optimizing payloads for Shuttle" include retrieval and re-use, on-orbit servicing, launch cost sharing, on-orbit check-out, reliability and test considerations, etc. Opportunities for Shuttle optimization are significantly reduced where dual compatibility with both ELV's and Shuttle must be retained.

Question. Are there cost benefits for "Shuttle optimized" payloads versus "Shuttle compatible" payloads?

DOD answer. "Shuttle optimized" payloads appear to offer cost savings to certain DOD payload classes. The retrieval and reuse of relatively short-lived expensive low earth orbit payloads is planned and is anticipated to result in significant cost savings. Likewise, payload and upper stage design is addressing length and diameter constraints commensurate with providing a high Shuttle load factor and thus reduced transportation costs. The cost savings attributed to other "Shuttle optimized" design approaches are yet to be determined for DOD payloads.

NASA answers. "Shuttle optimized" payloads have greater potential for cost savings than "Shuttle compatible" payloads. NASA has projected cost benefits for "Shuttle optimized" payloads in each of its Shuttle program assessments since 1972. The factors cited by NASA which contribute to overall program savings are: Lower cost payload design efforts; increased payload reliability; increased launch reliability; cost savings from payload reuse; and reduced weight and volume constraints.

As these factors have been applied by NASA to payloads in the payload model, overall cost savings from 25 to 40 percent are achievable when compared to launching the payloads on expendable launch vehicle. Obviously, these savings can only be realized for payload programs which are starting with a new design or have a block change in a continuing flight program. Furthermore, the benefits that can be derived from these factors will vary between classes of payloads. For example the recovery and reuse of a very expensive payload such as the space telescope will represent a very large overall program saving, whereas recovery of fairly small less expensive satellites designed for long life may derive little benefit from recovery and reuse.

Question. How many "Shuttle optimized" payloads are being developed?

DOD answer. As noted in response to the previous question a low earth orbit payload is planning for retrieval and reuse. The Global Positioning System Navigation satellite emphasizes satellite and upper stage design to achieve reduced launch cost through both payload mixing and satellite deployment to alternate mission orbits. The DSCS III communication satellite design is emphasizing payload mixing to achieve a reduction in launch cost. The Space Test Program research and development payloads are being designed for payload mixing. A special test rack, compatible with the standard Spacelab modules, is under development for research and development experimentation. Dual compatibility, i.e., compatibility with both Shuttle and expendable launch vehicles, to provide assured launch capability

for critical DOD missions early in the Shuttle era militates against maximum exploitation of full use of Shuttle unique capabilities.

NASA answer. Currently the following approved payloads are considered "Shuttle Optimized":

Long Duration Exposure Facility (LDEF).

SYNCOM IV (Commercial Communications Satellite).

Spacelab Payloads (Man-tended).

Operational Earth Observations Payloads: Landsat and Solar Maximum Mission.

Navy Transit Payload.

Space Telescope.

Tracking and Data Relay Satellite (TDRS).

Question. Why is DOD developing the Defense Satellite Communications System III as a "Shuttle compatible" rather than a "Shuttle optimized" payload? Won't this decision mean that it will be the 1990's before DOD will take full advantage of the Shuttle capabilities as they relate to communications satellites?

DOD answer. As noted in response to the third question on page 364, the distinction between a "Shuttle optimized" and a "Shuttle compatible" synchronous orbit payload is not unequivocal. The capability for synchronous orbit payload retrieval and for on-orbit service is not currently planned. The payload design is providing for both multiple and mixed payload launch which results in utilization of the Shuttle capability to optimize launch cost. The satellite is being designed to achieve its mission objectives with high reliability and long life on orbit. It is not evident at this time that a further "Shuttle optimization" could be achieved which would provide additional savings at comparable risk.

Question. Are any "Shuttle optimized" communications satellites currently under development by either government or private agencies?

DOD answer. With respect to DOD programs, see response to previous question.

NASA answer. The Civil Communications Satellites currently under development that are "Shuttle Optimized" are: Syncom IV and TDRSS.

ACCURACY OF GAO ANALYSIS OF MISSION MODEL

Question. The GAO testimony states that the current mission model would require a three-fold increase in space activity. Is the analysis accurate?

DOD answer. The DOD mission model reflects a generally constant level of activity that is largely related to continuation of current programs. In this sense, the DOD portion of national traffic model is considered to be conservative.

NASA answer. The GAO analysis is not accurate. The GAO has compared all missions projected for the Shuttle with the history of U.S. launches on expendable launch vehicles without considering obvious differences between the two launch systems.

A more realistic analysis would have compared the activity of the two systems for those payloads common to both capabilities. The following table illustrates the difference between the average annual

payloads launched in the past ten years and projections for the Shuttle for free-flying spacecraft from the current mission model:

	10-yr history	Shuttle
NASA.....	7.3	9
Commercial and foreign.....	6.4	13
DOD.....	14.0	12
Total.....	27.7	34

The results show that the current mission model represents an increase of only 7 flights per year in the Shuttle era over the actual payloads flown in last 10 years.

Spacelab activity comprises the remainder of the mission model projection. The unique nature of Spacelab activity, i.e., repetitive flights using the same flight facilities, has no meaningful historical analog and makes it difficult to translate the annual traffic in terms of equivalent programs in history.

GAO answer. The analysis of the mission model is accurate. Before going into the analysis, however, it is well to keep in mind that the "current" mission model—and the earlier versions—are not firm space requirements. The models are only planning estimates and have been revised almost annually since 1971. The table below lists the various models.

Year of mission model:	Number of shuttle flights projected
1972.....	581
1973.....	725
1975.....	572
1976.....	560
1977.....	¹ 552

¹ Or 487, assuming attrition of 1 orbiter.

Even the lowest mission model, the current 552-flight model, represents a several-fold increase in space activity. During the years of full Shuttle operations, 1983–1991, the model projects an average of 98 payloads a year. In contrast, the U.S. has launched an average of only 30 payloads a year over the past 5 years; the average rate during 1967–76 was 43 payloads a year. Even this numerical comparison does not fully reflect the increased capabilities of the Shuttle. For example, a Shuttle/Spacelab flight, with a multitude of experiments and a mission duration of 7 to 30 days, is counted as one Shuttle payload in the above comparison; the same mission would probably require several expendable launch vehicles.

COSTS OF THREEFOLD PAYLOAD INCREASE

Question. What would be the cost of the payloads if there were a three-fold increase, and how can an increasingly constrained budget provide for this increase in payload costs?

DOD answer. Non applicable, see response to previous question.

NASA answer. The NASA payload content in the mission model was based on an essentially level agency budget. Increased NASA payload activity in the Shuttle era is predicated on the level budget of about \$4 billion, reduced transportation costs allowing for a greater

share to payloads, and overall reductions in the cost of payloads owing to the properties of a reusable launch system like the Shuttle.

The 1977 Mission Model NASA payload costs amounted to \$12.9 billion (in FY 1979 dollars) from 1980 through 1991. This averages to slightly over \$1 billion annually. It is clear that this is not a three-fold increase over today's payload costs.

GAO answer. As shown in the table below, NASA estimated that its payloads projected in the 1976 mission model would cost about \$29 billion (this estimate is for payloads only and does not include transportation costs). In addition, NASA Headquarters estimated that the payloads projected for other U.S. Government civil agencies would cost approximately \$2.6 billion. The cost of Defense Department payloads was not provided.

Funding levels required for NASA payloads in 1976 mission model

	[Billions of Real Year Dollars]	
Spacelab payloads-----		\$4. 7
Space science-----		2. 70
Applications-----		1. 54
Technology-----		. 44
		10. 8
Free flying satellites-----		8. 02
Space science-----		1. 84
Applications-----		. 21
Technology-----		. 71
		13. 7
Space industrialization payloads-----		29. 2
Total-----		29. 2

SOURCE: Office of Payload Analysis and Mission Planning, Office of Planning and Program Integration, NASA Headquarters.

This cost data was provided by NASA Headquarters in August-September 1977 and to the 1976 mission model. On March 24, 1978, the Office of Space Transportation System Operations, NASA Headquarters, stated that the NASA payload costs associated with their current mission model the 1977 revision, were roughly \$21 billion (real year dollars); no breakdown of this figure was provided. A 1977 study done for OMB, however, does give a breakdown in FY 1979 dollars of NASA's portion of the revised model. Using this study, the following table compares the costs of NASA's payloads in the 1976 and 1977 mission models:

	1976 mission model ¹	1977 mission model ²	Percentage change (decrease)
Number of payloads:			
Automated-----	111	106	
Spacelab-----	394	377	
Space industrialization-----	34	12	
Total-----	539	495	8
Cost of payloads (fiscal year 1979 dollars)-----	\$20.865	\$12.944	38

¹ The source of this data is the "Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues," dated Oct. 15, 1976, which was prepared for OMB. The source study gives payload costs in fiscal year 1978 dollars; we used a 7-percent inflation factor to permit a comparison in fiscal year 1979 dollars.

² The source of this data is the 1977 update of the above study, also prepared for OMB.

As shown in the preceding table, Spacelab payloads constitute the great majority of NASA's projected activity. Some observers feel that such extensive use of the Orbiter for Spacelab missions is a misuse of a transportation vehicle. Basically, given the projected missions (number and duration), Spacelab is equivalent to a permanent presence in space. Indeed, the Shuttle Spacelab itself will include many of the characteristics of an early space station. In this light, the proposed level of Spacelab activity probably should be evaluated against the criteria used for space station proposals.

Some insight into the need for a space station is given by analogizing to an early proposal—DOD's Manned Orbiting Laboratory, which was cancelled in June 1969 even though over \$1 billion had been spent on the project. In explaining why this space station project was terminated, DOD stressed, among other reasons, that automated systems could perform the functions planned for the Manned Orbiting Laboratory.

More recent insight into the need for a space station is given by Issues "78, an OMB publication. Commenting upon a \$15 million line item (representing studies related to a possible future manned Earth-orbiting space station) in NASA's fiscal year 1978 budget request, the issue paper recommended deferral because:

"* * * An orbital space station would represent a major budgetary and policy commitment for the U.S. space program following the completion of space shuttle development. * * * a decision on whether and when to consider the development of a manned orbiting space station would need to address a broad range of issues, including:

"* * * long-range goals and objectives of the U.S. civilian space and aeronautics programs * * *"

Nevertheless, NASA contends that space stations are a logical intermediate step toward the long-range goal of manned planetary exploration and is already advocating development of an orbiting space station for operation in the mid-1980s.

Because Spacelab is such a substantial part of the mission model, we solicited comments from approximately 70 leaders, principally academicians and researchers, in the space sciences community regarding this planned STS usage. As a prefatory comment, several respondents stressed they were presenting:

General comments or impressions because they perhaps were not fully aware of the overall support picture; and

Personal views, not those of any organization to which they belong.

With these qualifications in mind, the following extracted comments are examples of the replies received.

"My overall impression of the STS economic studies is that estimated traffic has been unrealistically high."

"I greatly fear the pressure to make many [Spacelab] flights to prove the 'economy' of [Spacelab] will submerge the basic science program of the space agency."

"I certainly am concerned with the question of the practical number of spacelab flights which can be mounted, especially in view of the budget which NASA will have for science now and in the foreseeable future. * * * such a program is not practical under present ceilings."

Comments regarding the scientific opportunities offered by Spacelab were surprisingly diverse. Some were favorable:

" * * * 'Is Spacelab useful for astrophysics?' My answer is decidedly yes."

" * * * I don't consider 7 flights per year devoted to astrophysics at all excessive * * *"

"A mission duration one to four weeks would be adequate for most planetary investigations * * *"

"Since spacelab will presumably serve a national cross-section * * *, the flight frequency of 20 per year may be reasonable."

Others were unfavorable or critical:

"There are two primary limitations of Spacelab. One is that only near-earth orbits are accessible and the second is that 7-day missions offer a very low scientific return on investment of time and manpower for most missions."

"I believe that Spacelab missions as described will be of limited value to space physics * * *"

"Spacelab will not replace * * * free flying satellites for magnetospheric or solar terrestrial physics."

" * * * 7- to 30-days mission lifetime for Spacelab is a severe limitation for many scientific missions. The launch of long-lifetime free-flying satellites from Shuttle will often offer a better opportunity."

Finally, in our opinion, the most appropriate summary comments we received were:

"The Shuttle will be an extremely capable and technologically advanced vehicle, and it will clearly establish the U.S. as having an unmatched capability to operate in space. * * * However, the extensive use of such a large system will present some problems. The proposed Shuttle launch rates involve launch costs alone that are far in excess of those of recent years. Further, the projected number of flights will carry total payloads far in excess of those flown in the past. It will surely require greatly increased funding to develop well conceived payloads to make use of all this capability."

These summary comments are very similar to those presented by the National Academy of Sciences in a 1974 report, "Scientific Uses of the Space Shuttle". The Academy stated:

"The Shuttle can be an important asset to scientific research in and beyond the 1980's."

"The overall scale of Shuttle space science and the proportions of Shuttle opportunities that will go to various scientific disciplines can only be established when a realistic model of Shuttle operations becomes clearer. This model will, of course, depend very much on the funding available for space science and applications during and following the development of the Shuttle."

Presently, Shuttle development takes the major part of NASA's approximately \$4 billion annual budget. When the STS begins operations, NASA has estimated that its mission model can be accomplished with a "moderately increasing" budget. Without addressing the accuracy of this estimate, it should be noted that no agency can be guaranteed a constant budget, much less an increasing one. Even with an annual sustained budget of \$4 billion, NASA would be unable to both finance its mission model payloads and undertake any future major development, such as:

Developing a heavy-lift launch vehicle (up to \$12 billion). NASA has contracted a study of a vehicle that could be used to launch payloads larger and heavier than the Shuttle could carry. The Shuttle may be technically incapable of handling certain prospective space projects involving huge payload masses (costs), such as deploying an orbiting solar power generating system (over \$60 billion).

Constructing a six-to-twelve man space station (\$3 billion to \$5 billion).

Developing and operating an orbital transfer vehicle to extend manned operations to higher orbits (over \$1 billion).

Upgrading the Shuttle's present configuration (over \$1 billion). NASA's original goal was to have a fully reusable launch vehicle. The Shuttle's present configuration is only a partially reusable system and represents a first generation vehicle as a replacement for expendable launch vehicles. NASA has ongoing studies of ways to upgrade the Shuttle. Candidates being studied to improve the twin rocket boosters include (1) modifying the boosters' air frames and using liquid propellant, and (2) developing a cruise-back booster permitting land recovery. Either alternative would cost about \$1.4 billion.

Question. There is a trend for payloads to be increasingly reliable. For example, early communications satellites had lifetimes measured in *months*. Communications satellites being designed for flight in the early 1980's will have design lives of 7 to 10 *years*. In addition, these communications satellites will have significantly greater capacity per satellite, so that fewer satellites will be required to achieve any given level of communications capability. The trends in communications satellites are generally true for other classes of satellites as well. Given these trends of longer lives and higher capacity, how do you justify a three-fold increase in space activity?

DOD answer: Non applicable, see response to previous question.

NASA answer: Payload projections are made from various user requirements. The projections are based on three principal considerations:

The number of users.

The number of spacecraft required.

The spacecraft lifetime.

Even though spacecraft lifetimes have been increased significantly, the best available estimates indicate that the increase in the number of users and the communications traffic to be accommodated by each new user will more than offset the advantage of extended spacecraft lifetime.

In a recent study by Future Systems Incorporated (copy enclosed), the results indicate that a reasonable projection of communications traffic in the era of the mission model is about 3 times the volume assumed in the model.

In general, the projections of the mission model are considered fairly conservative to those in the communications field.

(CLERK'S NOTE: Due to the length of the study, and the consequent expense of printing, it was not reprinted in the record.)

Question. Satellites are also tending to become more capable per pound of payload. This is possible because of such factors as the use of large scale integrated circuits, which are lighter for any given electronic capability. Newer light weight materials have also been developed for

use in spacecraft. These new materials can provide a given level of strength at lower weight, thus lowering the overall weight of the payload. With lighter and more compact payloads, more satellites can be launched on each Shuttle flight. Given these facts, how do you justify the mission model?

DOD answer. The technological advancements identified are being incorporated on our new payload designs as practical and are tending to lower spacecraft weight. An offset to this exists, however, in that mission requirements continue to expand and place new demands on the spacecraft which tend to increase its weight—i.e., survivability. All such factors were considered in determining our mission manifesting and projecting our flight requirements.

Other factors impacting payload manifesting include payload orbital inclination and altitude, payload launch frequency, payload compatibility with other payloads (security, environments, etc.), payload deployment requirements, Shuttle and upper stage performance capabilities, etc. It is only after each of these factors are considered that a mission manifesting can be completed. Having completed this analysis we believe our traffic projections to be realistic.

NASA answer. In developing the mission model projections for the future a great deal of effort is applied to defining specific missions and establishing payload configurations on a parametric basis. In general, it is assumed that payloads projected for the Shuttle mission model will use the advanced engineering technology, including modulization, to enhance performance on orbit and simplify checkout and refurbishment. However, it should be noted that the cargo loading for each Shuttle flight involves more than payload weight and density. Other factors considered are: upper stages, orbital inclination, compatibility with other payloads, stay time on orbit, center of gravity for Shuttle cargo.

Each baseline mission model developed by NASA for Shuttle planning includes a detailed "cargo manifest" identifying the specific payloads for each flight including the payload parameters and mission requirements. An example of the data provided in the cargo manifest is attached.

Payload orbital inclination

Requirement for upper stages

Compatibility with other payloads

Shuttle capability to desired inclination

Stay-time on orbit and consumables requirement

Payload schedules for launch

Center of gravity of the Shuttle cargo

Mission compatibility of payloads

Distribution of Shuttle resources: electrical, cooling, data management

Crew activity timelines; etc.

Consideration for each of these factors in developing a cargo manifest provides the flight requirement of the Shuttle. As can be seen, it is erroneous to divide the weight lifting capability of the Shuttle (65,000 pounds due east from KSC) by the weight of a payload and deduce that the quotient is the number of payloads that could be carried on that particular Shuttle flight.

Over the entire mission model, the average load factor is about 75 percent. It is on this basis that the user charges are assessed.

Question. If fewer satellites are needed because of the trends mentioned above, doesn't this lessen the number of Orbiters required, and confirm the GAO estimate that fewer Orbiters are required?

DOD answer. Non applicable, see response to previous question.

NASA answer. NASA does not agree that payload reliability and compact payload designs imply a reduction in the number of payloads and in the number of Shuttle flights.

As previously mentioned, individual payload reliability does not alter the number of new users projected in the mission model nor does it reduce the number of spacecraft needed to establish an acceptable network for each user. Further, the number of orbiters required to satisfy any given mission model must be predicated on the ability to provide assured launch to the users and subsequent phaseout of expendable launch vehicles if the most economic operation is to be realized.

Mr. McKAY. Please provide for the record the answers to the following questions.

(CLERK'S NOTE: The questions submitted by Mr. McKay and the answers thereto follow.)

PROJECTED LAUNCHES FROM VANDENBERG

Question. The DOD and NASA statements indicate that certain missions cannot be launched from Kennedy because they require a polar orbit and are very heavy. Provide a list of all projected launches from Vandenberg, their estimated weight, why they must be launched into polar orbit, and the reasons they require the Space Shuttle.

DOD answer. The DOD payloads planned for launch from VAFB are:

Payload:	Weight, lbs ¹
DMSP-----	2, 500
DSSS-----	[Deleted]
X0760-05-----	[Deleted]
[Deleted]-----	[Deleted]
[Deleted]-----	[Deleted]

¹ Payload launch weight for current ELVs.

² Includes kick-stage.

Launch into near-polar or sun-synchronous orbits is necessary to satisfy the mission requirements for an orbit which maintains its initial orientation to the sun. For certain mission requirements, a noon-midnight sun-synchronous orbit can be selected which provides good earth visibility for about one-half of one revolution. Conversely, twilight orbits can be established in which the spacecraft is never in shadow, relieving the probability of power shortage through use of solar power. None of these VAFB launched missions have characteristics necessitating their launch on the Shuttle until the mid-1980's. Starting in the mid-1980's the [deleted] will no longer be compatible with the Titan III(34)D launch capability and the Shuttle provides a capability for recovery of low earth orbit payloads and thus provides a more economical operation.

NASA response. The number of projected STS launches from Vandenberg as determined in the 1977 OMB Study Update for the 487 Mission Model are given in sheet 1-1 and are broken down by fiscal year. The estimated cargo weights for the non-DOD missions and the

required orbital inclinations for these missions are given in sheets 2-1 and 2-2. Identification of specific payloads accommodated on each of these missions is provided in the 1977 NASA STS mission model dated October 1977, attached. The Vandenberg launch site will be used for missions requiring orbital inclinations between 56° and 104° to avoid overflight of densely populated areas during the crucial phases of the launch. Since the missions identified in the attached sheets require orbital inclinations in this range, they must be flown from Vandenberg rather than from KSC. These missions must be launched into high inclination orbits to meet the scientific objectives of the payloads.

The STS 487 Mission Model identifies 129 missions that will be launched from Vandenberg. Thirty-nine of these missions are Spacelabs. The Space Shuttle must be used to launch the Spacelab missions because the Spacelab cannot be launched with expendable boosters. The remaining missions could be launched from Vandenberg using ELV's rather than the Space Shuttle. A decision to use ELV's would, however, result in increased transportation costs of \$2.1 billion and payload cost penalties of \$2.0 billion in the time period from FY 1983 to FY 1992. These cost penalties were derived from data developed in the 1977 OMB Study Update.

Projected STS launches from Vandenberg Air Force Base

Fiscal Year:	Number of launches ¹
1983-----	4
1984-----	9
1985-----	12
1986-----	14
1987-----	17
1988-----	17
1989-----	14
1990-----	15
1991-----	16
1992 (first quarter)-----	4
Total-----	122

¹ Does not include estimates for reflights.

ESTIMATED WEIGHTS AND ORBITAL INCLINATIONS FOR NON-DOD LAUNCHES FROM VAFB

Fiscal year:	Estimated cargo weight (Klbs.)	Orbit inclination (deg.)
1983-----	15.5	98
	8.4	100
1984-----	15.0	100
	25.2	100
	30.6	90
	22.5	100
1985-----	29.2	100
	25.8	100
	33.3	90
	29.3	90
	21.2	90
	20.5	100
	22.8	98
1986-----	24.7	90
	19.1	100
	23.0	100
	18.6	100
	16.9	100
	33.3	90
	33.3	90
	35.7	90
	35.7	90
	26.9	90

ESTIMATED WEIGHTS AND ORBITAL INCLINATIONS FOR NON-DOD LAUNCHES FROM VAFB—Continued

Fiscal year—Continued	Estimated cargo weight (Klbs.)	Orbit inclination (deg.)
1987-----	12.0	90
	17.2	100
	23.5	100
	20.6	100
	10.6	100
	28.9	90
	33.3	90
	33.3	90
	35.7	90
	35.7	90
	26.9	90
1988-----	19.1	100
	29.5	100
	15.0	90
	23.5	100
	20.6	100
	14.3	100
	33.3	90
	33.3	90
	35.6	90
	35.6	90
	26.9	90
1989-----	16.2	100
	23.5	100
	20.0	100
	33.3	90
	33.3	90
	35.6	90
	35.6	90
	26.9	90
1990-----	29.6	100
	21.4	100
	23.5	100
	20.6	100
	10.3	100
	8.0	100
	33.3	90
	33.3	90
	35.6	90
	36.5	90
	26.9	90
1991-----	16.9	90
	21.8	100
	23.5	100
	26.8	100
	14.5	100
	33.3	90
	33.3	90
	35.6	90
	35.6	90
	26.9	90

(CLERK'S NOTE: Due to the cost of printing, the Committee did not reprint a lengthy study entitled "NASA STS Mission Model Payload Descriptions and Space Transportation System Cargo Manifests".)

Question. Explain why each of the above launches cannot be launched from Kennedy on a normal Space Shuttle launch.

DOD answer. Each of the above payloads with exception of (deleted) can be launched from KSC without violating current range safety limits. In this launch mode the Shuttle is launched into a 35 degree launch azimuth and an upper stage is used to provide the plan change necessary to achieve the required near-polar orbit.

The effective weight of the [deleted] payload when flown on the Shuttle is increased from the need for: (1) payload redesign for compliance with Shuttle loads, (2) a payload cradle, and (3) payload sup-

port equipment for payloads flown on the Shuttle. The need for support equipment arises because of the prolonged storage of the payload in the confinement of the payload bay prior to deployment.

The performance capability and payload bay size of the Shuttle are such that the size and weight of the [deleted] payload preclude its launch from KSC in the normal Shuttle manner. Launch of [deleted] from KSC will require launch directly into the desired mission orbit inclination or along a launch azimuth from which the Shuttle can be yaw-steered to the final mission orbit. Both these launch modes result in Shuttle overflight of the CONUS and foreign territories. This overflight is considered unacceptable because of the risk of international incident and the risk of casualty/property damage. There are also problems with sonic boom overpressures and solid rocket booster and external tank impact.

NASA answer. The STS launches identified in response to the above question, which cannot be launched from KSC, fall into two categories.

(1) Certain high priority free-flying DOD payloads which exceed the capability of the Shuttle launched from KSC.

(2) All projected high inclination Spacelab missions which have to remain attached to the Shuttle.

[GAO information follows:]

A KSC-launched Space Shuttle can carry over 32,000 pounds to 98-degree inclination orbits. To accomplish northerly launches from KSC to polar and near-polar orbits, the Space Shuttle must change its launch trajectory in flight.

A KSC-based STS can accommodate all of the payloads, civil (including space-lab) and military, projected for the 1980-91 period, including those projected for high inclination orbits.

Pursuant to the Chairman's directive that GAO, NASA, and DOD get together after the hearings and reconcile their differences on payload carrying capabilities, a meeting was held at Johnson Space Center on March 17, 1978. Headquarters representatives from all agencies were present. At this meeting, tentative agreement was reached on the following performance figures:

Shuttle performance capability for northerly launches from KSC (assuming initial launch ascent azimuths of 8, 10, 13, and 19 degrees, with a subsequent dogleg maneuver to obtain a 98 degrees—150 nautical miles orbit

Initial launch ascent azimuth (degrees):

	<i>Weight-carrying capability (pounds)</i>
8.....	34, 922
10.....	33, 512
13.....	31, 148
19.....	25, 729

The figures shown above do not reflect the less severe wind conditions that exist at KSC as compared to Vandenberg which could result in additional performance capability, perhaps ranging from 750 to 2,100 pounds depending on actual winds at time of launch. Additionally, NASA has underway several studies involving ways to modify the Shuttle's design to give additional performance capability ranging from 2,000 to 20,000 pounds. One of the studies involves adding a catalyst to the SRB propellant, which could improve the Shuttle's capability by 5,000 pounds. The studies, are targeted for completion in June 1978.

As a point of understanding for the record, we note that the performance figures discussed at the March 17th meeting are not based on system changes which affect abort procedures or in any way compromise orbiter and crew safety. The figures do not include any deployment manifest deletions from the orbiter, that is, no items were off-loaded from the standard delivery configuration even though it was generally recognized that certain nonsafety items (televisions, cameras, etc.) were not mission-essential.

Question. Explain why each of the above launches could not use an expendable launch vehicle.

DOD answer. Each of the missions can be launched on current expendable launch vehicles or growth versions at increased operational costs.

NASA answer. The DOD missions could be launched on expendable vehicles from VAFB if ELV launch capability is retained for a cost in excess of \$1.3 billion. The Spacelab missions could not be flown on ELV's because the Spacelab must remain attached to the Shuttle. These Spacelab missions would have to be eliminated or flown at a lower inclination within the performance limit of the Shuttle from KSC with attendant degradation in scientific returns.

Question. How many DOD launches are projected to be made from Vandenberg through 1992? What is the weight of each of these? Why must they be launched by the Shuttle and not by expendables?

DOD answer. A total of 129 launches have been projected for VAFB through the first quarter of FY 1992. Of these, 44 are DOD launches. The missions comprising these launches and their specific payload weights are presented in the response to a previous question on page 372. As previously noted, these missions can be launched by current expendable launch vehicles until the mid-1980's. In addition, the Shuttle provides a capability for recovery not available with ELVs and provides for economy in operations.

NUMBER OF VANDENBERG LAUNCHES

Question. What is the total number of launches proposed for the Space Shuttle from both Kennedy and Vandenberg through 1992? What is the basis of this estimate?

DOD answer. The total number of launches planned for the Space Shuttle from FY 1980 through the first quarter of FY 1992 is 487. The basis of this estimate is the combination of the current DOD mission model (Revision 6 (modified)) and the latest NASA payload model. The combination of these two models yields a requirement for 552 flights. The flight model was reduced to 487 by deleting Spacelab missions in order to remain within the launch capacity of a five Orbiter fleet when attrition is considered. The DOD launch traffic projections are based upon estimates by the various payload program offices of their operational requirements. These estimates are in turn reviewed and approved by a joint service/DOD Space Shuttle User's Committee.

NASA answer. The total number of Shuttle launches from both KSC and VAFB through 1992 as defined in the 1977 OMB Study Update is 487 flights.

The national payload model was developed from requirements provided by all classes of users—both civil and defense. These requirements have been carefully evaluated and refined, as necessary, to provide compatibility with the users budget and program planning.

The NASA program addresses space activities in four major areas: General Science, Earth Applications, Technology, and Space Operations Development. The payloads associated with these activities represent one of a number of programmatic options that the agency might choose for the 1980-1991 time frame based on current program objectives and budget projections.

The non-NASA Civil Program was derived through extensive contacts with representatives of other government agencies and commercial organizations who utilize or plan to utilize space to support their activities.

The DOD payload content is represented by their Revision 6 dated July 20, 1977, and modified September 6, 1977.

While the civil programs show future expansion to capitalize on the STS capabilities, the DOD payload model is conservative and it is expected that a broad spectrum of new national defense concepts and programs will evolve to exploit the STS capabilities.

The payload program thus defined resulted in a Shuttle requirement for 552 flights from mid-CY 1980 through CY 1991. As a baseline for the analyses included in the 1977 OMB Study Update, a fleet capability was groundruled which considered one orbiter attrition in all cases. Orbiter attrition introduced a variation in the ground operations flows at the two launch sites that had not been considered heretofore. Whereas the five-orbiter fleet assumes a nominal five-day, two-shift operation providing an annual capability of at least 53 flights per year, a four-orbiter fleet can also support a maximum of 53 flights per year but requires a seven-day, two-shift operation.

The payload model was reduced in the number of NASA Spacelab missions in order to meet the more conservative capability of the 5 orbiter/2 site operation with attrition, resulting in deletion of about eight Spacelab missions per year from 1986 through 1991. A reexamination of the mission model with these attendant adjustments reduced the number of STS flights from 552 to 487.

Question. How many of these launches are from Kennedy? From Vandenberg?

DOD answer. Of the total of 487 flights from FY 80 through the first quarter of FY 92, 358 flights are launched from Kennedy and 129 flights from Vandenberg.

NASA answer. Of these 487 flights, 358 flights are projected for the Kennedy Space Center and 129 for the Vandenberg Air Force Base.

Question. Provide a table that shows the flights and users (NASA, DOD, other government, and private sector) of the Space Shuttle through 1992. Identify the launch site for each of these flights.

DOD and NASA answer: The requested table is attached showing the projected Shuttle launches for the period FY 80 through the first quarter of FY 92.

UTILIZATION OF ELV'S

Question. What is the status of development of the Titan IIID booster? How much R&D and procurement funds have been appropriated for this missile system? How much more will be required to complete RDT&E?

DOD answer. The hardware design is essentially complete and the analytical, software, and test effort is proceeding very smoothly. The prior year funds for Titan III(34)D vehicle systems work include \$31.6 million of RDT&E funds and \$201.3 million of missile procurement funds. The FY 79 RDT&E request includes \$25.4 million for the Titan III(34)D/Inertial Upper Stage integration with an additional \$17.2 million required to complete the program.

STS TRAFFIC MODEL

487 FLIGHT MODEL

(USERS)

	FY	80	81	82	83	84	85	86	87	88	89	90	91	92	TOTAL
ETR NASA		1	6	10	10	18	17	19	18	15	17	17	16	3	167
U.S. GOV'T		1	1			1				1		1	1		6
U.S. COM'L		1	3	1	2	3	4	5	4	9	8	8	4	2	54
FOREIGN			1	3	3	3	3	3	5	5	5	6	6	1	44
DOD				2	6	7	8	7	5	8	6	7	9	2	67
SUBTOTAL		3	11	16	21	32	32	34	32	38	36	39	36	8	338
REFLIGHTS				2	1	2	2	2	2	2	2	2	2	1	20
TOTAL ETR		3	11	18	22	34	34	36	34	40	38	41	38	9	358
WTR NASA					1	4	6	5	5	6	4	6	6	1	44
U.S. GOV'T					1	1	1	2	2	4	2	4	2	1	20
U.S. COM'L								1	1				1		3
FOREIGN								2	3	1	2	1	1	1	11
DOD					2	4	5	4	6	6	6	4	6	1	44
SUBTOTAL					4	9	12	14	17	17	14	15	16	4	122
REFLIGHTS						1	1	1	1	1	1	1	1		7
TOTAL WTR					4	9	13	15	18	18	15	16	17	4	129
MISSION MODEL TOTAL		3	11	18	26	43	47	51	52	58	53	57	55	13	487

Question. When will development be completed?

DOD answer. The initial launch capability for the Titan III(34)D at the Cape Canaveral AFS, FL, is scheduled for July 1980 with a Vandenberg AFB, CA, initial launch capability in December 1981.

Question. How many Titan III boosters are now in Air Force inventory? How many are under contract? How many more will be procured?

DOD answer. The DOD Titan III procurement data is as follows:

	Inventory	On contract	Planned	Total
Vehicles for pre-Shuttle missions:				
Titan III B.....	5	6	0	11
Titan III C.....	4	5	0	9
Titan III(23)D.....	[Deleted]	[Deleted]	[Deleted]	[Deleted]
Titan III(34)D.....	[Deleted]	[Deleted]	[Deleted]	[Deleted]
Titan III(34)D/IUS.....	0	4	1	5
Assets for Shuttle backup:				
Titan III(34)D:				
Complete.....	0	2	0	2
Subassemblies.....	0	0	2	2
Material.....	0	0	2	2
Titan III(34)D/IUS: ¹				
Complete.....	0	0	1	1
Subassemblies.....	0	0	2	2
Material.....	0	0	2	2

¹ The inertial upper stage (IUS) scheduled for the Shuttle mission would be used with the backup Titan III(34)D to launch the payload.

Question. How many Titan IIID boosters are planned to be procured? What is the procurement unit cost for each of these?

DOD answer. The Titan III(34)D production program consists of 11 complete vehicles, 4 sets of subassemblies and details, and 4 sets

of long lead material. Three of the completed vehicles are scheduled for launch from Vandenberg AFB, CA and five are scheduled for launches with the Inertial Upper Stage from Cape Canaveral AFS, FL. The remaining three completed vehicles and the eight partial vehicles provide a backup capability for critical DOD space missions during the early years of Shuttle operation. The Titan III(34)D unit cost, including hardware, production support, propellants, and launch services in FY 79 dollars at a 4 per year rate is projected at \$44.3 million.

Question. What is the payload of the Titan IIID booster? What was the planned payload when the R&D program began?

DOD answer. The Titan III(34)D/Inertial Upper Stage payloads include the Defense Satellite Communications System Satellite (Phase II for pre-Shuttle missions and Phase III for backup missions), and other classified DOD payloads. The Titan III(34)D payloads are all classified DOD missions. These are the same payloads that were previously planned.

Question. What existing or planned DOD payloads cannot be used on the Titan III(34)D because of weight, size, or other limitations? Explain why not.

DOD answer. In the mid-1980's, a classified low earth orbit payload weight is projected to exceed the 24,300 lbs capability of the Titan III(34)D. It is pertinent to note that the other DOD low earth orbit payloads are too small for economical launch on the Titan III(34)D.

Question. How many of the DOD payloads cannot use the Titan IIID booster? Break this down by number of launches per year from Vandenberg?

DOD answer. Based on projected payload weights and DOD Space Mission Model Rev 6, two missions per year from Vandenberg are expected to exceed the Titan III(34)D capability after the mid-1980 time period.

Question. How many other payloads cannot use the Titan IIID or other expendable boosters from Vandenberg?

NASA answer. The total number of civil missions which cannot be launched from Vandenberg on expendable boosters is 39. This figure represents Spacelab missions in the STS 487 Traffic Model which must be flown by the Space Shuttle from Vandenberg Air Force Base.

Question. What "backup" support is planned and can be accommodated by the Titan boosters and launch facility planned for Vandenberg?

DOD answer. The Titan III(34)D Space Shuttle backup capability planned for Vandenberg missions consists of one completed vehicle, two sets of subassemblies and details, and two sets of materials. These assets are also capable of being transferred to support any backup requirement for missions scheduled from the Shuttle's Eastern Launch Site and conversely, assets planned for KSC backup support can be reallocated to VAFB if not otherwise needed.

Question. What Titan launch facilities now exist at Vandenberg? Why is this not suitable, and why do modifications to existing facilities have to be made? Explain the nature of these modifications.

DOD answer. There are two Titan III launch complexes at Vandenberg AFB, CA. Space Launch Complex-4W supports Titan IIIB missions, and Space Launch Complex-4E supports Titan III(23)D

missions. The Titan III(34)D is 68 inches longer than the Titan III (23)D and has provisions for Inertial Upper Stage avionics. The longer and heavier vehicle with new avionics necessitates the facility modifications. These modifications requested in the FY 1979 submittal consist of adjustments to the existing work platforms and installation of a larger capacity crane in the Mobile Service Tower; new launch and space vehicle umbilical booms on the Umbilical Tower; new bearing plates for the Launch Mount; and, interior modifications to the Launch and Service Building and Launch Operations Building to accommodate new electrical—electronic launch checkout equipment.

Question. Could a payload be launched into polar orbit from Vandenberg and recovered by a Shuttle Orbiter launched from Kennedy? Explain the answer.

NASA answer. Although no detailed analysis of this concept has been made, it is probable that payloads launched from VAFB could be recovered on a Shuttle mission designated to accomplish this retrieval. This is possible, however, only if overflight of the U.S. were accepted. The Shuttle could not accomplish this recovery if current and planned KSC launch safety constraints are observed, i.e., launch inclination no greater than 57 degrees.

GAO answer. It is technically possible to recover a payload launched from Vandenberg with a KSC launched Shuttle. Whether such a feat is practical in any given instance depends on a variety of circumstances, such as the orbit of the payload, and whether or not land overflight of the U.S. and Canada would be allowed by the KSC launched Shuttle. Also, in some instances it might not be cost-effective to perform such a maneuver since the Shuttle might have to be launched empty and thus all launch cost would be chargeable to the recovered payload.

VANDENBERG LAUNCH FACILITY

Question. Provide for the record a description of the proposed Western Launch Site for the Space Shuttle. Include a description of the existing facilities that are to be modified, a mission statement for Vandenberg, and other pertinent information.

DOD answer.

VANDENBERG GROUND SUPPORT SYSTEM (GSS) MISSION STATEMENT

The DOD-provided Vandenberg GSS will provide the necessary facilities, equipment and software necessary to receive, process, launch, and recover the Space Shuttle vehicle. The STS capability will thereby expand to high inclination (polar) launch capability (effective June 1983) to complement the low inclination launch capability provided from the NASA facilities at Kennedy Space Center.

VANDENBERG GROUND SUPPORT SYSTEM DESCRIPTION

The VAFB Ground Support System encompasses the facilities, hardware, software and support functions that must be properly integrated to receive, process, launch and recover Space Shuttle Vehicle (SSV). This includes all handling, transporting, mating, servicing, maintenance, and checkout operations. The GSS will also provide for the installation and removal of payloads flown and retrieved by the SSV

in support of both DOD and NASA missions. These operational requirements have been translated into facilities and equipment designs which have been grouped into "station sets." Station sets are the accumulation of equipment at a specific site (geographical station set) or the accumulation of equipment required to support a specific function (functional station set). There are three locations of geographical station sets: North Vandenberg AFB (grouped around the runway), South Vandenberg AFB (grouped around the launch pad) and Port Hueneme.

NORTH VAFB STATION SETS DESCRIPTIONS

The following station sets constitute the North VAFB Ground Support Systems: landing, mate/demate, Orbiter maintenance and checkout, safing and deservicing, hypergolic maintenance and checkout, flight crew systems, and parachute refurbishment.

V17—Landing. The landing station set includes the associated support equipment to support Orbiter landing, post-landing, and ferry operations. The landing facilities located at the existing Vandenberg Air Force Base airfield site consists of a 200 foot x 15,000 foot runway, associated taxiways, and pads for necessary support equipment. The existing Vandenberg Air Force Base control tower will be used for the STS program. The existing VAFB runway will be lengthened and the existing part resurfaced.

V18—Mate/Demate. The mate/demate station set includes the support equipment to mate or demate the Orbiter with the Shuttle Carrier Aircraft for ferry operations. The mate/demate facility (MDF) consists of a large structural steel fixture located on a concrete apron southeast of the existing airfield operations area.

V19—Orbiter Maintenance and Checkout. The Orbiter maintenance and checkout station set includes the associated support equipment needed for payload removal/installation; Orbiter maintenance and systems checkout; re-installation of hypergolic modules; removal/installation of Space Shuttle main engines, flight kits and ferry kits, and Vandenberg Launch Processing System control/monitor of functions in Station Sets V19, V19A, and V21. The Orbiter maintenance and checkout facility (OMCF) is a new large one bay hangar with associated shop and technical areas for the Orbiter, required support equipment and personnel, and an existing single story concrete building for housing the Vandenberg Launch Processing System, communications, and personnel. The hangar is located at the southwest end of the airfield operations area and the Vandenberg Launch Processing System Building (Building 8510) is located in the industrial area.

V19A—Safing and Deservicing. The safing and deservicing station set includes the associated support equipment for Orbiter system safing, deservicing, and hypergolic module removal. The safing and deservicing facility (SDF) is a new large one bay hangar with associated shop and technical areas, and remote deservice pads for hypergolic fuel and oxidizer, liquid hydrogen, and liquid oxygen. The SDF is located at the southwest end of the airfield operations area.

V21—Hypergolic Maintenance and Checkout. The hypergolic maintenance and checkout station set includes the associated support equipment for organizational maintenance and checkout of the Aft Propulsion System, Forward Reaction Control System, Orbiter Maneuvering Subsystem, and components of the Auxiliary Power Unit. The Hypergolic Service Facility (HSF) consists of new steel and concrete structures with space designated for shops, technical and module storage areas, test cells, and adjacent deservicing pads for fuel and oxidizer. The HSF is located adjacent to the SDF and OMCF.

V27—Flight Crew Systems. The flight crew systems station set includes:

- a. Crew living quarters.
- b. Medical facilities.
- c. Flight suit maintenance and checkout.
- d. Clean rooms.
- e. Maintenance and checkout of extravehicular mobility units and manned maneuvering units.
- f. Vandenberg launch processing system equipment.
- g. Refrigerated storage for food, film, etc.
- h. Transportation vans.

Flight Crew Equipment (FCE) preflight processing including pre-packaging of stowage containers will be done at Johnson Space Center (JSC). All flight crew equipment transportation is considered a function of the V27 station set. The existing VAFB Building 8505 built for the Manned Orbiting Laboratory Program (MOL) will revert to a crew quarters facility.

V30—Parachute Refurbishment. The parachute refurbishment station set provides the capability to wash, inspect, repair, assemble, checkout, and pack parachutes. The Parachute Refurbishment Facility (PRF) uses existing Building 1728 with modifications and additions. Recovered parachutes will be transported wet and on reels from Port Hueneme to the PRF by truck or rail car. Parachutes will be stored as a "pack" in station set V31—Solid Rocket Booster Refurbishment and Subassembly Facility (SRSF).

SOUTH VAFB STATION SETS DESCRIPTIONS

The following station sets constitute the South VAFB Ground Support System: launch pad, launch control center, solid rocket booster refurbishment and subassembly, and external tank processing and storage. In addition to the GSS station sets, the replacement for the Space Launch Complex (SLC)—6 Segment Receipt—Inspection (RIS) building, used for the SRSF, will be constructed at South VAFB as a part of the GSS construction effort to maintain the Titan solid rocket booster processing capability during the transition period.

V23—Launch Pad. The Launch Pad (LP) consists of the launch stand, supporting technical facilities, and support equipment which provides the capability for on-stand assembly, checkout and maintenance of the SSV; payload installation and removal (if required); integrated checkout; and launch of the SSV. The LP is located on VAFB near Point Arguello and is a modification of the existing SLC-6 facilities. The major facilities of the Launch Pad are:

- a. Launch Stand and Exhaust Ducts (modified)
- b. Mobile Service Tower (modified)

- c. Access Tower (new)
- d. Payload Preparation Room (PPR) (new)
- e. Payload Changeout Room (PCR) (new)
- f. Hypergolic Storage Areas (MMH and N_2O_4) (modified)
- g. Gas Storage Area (modified)
- h. LO_2 and LH_2 Storage Area (new)
- i. Support Equipment Building (modified)

V28—Launch Control Center. The Launch Control Center (LCC) is a two-story concrete building that houses the portion of the Vandenberg Launch Processing System and other associated support equipment needed to control and monitor activities at the Launch Pad (V23), (V31), and (V33). The LCC utilizes the existing SLC-6 LCC with modifications.

V31—Solid Rocket Booster Refurbishment and Subassembly. The SRB Refurbishment and Subassembly station set includes the support equipment for SRB component receiving, refurbishment, subassembly, checkout, and storage. The Solid Rocket Booster Refurbishment and Subassembly Facility, a steel structure with shop and technical areas to support SRB operations, utilizes the existing SLC-6 RIS building (Building 520) with major modifications and additions.

V33—External Tank Processing and Storage. The ET Processing and Storage station set provides a marine facility for off-loading external tanks from the shallow draft barge used to transport them from the manufacturing facility in Louisiana, a towroute to enable ET movement from the dock to the Tank Storage and Checkout Facility and subsequently to the launch pad, Tank Storage and Checkout Facility, and associated support equipment for ET handling, receiving, storage and checkout. The existing South VAFB boat harbor will be modified to receive the NASA ET barge for ET deliveries. The marine facility includes an elevated concrete dock located southeast of the launch pad. The Tank Storage and Checkout Facility is a new five bay steel structure with shops and technical support areas located south of the launch pad on the towroute to the marine facility.

TITAN IIID SOLID MOTOR PROCESSING AND STORAGE AREA (SMPSA)

The SMPSA provides the capability to receive, inspect, checkout, subassemble and store Titan IIID SRM components. The facility is a steel structure with shop, technical areas and outside storage area.

PORT HUENEME STATION SET DESCRIPTION

The SRB retrieval and disassembly station set constitutes the Ground Support System at Port Hueneme.

V32—SRB Retrieval and Disassembly. The SRB retrieval and disassembly station set provides the marine facilities with attendant recovery vessels and support equipment for water retrieval and handling of Solid Rocket Boosters (SRB's) and components, and SRB safing, cleaning, handling, disassembly, preservation and preparation for shipment to the refurbishment sites. Existing Port Hueneme harbor facilities will be used to dock and receive the retrieved SRBs for processing. The facility includes new rail and truck access routes and an adjacent outdoor wash area.

FUNCTIONAL SUPPORT STATION SETS DESCRIPTIONS

The functional support station sets identified for Vandenberg include transportation, communications, utilities and logistics. These stations provide the interconnecting support required by the geographic stations.

V80—Transportation. This station set provides the External Tank, Solid Rocket Booster element and Orbiter transporters and prime movers, and facility interconnecting tow roads. Various portions of the existing VAFB road network will be used, expanded or upgraded for this function.

V81—Communications. This functional station set contains both hardline and RF communications systems that include voice, television, telemetry, timing, navigation, tracking and location, landing aids, and measurements (remote facility and environmental). The existing VAFB range/technical communications/data transfer system will be used, modified, and expanded for STS use.

V84—Vandenberg Launch Processing System. This functional station set contains the computerized Vandenberg Air Force Base Launch Processing System (VLPS) which provides remote monitor and control of vehicle and ground systems at various geographical station sets, data processing and storage and Engineering/Operations—Information Management System (E/O—IMS) processing. Existing VAFB Building 8510 and the LCC will be used to house the LPS equipment.

V86—Utilities. This functional station set is the collection of the requirements on the Vandenberg Air Force Base from all geographical station sets. Existing VAFB utilities (power, water, etc.) will be used, modified or expanded for STS use.

V88—Logistics. The logistics (supply and maintenance) station set is defined as all of the equipment, facilities and services necessary to provide material management and line replaceable unit (LRU) maintenance management for ground operation of the STS at VAFB. Functions include material acquisition and control, material warehousing, logistics transportation, propellant and ordnance management, and repair of selected items of flight hardware and ground support equipment. The logistics (S&M) station set requires the use of a building in the industrial area of VAFB as the centralized facility for material management and LRU maintenance activities. Personnel required to perform the above functions will be located in this facility, along with the necessary communications systems, on-line teleprocessing terminals and transportation and maintenance equipment required to support this activity. The station set will provide warehousing facilities for items designed for centralized storage and provide the shops, laboratories, equipment and facilities to accomplish LRU maintenance. In addition, decentralized material service centers are required on South VAFB and at Port Hueneme to provide easily accessible areas for supply support of the geographic station sets. Existing VAFB buildings will be used to the maximum extent possible, augmented by new or temporary structures, to house logistics and support functions.

ACTIVITY LEVELS AT VANDENBERG

Question. What is the current type and level of activity at Vandenberg? Provide for the record a list of launches from Vandenberg for the past two years and a list of scheduled launches for the next two years.

DOD answer. Vandenberg AFB and its associated test range is a major DOD test facility supporting U.S. Government space launches, ballistic missile R&D and operational test launches, and aeronautical test activity. The space launch activity includes large space launch vehicles of the Titan class, medium space launch vehicles of the Atlas and Thor classes, and small space launch vehicles of the Scout class. Range activity for these launch vehicle classes is as follows:

Fiscal year	DOD			NASA	
	Large	Medium	Small	Medium	Small
1976.....	6	5	2	2	0
1977.....	2	4	1	0	0
1978.....	[Deleted]	10	1	5	1
1979.....	[Deleted]	5	1	1	1
1980.....	[Deleted]	5	1	1	0

FACILITIES AT KENNEDY

Question. Provide a list of each facility now at the Kennedy Space Center and required for the Space Shuttle program. Include the cost of each facility, year of construction completion, and a summary of the function of each.

NASA answer. The following information is provided for KSC launch facilities for Shuttle and the estimated cost in millions.

A. Mate/Demate Device (MDD): To remove the orbiter from 747 or mate the orbiter to the 747. Est. cost \$1.7M.

B. Emergency Power: To provide emergency power to critical operations—launch and landing. Est. cost \$2.2M.

C. Channel Barge Dredging: To provide adequate channel for barge movement of ET's and SRB retrieval. Est. cost \$2.1M.

D. Solid Rocket Booster (SRB) Processing: Acceptance and handling of SRM's. Major SRB building and processing. Est. cost \$5.2M.

E. SRB Refurbishment: Repair, check-out, cleaning, and preparation and minor SRB subassembly. Est. cost \$3.4M.

F. SRB Parachute: Cleaning, check-out, repair, and processing of SRB parachutes. Est. cost \$1.7M.

G. SRB Disassembly: Removal of SRB's from water, clean, disassemble SRB's. Est. cost \$5.3M.

H. Pad A-Pad B: Payload vertical insertion or removal, prelaunch check-out of Space Shuttle vehicle, fueling—launch: Pad A—\$35.9M; Pad B—\$48.8M.

I. Mobile Launch Platform 1-Mobile Launch Platform 2: Assembly platform for the Space Shuttle vehicle, transfer vehicle from VAFB to pads, launch platform: MLP 1—\$13.8M; MLP 2—\$14.4M.

J. Vertical Assembly Building (VAB): Integration, buildup and checkout of the Space Shuttle vehicle. Processing and storage of the External Tanks: High Bays 3 & 4, \$8.2M; High Bays 1 & 2, \$2.2M.

K. Orbiter Processing Facility (OPF): Safing, maintenance, checkout & repair of the orbiter. Payload removal and horizontal payload insertion. Est. cost, \$27.5M.

L. Orbiter Landing Facility (OLF): Land the Orbiter. Est. cost, \$27.2M.

M. Launch Equipment Test Facility (LETF): Developmental facility for the development, testing and continual certification of launch systems hardware (i.e. swing arms, tail service mast, hold down arms, etc.). Est. cost, \$2.0M.

N. Hypergolic Maintenance Facility (HMF): Checkout, maintenance, repair and storage of the RCS and OMS hypergolic systems. Est. cost, \$5.2M.

KSC SPACE SHUTTLE FACILITIES AS OF APR. 14, 1978

Project	Construction completion date	Operational readiness date	Estimated project cost (in millions)
LC-39:			
Pad A	May 1978	November 1978	\$35.9
Pad B	October 1981	October 1982	48.8
MLP-1	June 1978	September 1978	13.8
MLP-2	October 1980	March 1981	14.4
VAB:			
HB's 3 and 4	January 1978	August 1978	7.9
HB's 1 and 2	September 1978	October 1982	8.2
LCC	May 1978	October 1978	2.2
Orbiter processing facility:			
Phase I	November 1977	July 1978	15.5
Phase II	August 1978	March 1981	12.0
Orbiter landing facility	December 1977	July 1978	27.2
Launch equipment test facility	January 1978	February 1978	2.0
Hypergolic maintenance facility	May 1978	August 1978	5.2
Mate/demate device	June 1978	July 1978	1.7
Emergency power	October 1978	October 1978	2.2
Barge channel dredging	August 1978	September 1978	2.1
SRB facilities:			
Processing	January 1978	September 1978	5.2
Refurbishment	March 1978	March 1978	3.4
Parachute	August 1978	January 1979	1.7
Disassembly	December 1978	do	5.3

FACILITIES TO BE CONSTRUCTED AT VANDENBERG

Question. Provide a list of each facility proposed to be constructed or modified at the Vandenberg site required for the Space Shuttle, the function of each, and the estimated cost of construction. Provide a list of what is included in the fiscal year 1979 request and the cost of each.

DOD answer. Facilities included in the FY 1979 request and facility construction costs:

Airfield Modifications	Millions
Launch Pad Modifications	\$32.1
	104.7
Total	136.8

Remaining facilities and estimated construction cost:

Orbiter Maintenance and Checkout Facility.

Safing and Deservicing Facility.

Hypergolic Servicing Facility.

External Tank Processing Facility.
 Harbor Modifications.
 Solid Rocket Booster Refurbishment and Assembly Facility.
 Solid Rocket Booster Retrieval and Disassembly.
 Parachute Refurbishment Facility.
 Flight Crew Systems Facility.
 Transportation Route.
 Utilities.
 Logistic Facilities.
 Support Facilities.
 Titan Replacement Facility.
 Current total estimated cost: \$115.0M.

Estimated cost based in part on pre-design estimates. The progression through design, and the culmination of several on-going systems-oriented studies may alter the list of facilities and/or the total cost estimate prior to submittal for funding.

Question. Will the Vandenberg launch site require a second launch pad for the Space Shuttle? If not, why not?

DOD answer. The Vandenberg launch site design has provisions for a second launch site to the south of the SLC-6 complex. Current Shuttle traffic projections, however, do not justify the construction of the second launch pad. We have not, therefore, requested authorization for the construction of the second launch pad.

NASA answer. The present VAFB design concept is predicated on the capability of launching twenty flights per year if two orbiters are dedicated to VAFB operation.

The analysis performed in the 1977 OMB Study Update based on the 487 mission model assumed only one launch pad at VAFB. As determined in this analysis all projected VAFB launches (15-18 flights per year) could be accomplished with an adequate orbiter fleet size using the orbiter fleet interchangeably between KSC and VAFB.

DIFFERENCES BETWEEN KENNEDY AND VANDENBERG

Question. Provide a list of all facilities at Kennedy for the Space Shuttle program which are not required or proposed at Vandenberg, and explain why they are not needed at Vandenberg.

Provide a list of all facilities proposed for Vandenberg that are not at Kennedy, and explain why each is required at one site and not the other.

Provide a side by side comparison of Vandenberg and Kennedy Space Center launch facilities.

DOD answer. Kennedy and Vandenberg accomplish similar operational tasks using differing operational concepts dictated by the geography of the two sites and the existence of facilities inherited from previous programs. Kennedy, using the Apollo program facilities and equipment, has a centralized operation featuring an integrate transfer launch concept. Specifically, the Space Shuttle Vehicle (Orbiter, external tank, and solid rocket booster) is built up and integrated in the Shuttle Vehicle Assembly Building (the Apollo Vertical Assembly Building), transferred to the launch pad (on Apollo Mobile Launch Platforms), and launched (from Apollo launch pads). The geography of Kennedy allowed the runway to be built near the Orbiter refurb-

bishment facility (the Orbiter Processing Facility) which, in turn, is adjacent to the Shuttle Vehicle Assembly Building. Thus Kennedy can geographically centralize the major tasks involved in generating the next flight—the processing of the Orbiter and its integration and checkout as a part of the Space Shuttle Vehicle.

Vandenberg uses Manned Orbiting Laboratory Program facilities and equipment and the existing Vandenberg AFB runway (all with extensive modifications). No mobile launch platforms exist at Vandenberg; therefore, the Space Shuttle Vehicle must be built up from its component parts on the launch pad using the integrate on pad concept. This requires a much more complex launch pad but eliminates the need for a Shuttle Vehicle Assembly Building. The Manned Orbiting Laboratory program launch pad (Space Launch Complex-6) will be modified to accommodate the integrate on pad concept for the STS. However, the need to service the Orbiter immediately upon landing and the location of the existing Vandenberg AFB airfield dictated that the Orbiter refurbishment activities be accomplished near the runway some 14 miles from the launch pad. This decentralization of activity is characteristic of Vandenberg STS operations.

Given these differences, the major facilities at Kennedy and Vandenberg can be compared on a functional basis. Generally, the station sets listed accomplish similar functions.

	Kennedy	Vandenberg
Runway	SS-17	V-17
Mate-demate	Part of SS-17 ¹	V-18
Orbiter maintenance and checkout	SS-19	V-19
Safing and deservicing	Performed in OPF	V-19A
Hypergolic service	SS-21	V-21
Launch pad	SS-23	V-23
Launch control center	SS-28	V-28
Parachute refurbishment	SS-30	V-30
SRB refurbishment and subassembly	SS-31	V-31
SRB retrieval and disassembly	SS-32	V-32
External tank processing	Performed in VAB ²	V-33

¹ The distinction is administrative; the equipment is functionally and physically similar.

² Vandenberg has no equivalent to the Shuttle vehicle assembly building at Kennedy.

Not listed above are the facilities at Kennedy devoted to the Inertial Upper Stage (the East Wing of the Solid Motor Assembly Building—a Titan III facility). IUS operations will be conducted from Kennedy only reflecting the differing mission destinations of payloads launched from the two sites (Kennedy—low to middle inclinations, at high and low altitudes; Vandenberg—high inclination at low altitudes).

SELECTION OF A WESTERN LAUNCH FACILITY

Question. How was the decision made to use Vandenberg as the western launch site for the Space Shuttle?

NASA answer. To insure proper consideration of all possible candidate sites for Space Shuttle launch and landing support, NASA convened a site selection review board in April 1971. The Board completed its activities in April 1972 and, following a final briefing to the Administrator, NASA selected KSC and VAFB as Space Shuttle launch and landing sites. DOD concurred in the site selection and

agreed to provide the general purpose Space Shuttle facilities at VAFB. A summary of the site selection activity is given below.

The Space Shuttle must be able to deliver and to retrieve a variety of earth orbital payloads for all users—civil and defense. These payloads are distributed among multiple launch azimuths to accomplish the missions as efficiently as possible. Low inclinations are required by the planetary missions and a variety of other civil and DOD payloads. High inclinations are used by missions such as earth observations, experiment modules, and Space Station supply. Polar and near polar inclinations are used for science and applications missions and unique DOD missions.

The main features of the system which govern launch and landing site considerations are ascent sonic boom, water recovery of the solid rocket boosters, disposal of the hydrogen/oxygen tank, and orbiter recovery by glide-in runway landing. Additionally, a space vehicle system of this size and configuration requires significant resources in the areas of propellants, gases, clean rooms, ground support equipment, processing facilities and transportation facilities. The selected site must provide buffer zones surrounding the site, unpopulated areas for the booster impact and safe ascent aborts, remoteness from downrange populous areas to minimize overflight risks, and a supporting community. Vertical flight development and subsequent program operations are to be accomplished from the same site and require tracking and data acquisition systems that will give detailed coverage during boost, separation, orbiter ascent, and orbiter return phases. Particular site requirements used in the screening process were orbiter return to a landing field meeting FAA and DOD requirements and booster impact in 20 fathoms or more of water from 100 to 200 nautical miles downrange along each launch azimuth.

The following technical evaluation criteria were utilized in judging the extent to which the sites could accept the planned program and would have flexibility to accommodate a program beyond that currently foreseen.

Mission capability—Can mission requirements (payloads and orbits) be achieved with minimum degradation in vehicle performance?

Booster recovery—Are adequate water area and depth available for recovery operations?

Abort planning—Are safe impact zones available for emergency jettison of external tanks?—are ranges of azimuths available with acceptable overflight conditions?

Logistics planning—Is there convenient access to modes of transportation, power, and fuels?—does the site adapt well to overall Shuttle logistics planning?

Weather and climate—Are weather conditions conducive to continuous operations?

Air and water quality—Can the local region accept this program with acceptable impact on air and water quality?

Noise/sonic boom—Are buffer zones available to assure acceptable engine noise levels in surrounding communities?—are areas available for acceptable placement of ascent and orbiter return sonic booms?

Considering the foregoing requirements and criteria and applicable cost data, NASA selected both KSC and VAFB as the Shuttle launch and landing sites versus the one remaining potential single site in

Matagorda County, Texas. Costs, performance, environment and growth factors favored the dual site approach.

Question. What other sites or locations were considered?

NASA answer. The original Shuttle program called for a fully reusable, flyable booster (first stage) which took off as a rocket but landed as an airplane. The implications of a new operational plan and consequent new operational site resulted in a total field of some 150 contending sites.

The later selection of a ballistic (i.e., unguided), water-recoverable booster stage, in effect, limited the feasible candidate sites to coastal areas. This decision also led to methods of operation and site requirements very similar to those currently in effect at existing launch sites.

Screening to meet major mission and site requirements resulted in two final candidate options:

A single, virgin, Gulf-coast area (Matagorda, Texas).

The pair of existing east/west coastal sites (KSC/VAFB).

No existing single site could satisfy total program requirements.

GAO answer. A Space Shuttle Launch and Recovery Site Review Board, having NASA and DOD membership, was formally established by NASA in April 1971 to evaluate candidate sites. At that time, Shuttle designs still planned for a fully reusable system, with no components to be jettisoned during ascent for recovery at sea. Spokesmen in 40 states requested the site be located within their State; altogether, the Board reviewed some 150 contending sites. However, the early 1972 conversion to a water-recoverable booster stage and an expendable external tank reduced the acceptable launch sites to coastal locations. Screening narrowed site selection to a choice between a single site operation in Matagorda County, Texas, on the Gulf coast; or a two-site operation at KSC and VAFB.

In its final report, dated April 10, 1972, the Board commented:

* * * there is no clear economic advantage to establishing a *new* single launch site with the capability to handle all Shuttle launches as compared to continued utilization of the two existing launch sites. *The main reason* for this result is that the ultimate reduction in annual operating *cost* for a single site is not sufficient in magnitude and is too far distant in time to overcome the large initial costs. (Italic supplied.)

Despite the nonselection of Matagorda County due to the large initial investment costs, the review established the technical feasibility of single-site operations; actually, selection of a single site was the primary thrust of the Board's efforts. However, the Board did not consider it feasible to have either KSC or VAFB as a single STS launch site.

Question. Has an environmental impact statement been prepared for Vandenberg?

DOD answer. An environmental statement has been prepared for the Western Launch and landing site which includes the Space Shuttle facilities at Vandenberg AFB and Port Hueneme, CA. The final environmental statement was filed with the Council on Environmental Quality on 7 Feb. 1978.

COSTS OF THE VANDENBERG LAUNCH FACILITY

Question. What are the projected total O&M costs for operating Vandenberg through 1985? Through 1992? Provide for the record a

description of how these costs are estimated and broken down in terms of number of personnel, utilities, real property maintenance activities (RPMA), etc.

DOD answer. O&M costs for Vandenberg begin when Vandenberg is declared operational (IOC). Costs were estimated as follows:

Direct Manpower Costs:

Contractor Manpower—Contractor Studies (modified based upon government experience and reviews).

Government Manpower—Manpower estimates from the units affected

Other Direct:

Spares—AFLC spares support estimates.

Pad Refurbishment—Titan experience.

Supplies—System Program Office estimate.

Propellant—NASA predictions of usage rates; unit costs from Air Force Fuels Management Center, San Antonio, TX.

Indirect Manpower Costs:

Indirect Manning—Pro-rata share of total indirects at Vandenberg. Pro-rata share determined by ratio of direct manpower.

Other Indirect Costs:

Utilities and Facility Maintenance—System Program Office estimates.

Typical numbers of personnel for a 16 launch per year operation:

Direct manning:

STS contractor.....	1,700
Government (military, civil service, FCRC).....	300

Total.....	2,000
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Indirect manning:

Launch and range support.....	475
Host base support.....	680
Air Force overhead and contract management.....	145

Subtotal.....	1,300
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Total.....	3,300
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Based upon these estimates the average cost of a year's operation at Vandenberg is \$160 million (FY 79 dollars):

	(Millions)
Direct manpower.....	93
Other direct.....	20
Indirect manpower.....	43
Other indirect costs.....	4

The total cost of operating Vandenberg through 1985 is \$390 million (FY 79\$). The total cost through the first quarter of FY 92 is \$1,360M (FY 79\$). This equates to roughly \$2.6 billion when escalated at a seven percent annual rate.

Question. What are the fixed O & M costs for operating Vandenberg for Shuttle Launches and what are the variable costs that change according to the number of launches?

DOD answer. Vandenberg facilities and manpower were estimated on the basis of relatively evenly spaced launches. The expected average number of launches is 16 per year. So long as the launch rate remains within the 14-18 per year range the O & M costs are expected to behave as follows:

Direct Manpower Costs:

Contractor.....	Constant.
Government.....	Constant.

Other Direct Costs:

Ground Support Equipment Spares.....	Constant.
Pad Refurbishment.....	Variable.
Supplies.....	Constant.
Propellants.....	Variable.
Indirect Manpower Costs.....	Constant.
Other Indirect Costs.....	Constant.

Question. What are the annual O & M costs for operating Vandenberg? How many personnel are currently authorized at Vandenberg? How many are assigned?

DOD answer. The space launch program using expendable launch vehicles and their replacement, the Space Shuttle, is one of three major activities at Vandenberg. The other two are the ballistic missile launch program (both research and development and operational test launches) and the aeronautical test program. The O & M costs listed below are that portion of the total Vandenberg O & M costs that are identified with the space launch program. The remainder are costs that are independent of the decision to implement STS operations at Vandenberg AFB.

Current expendable launch vehicle operations at Vandenberg experience typical costs of \$54 million per year for launch support and an additional \$16 million per year for range support. We estimate about \$30 million per year indirect costs from SAMTEC and the host base are also attributed to the space launch program. All costs are in FY 79 dollars and represent the costs of current operations. The working population of Vandenberg is approximately 10,300 government employees and contractors. Most of the major organizations on base provide support to more than the expendable launch vehicle program, e.g., Space and Missile Test Center (SAMTEC) supports both space and ballistic missile test launches, and Strategic Air Command, as the operator of the base, supports all activities on the base. The manning figures that follow are our estimate of the portion of the 10,300 that can be attributed to the expendable launch vehicle operations.

Direct:

Military and civil service.....	350
Launch support contractors.....	1,200
Total.....	<u>1,550</u>

Indirect:

Range support contractor.....	500
Launch, range, and base support (estimate).....	950
Subtotal.....	<u>1,450</u>
Total.....	<u>3,000</u>

Not included in the manning estimates is the contractor support at the factory (off Vandenberg) which is normally included in the launch services contract cost.

Question. How many additional personnel over and above the current authorized and assigned strength at Vandenberg will be required for the Shuttle mission?

DOD answer. We estimate that the current Vandenberg AFB working population of approximately 10,300 people will grow by approximately 300 to 500 people during the full operational period of the Shuttle (1986-1991.)

Question. What is the total incremental cost to operate Vandenberg as a Space Shuttle base over and above the current cost to operate it now?

DOD answer. The incremental cost to operate Vandenberg is \$60 million (FY 79\$). This is the difference between the \$160 million per year average cost of the typical Shuttle operational year (16 launches per year) and the \$100 million per year cost of the current expendable launch vehicle operation (10 launches per year).

The above data, however, represents only half the impact. Currently DOD operates expendable launch vehicles from both Vandenberg AFB, CA and Cape Canaveral AFS, FL. We provide launch crews and management personnel at both sites. In the Shuttle era we will provide a Shuttle launch crew at Vandenberg only with a much smaller launch crew at Cape Canaveral AFS, FL for the Inertial Upper Stage. Thus, the \$160 million per year for Vandenberg Shuttle launch operations represents the DOD operations contribution to the Space Shuttle (excluding the Inertial Upper Stage), in return for which, the DOD can obtain Space Shuttle launches from either coast without further operations (manpower) costs as provided under the DOD/NASA launch reimbursement agreement.

In addition, civil and foreign users of VAFB that have not contributed to investment in STS capabilities will be charged a use fee, a portion of which will be reimbursed to DOD in consideration of VAFB facility amortization.

Question. Using the planned number of launches through 1992, what is the per launch cost, taking into consideration the capital construction costs, O&M costs, R&D, and total procurement costs?

DOD answer. Using the planned number of launches through the first quarter of fiscal year 1992 (consistent with the *Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues* dated November 1, 1977) the average cost per launch for the 129 STS flights from Vandenberg Air Force Base is estimated to be \$24.7 million (FY 1979 dollars). This cost per launch is a summation of launch site dependent operations costs which are dependent only upon the portion of the mission model flown from the particular launch site *and* the common support costs which are dependent upon the full mission model flown from both launch sites. This cost per launch estimate includes the cost of contractor and civil service launch and flight operations manpower, recurring materials and services costs, and all facility and equipment O&M costs.

Investment costs are not amortized directly within the \$24.7 million per launch cost for Shuttle services. Non-U.S. Government users, however, are charged a "use fee" to recover the pro-rata share of capital construction costs. Further discussion of amortization is covered in the response to Questions 1 and 2 under "Amortization of the Shuttle Program."

NASA answer. Using the planned number of launches through the first quarter of fiscal year 1992 (consistent with the *Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues* dated November 1, 1977) the average cost per launch for STS flights from Vandenberg Air Force Base is estimated to be \$24.7M (FY 1979 dollars). This cost per launch is a summation of launch site dependent operations costs which are dependent only upon the portion of the mission model flown from the particular launch site *and* the common support costs which are dependent upon the full mission model flown from both launch sites. This cost per launch estimate includes the cost of contractor and civil service launch and flight operations manpower, Shuttle external tank production costs, solid rocket motor refurbishment costs, and all facility and equipment O&M costs.

Capital construction costs are not amortized directly within the \$24.7M per launch cost for Shuttle services. Non-U.S. Government users, however, are charged a "use fee" to recover the pro-rata share of capital construction costs. Further discussion of amortization is covered in the response to the first two questions under "Amortization of the Shuttle Program".

DETAILS OF GAO ESTIMATES

Question. How did the GAO arrive at its cost estimates? Provide details for the record.

GAO answer. As shown below, a single-site STS program could save the Government from \$2.3 billion to \$3.5 billion, depending upon the annual launch rate from KSC.

COST ADVANTAGES OF ONE-SITE (KSC) SHUTTLE PROGRAM

[In billions of real year dollars]

Annual launch rate from KSC	Cost savings of not modifying Vandenberg to accommodate Shuttle operations		Total
	Facilities	Manpower (fiscal years 1983-92)	
40.....	1.0	2.5	3.5
60.....	.8	1.5	2.3

Savings accrue from single-site operations because Vandenberg Facilities would not be built and manpower to operate the site would not be needed (see charts 1 and 2.) These savings, however, must be offset by the additional facilities and manpower required at KSC to handle any additional workload. Planned facilities and manpower at KSC can handle over 40 Shuttle flights a year. However, additional facilities (costing about \$0.2 billion—see chart 3 below, note 4) and manpower (costing about \$1.0 billion—see chart 4 below, note 2) would be needed at KSC to support 60 or more yearly launches, thus slightly reducing overall facility savings to \$0.8 billion (\$1.0 billion minus \$0.2 billion) and overall operations savings to \$1.5 billion (\$2.5 billion minus \$1.0 billion). Based upon present

and past levels of about 26 to 35 expendable launch vehicle flights per year, 40 Shuttle launches a year is a more realistic level of activity than 60; thus, KSC-only STS operations could save the Government up to \$3.5 billion over the next decade. It is important to note that the \$3.5 billion establishes the maximum savings due to elimination of Vandenberg. Under certain circumstances, a portion of the \$3.5 billion savings could be achieved by simply reducing the flight level of a two site operation from 60 to 40 flights per year.

The detail and sources of the \$2.3 billion to \$3.5 billion potential savings are given in the following five charts:

CHART 1.—Vandenberg facilities investment

Category:	[Millions of real year dollars]	Amount
Research and development.....		¹ \$338. 0
Support equipment.....		¹ 269. 0
Communications equipment.....		¹ 44. 0
Military construction.....		¹ 226. 0
Subtotal.....		² 877. 0
Launch Pad No. 2.....		³ 175. 7
Total.....		1, 052. 7
Costs incurred through fiscal year 1978.....		⁴ (80. 9)
Vandenberg facilities savings.....		⁵ 971. 8

¹ These are the estimated amounts through fiscal year 1983. The figures are as presented by General Coy in his testimony.

² According to General Coy's testimony the upper bound of this estimate is \$1.2 billion. Therefore, potential facilities savings could be higher than shown on this chart.

³ This estimate was provided us by the Air Force's Space and Missile Systems Organization (SAMSO).

⁴ See chart 5.

⁵ This figure rounds to \$1 billion.

CHART 2.—Vandenberg manpower costs (direct and indirect) fiscal years 1983-92

Fiscal year:	[Millions of real year dollars]	Amount
1983.....		¹ \$168. 5
1984.....		¹ 241. 8
1985.....		¹ 258. 9
1986.....		¹ 265. 0
1987.....		¹ 276. 6
1988.....		¹ 295. 9
1989.....		¹ 316. 7
1990.....		¹ 338. 8
1991.....		¹ 362. 5
1992.....		¹ 96. 8
Subtotal.....		2, 621. 5
Minus overhead.....		² (100. 0)
Total.....		³ 2, 521. 5

¹ The source of these costs, is the *Space/Shuttle Preliminary Cost Data Base*, dated June 1977, prepared by the Operations Resources Analysis Office, Johnson Space Center. The figures were given in FY 1975 dollars; we converted them to real year dollars, using an annual inflation factor of seven percent. The source document contained the following introductory comments: "The resources data contained within this document covers all those costs and associated manpower (direct and indirect) to provide the standard Shuttle services * * * for the current STS Flight Traffic Model."

² According to NASA Headquarters and DOD (Pentagon) officials, the manpower estimates for Vandenberg include about \$100 million of overhead costs which may not disappear if Shuttle operations do not materialize at Vandenberg.

³ This rounds to \$2.5 billion.

Chart 3.—*Single-site Shuttle program: Additional facilities costs at KSC if launch rate increases from 40 flights per year to 60*

[Millions of real year dollars]

Shuttle research and development: Launch processing system equipment, equipment surcharge for non-Government furnished equipment, site activation, and design support.....	\$69
Payload research and development: Ground support equipment, launch processing system, and design support.....	24
Construction of facilities: Mobile launch platform No. 3, SRB disassembly workstands, and orbiter processing facility.....	¹ 88
Additional mobile launch: Platform No. 4.....	25
Other: Program ground support equipment, spares, propellants, pay load support, and shop capability.....	² 40
Total.....	³ 4 246

¹ Present planning, which anticipates 40 flights a year at KSC, calls for three mobile launch platforms. Therefore, this figure (\$88 million) is overstated by \$25 million.

² We disagree with these costs; they appear to be operations costs which would not represent "additional" facilities costs associated with single-site operations.

³ This total, and the detailed breakdown given above, were provided us by Mission Analysis and Integration, NASA Headquarters.

⁴ This total, adjusted per notes 1 and 2, is \$181 million, which rounds to \$0.2 billion.

CHART 4.—*Single-site Shuttle program: Additional manpower costs at KSC if launch rate increases from 40 flights per year to 60*

[Millions of real year dollars]

Fiscal year:	Amount
1983.....	¹ \$282.6
1984.....	¹ 277.7
1985.....	¹ 297.2
1986.....	¹ 318.0
1987.....	¹ 340.2
1988.....	¹ 364.0
1989.....	¹ 389.5
1990.....	¹ 416.8
1991.....	¹ 446.0
1992.....	¹ 122.7
Subtotal.....	² 3,254.7
Times (percent).....	30
Total.....	² 976.4

¹ The source of these costs is the document indicated in chart 2, footnote 1.

² Kennedy Space Center, as currently planned, will support 40 Shuttle flights per year. Based upon discussions with officials at NASA Headquarters, Johnson Space Center (JSC), and KSC, apparently no studies have been made of how much additional manpower would be required at KSC to support up to 60 Shuttle flights a year (a 50 percent increase in the currently planned flight activity). However, JSC and KSC representatives have commented informally that any increase in manpower requirements would be minimal but could approach 30 percent. On March 30, 1978, officials in NASA Headquarters Space Transportation System Operations Office stated that 60 launches a year from KSC might require slightly more than a 30 percent increase in the proposed shuttle manpower level at KSC. However, as stated above, this information was not based on any detailed evaluation.

CHART 5.—VANDENBERG FACILITIES COSTS INCURRED THROUGH FISCAL YEAR 1978

[In millions of real year dollars]

Category	Prior years	Fiscal year 1978	Totals through fiscal year 1978
Research and development.....	\$31.2	\$24.3	\$55.5
Support equipment.....		17.2	17.2
Communications equipment.....		8.2	8.2
Military construction.....			
Total.....	31.2	49.7	80.9

Note: The figures are as presented by General Coy in his testimony.

AMORTIZATION OF THE SHUTTLE PROGRAM

Question. Will all or a portion of the costs of constructing the Vandenberg launch site be recovered or amortized through 1992? If not, why not?

DOD answer. We have amortized the VAFB investment over the life of facilities and equipment (20 years and 15 years respectively). A prorata share of the yearly amortized cost will be charged to each civil and non-participating foreign user. U.S. Government and participating foreign users (European Space Agency and Canada) are exempt. Our current estimate of the per flight "user fee" is \$5.5 million for a Vandenberg flight. This charge contains \$3.2 million per flight for the amortization of VAFB facilities and equipment.

From a different perspective, considering DOD traffic only, the lower transportation costs of Shuttle versus expendable launch vehicles will offset VAFB investment costs by 1990. Considering the aggregate VAFB traffic projections of all users, a net savings of \$3.9 billion is forecast through 1991 with use of Shuttle for high inclination launches.

NASA answer. Non-U.S. Government users are charged a use fee for the use of the STS. These use fees are based on an estimate of the depreciation of value of the facilities, equipment, and orbiter fleet. For a dedicated flight from KSC we charge a use fee of \$4.3M (real year-not to be escalated) per flight to non-U.S. Government users and at Vandenberg Air Force Base we charge a use fee of \$5.5M (real year-not to be escalated) per flight of which \$3.2M is for the use of Vandenberg AFB facilities.

Question. Will any of the R & D costs of the Space Shuttle program be amortized or recovered through user charges? If not, why not?

DOD answer. R & D costs will not be recovered. The Space Shuttle is being developed as a national capability, and we consider the R & D costs an investment in the technological progress and quality of life of the nation. The non-U.S. Government users will pay a user charge sufficient to maintain the capability. Specifically, foreign and commercial users will pay for the depreciation of the facilities and flight hardware (European Space Agency and Canada as participants in STS investment are exempt).

Further, high traffic volume will lower the cost per flight for all users. Therefore, NASA chose not to apply the R & D costs to the cost per flight in order to attract a wide range of users.

NASA answer. No R & D costs of the Space Shuttle, whether NASA or DOD costs, are recovered through user charges. The reason is that the R & D costs are considered an investment in a national asset. Public benefit is expected to result directly from STS operations, consequently the total operations costs are recovered as an amortized basis from STS users.

STATUS OF VANDENBERG DESIGN AND R&D

Question. What is the total estimate of costs to design the Vandenberg complex? What portion of this is available in existing appropriations? What portion is required in fiscal years 1979, 1980, 1981?

DOD answer. The total design cost for the Vandenberg complex is currently estimated at \$14.0 million. Of this amount \$11.0 million has been appropriated, and the remaining \$3.0 million is in the FY 1979 budget request.

Question. Which Shuttle facility designs from Kennedy are being used in designing the Vandenberg facility? If none, explain why not.

DOD answer. There are no Shuttle facility designs from Kennedy being used directly in the design of the Vandenberg complex. The reason why a direct application cannot be made is because in order to insure minimum acquisition costs at both locations, the use of modified existing facilities is being planned to the maximum extent possible. At Kennedy, this means modification of existing Apollo facilities, and at Vandenberg modification of existing Manned Orbiting Laboratory (MOL) and other base facilities. Although, from a functional standpoint, the same processing of the Space Shuttle will occur, the use of existing facilities will alter the manner in which the functions will be performed at each location. An example is the mating of the Orbiter, solid rocket boosters, and external tank. At Kennedy, this process will occur in the large Vehicle Assembly Building (VAB) and the entire assemblage transferred to the launch pad on the mobile launch platform. This process is known as the Integrate-Transfer-Launch mode. At Vandenberg, each element of the Space Shuttle arrives at the pad separately and is erected on a stationary launch mount at the pad. This process is known as the Integrate-on-Pad mode. Each mode has been dictated by the availability of existing facilities.

Question. What is the status of the R&D program for the Vandenberg launch facility? What test and evaluation work remains to be done in fiscal years 1979, 1980, 1981 and beyond?

DOD answer. The definition of requirements is being finalized and the design of the facilities associated with the 79 MCP is underway. The attached schedule shows the facility design effort currently underway and effort yet to be started. It also shows that the entire test and evaluation effort for Vandenberg remains to be accomplished. This test and evaluation effort consists of the software testing for the launch processing system and the system level testing which culminates with the determination of initial operational capability (IOC).

Question. What is the status of design on the Titan IIID launch facility for Vandenberg?

DOD answer. Design on this facility project is scheduled to commence 1 April 1978 and be completed on or about 1 August 1978. Design criteria are complete.

Mr. BOLAND. Thank you very much, Gentlemen. This committee stands adjourned sine die.

LETTERS PROVIDED SUBSEQUENT TO HEARING

[Clerk's note: Subsequent to the hearing, the Committee received letters from the Secretary of Defense, the Director of the National Aeronautics and Space Administration, and the Director of Procurement and Systems Acquisition Division of the General Accounting Office, summarizing the principal conclusions of each of the three agencies with regard to the issues discussed in the hearing. The three letters follow:]

THE SECRETARY OF DEFENSE
WASHINGTON, D. C. 20301

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Honorable George H. Mahon
Chairman, Committee on Appropriations
House of Representatives
Washington, D. C. 20515

Dear Mr. Chairman:

On March 9, 1978, the Department of Defense testified along with NASA and GAO before your Subcommittees on Defense, Military Construction, and Housing and Urban Development and Independent Agencies in a joint hearing devoted to the Space Shuttle. This joint hearing focused on the need for a Shuttle launch capability from Vandenberg Air Force Base. Since a large amount of information was provided in the various statements, briefings, and responses to questions, I want to be certain that the DoD position remains clear on the need for a Shuttle launch and landing capability at Vandenberg.

The GAO has taken the position that polar launches could be conducted safely on a routine basis from Kennedy Space Center (KSC) with adequate Shuttle payload delivery capability. The GAO feels that concerns about international overflight can be resolved. Thus, the GAO does not support the development of the Shuttle launch capability at Vandenberg.

Polar launches from KSC using the Shuttle would require overflight of the northeastern United States and Canada. The DoD considers the risks to life and property due to potential accidents during such launches to be unacceptable. We are not prepared to conduct such launches on a routine basis.

The GAO suggests that the 1971 Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War Between the United States of America and the Union of Soviet Socialist Republics may provide an acceptable basis for routinely notifying the Soviets of our intention to launch over their territory. The spirit of this Agreement is to encourage both parties to avoid incidents which could be misinterpreted so as to raise the risk of nuclear war. The Agreement was not intended to encourage acts which either party might interpret as potentially hostile. An approach to the Soviets to use this Agreement to request permission for overflight could lead to many unacceptable situations for us. There could be requests for reciprocal overflights of the US by Soviet launch vehicles, or indeterminate delays while issues are discussed. We cannot put this country into a position where it must rely on prior Soviet approval of our highest priority launches.

NASA, the most qualified agency to determine Shuttle performance, has stated that northerly launches from KSC would result in severe degradation of the payload delivery capability of the Shuttle. This degraded performance is unacceptable to DoD.

Safety, international, and performance considerations lead us to conclude that KSC polar launches are not acceptable and that we must have Shuttle launch and landing facilities at Vandenberg. I ask your support of the full \$423.9 million which we are requesting in FY 1979 for our activities leading to DoD Shuttle use.

Sincerely,

Harold Brown



National Aeronautics and
Space Administration

Washington, D.C.
20546

Office of the Administrator

April 7, 1978

Honorable George H. Mahon
Chairman
Committee on Appropriations
House of Representatives
Washington, DC 20515

Dear Mr. Chairman:

I am seriously concerned that, following the joint hearing on March 9, 1978, before your Subcommittees on Defense, HUD-Independent Agencies, and Military Construction, NASA has been unable to reconcile all the disagreements expressed during this hearing. While we have met with GAO several times in response to Chairman Boland's charge to us to sort out the differences of fact and have, I believe, reconciled a number of them since the hearing, NASA and GAO still hold a fundamentally differing viewpoint on the issue of land overflight and related implications. This letter sets forth my views on these matters for your consideration during Committee deliberations.

My particular concern relates to the GAO proposal to cancel the planned Shuttle capability at the Vandenberg Air Force Base (VAFB) and, instead, to launch all missions from the NASA Kennedy Space Center (KSC). The GAO is suggesting that Congress consider a national policy accepting land overflight during the suborbital* launch phase (when severe accidents would result in ground impact of major debris in heavily populated areas of the U.S. and Canada) as an inherent feature of Shuttle operations from KSC. As NASA Administrator, I could not, in good conscience, recommend the risk inherent in such a policy except in the case of dire national emergency, and I have been informed that the DOD shares my feelings.

A major argument against overflight during the suborbital launch phase is one of safety. The area encompassed by the flight path groundtracks for launch of polar and near-polar

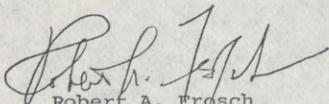
missions contains over 50 million people and includes major population centers such as Pittsburgh, Detroit, and Toronto. If such overflight by the Space Shuttle were to be supported by the Congress, a reciprocity agreement which would accept routine suborbital overflight of the continental U.S. by Soviet space launch vehicles must also be considered. NASA, DOD, the Department of State, and the OMB all agree that suborbital overflight of the continental U.S., Canada and the Soviet Union by high inclination Space Shuttle flights is clearly unacceptable. It should be recognized that it will be years before Shuttle operating experience will provide a sufficient data base for judgments on safety equivalent of those required for certification of a commercial aircraft. Further, even assuming proven Shuttle reliability, it would be unreasonable to base our national space capability on launch overflight, accepting the risk that launches could be terminated suddenly due to international complications or unacceptable hazards created by increasing population density in the launch corridors.

A second argument against launch overflight is one of security. We should not base this Nation's access to space on one site alone, with its inherent vulnerabilities. In addition, there are current and projected high priority DOD payloads which should not, from a national security viewpoint, be launched from KSC with a suborbital overflight trajectory. Therefore, any alternatives proposed for the national program must provide for Space Shuttle or expendable launch vehicles from VAFB. The principal feature of the GAO argument for overflight is based on a cost saving from single site Shuttle operations. In contrast, our studies, done with DOD, show a four or five orbiter fleet operating from both east and west coast launch sites is more cost effective and offers a higher Shuttle performance potential.

In summary, the NASA analyses show that the requirement for a VAFB Space Shuttle launch site is national in character and based on firm performance requirements and sound economic benefits. An adequate Shuttle fleet to serve all users -- civil and military -- will provide the assured launch capability necessary to promote early transition by all users and to permit phase-out of expendable launch vehicles -- actions which provide important economic benefits. Decisions made now on the Space Transportation System will establish

the future level of this Nation's space capability for many years. The issues and alternatives are complex and the stakes are high -- scientific and technological leadership, national security, and international prestige. I am prepared to address in more detail any of these or other related issues if you so wish.

Very truly yours,

A handwritten signature in dark ink, appearing to read "Robert A. Frosch". The signature is fluid and cursive, with the first name being the most prominent.

Robert A. Frosch
Administrator

* Suborbital in the above discussion includes the launch phase to orbit and the portion of first orbit necessary to fully establish orbital parameters.



UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

PROCUREMENT AND SYSTEMS
ACQUISITION DIVISION

APR 20 1978

The Honorable George H. Mahon
Chairman, Committee on Appropriations
House of Representatives
Washington, D.C. 20515

Dear Mr. Chairman:

During the March 9, 1978, hearings before your Subcommittees on Defense, HUD-Independent Agencies and Military Construction, Chairman Boland asked that we work with NASA and DOD to reconcile some differences in fact concerning how much payload weight could be launched in a northerly direction out of Kennedy Space Center by the Space Shuttle and the risks of such launches.

We met with NASA and DOD on several occasions and reached agreement that DOD's payload requirements of 32,000 pounds could be launched out of Kennedy by making changes to the launch trajectory and mission configuration. There are remaining differences of opinion concerning safety considerations and the disadvantages of having only one Shuttle launch site.

With regard to safety considerations, we believe that if NASA meets its reliability goals there will be relatively minor risk to the U.S. and Canadian population. Actual Space Shuttle reliability, of course, must be demonstrated. The exact number of Shuttle launches required to gain confidence in the Shuttle's performance reliability has not been determined. By June 1983, however, when polar Shuttle launches are scheduled to begin, the STS will have had over 3-years experience, entailing over 50 Shuttle flights. This would constitute a strong basis for assuming that these flights will provide a sufficient "shake down" period in which any problems will be identified and corrected. If uncertainties and problems still exist after 3 or 4 years of operations, there would be a serious question concerning the viability of the entire Shuttle program.

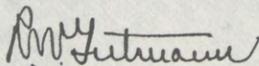
Shuttle experts agree that the most critical phase of a Shuttle launch is between lift-off and solid rocket booster (SRB) separation. This phase will have been completed long before land overflight occurs on a northerly launch from Kennedy. SRB separation takes place over the ocean 31 miles from the launch site. The orbiter and external tank continue ascending over 314 miles of open ocean and will be about 70 miles high when land overflight begins.

With regard to having only one launch site, we know of no way to measure the differences in risks between a one-site operation and a two-site operation. Single site operations at Kennedy, using the two launch pads planned, may provide more responsive backup than is currently being experienced with existing expendable launch vehicles (ELVs). For instance, the planned two-weeks turnaround time for the Shuttle is much faster than for ELVs. At Kennedy, 17 weeks are needed to ready a replacement Titan III. At Vandenberg, ELVs are assembled on the pad, and turnaround time for a replacement ELV is about 4 to 6 months. These turnaround times are lengthy because, under current operations, ELV launches are not "backed-up" with a standby ELV; the production pipelines must provide replacements.

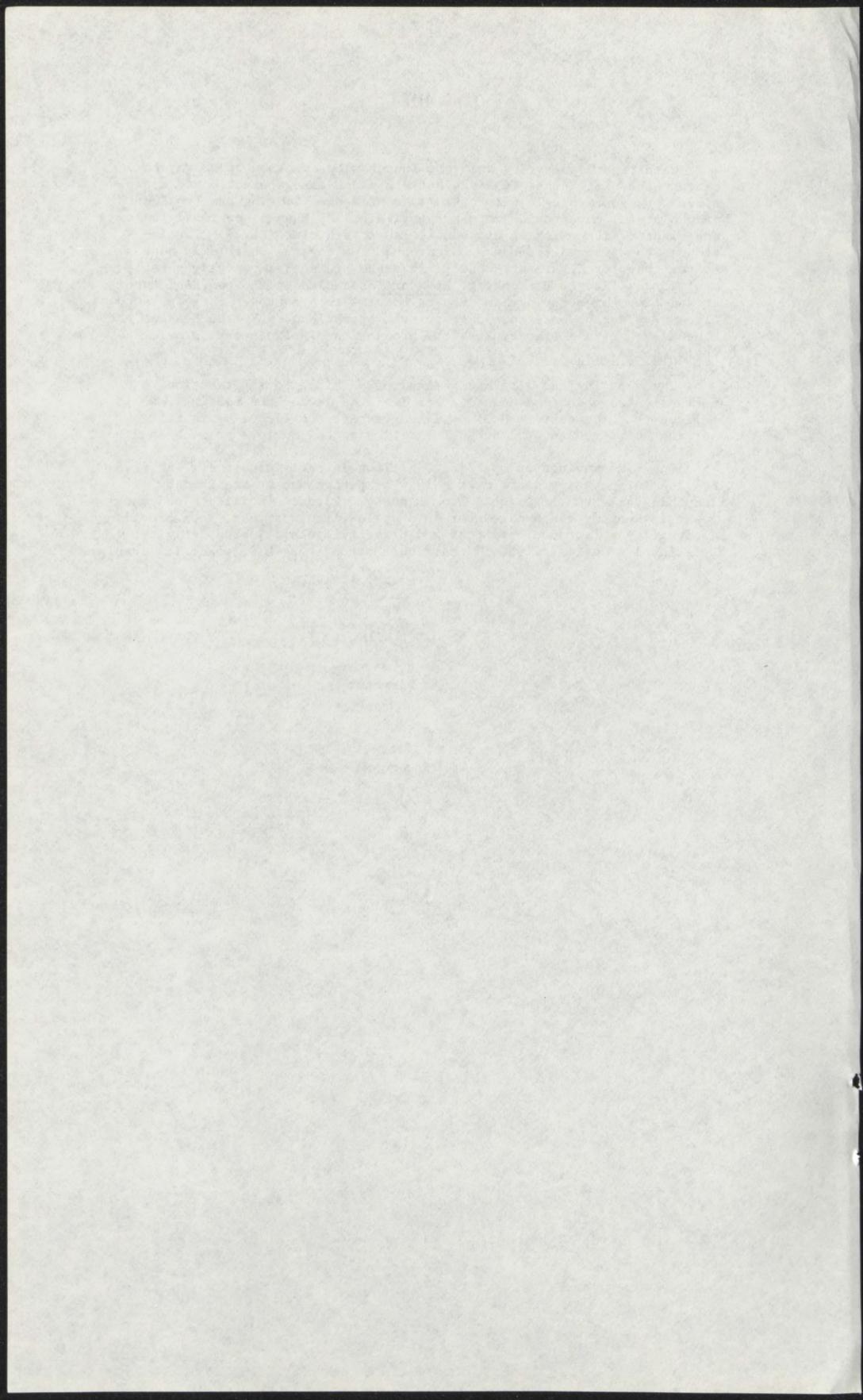
The question has also been raised of possible Soviet reaction to northerly launches from Kennedy. As I stated during the hearings, we believe that the current U.S.-Soviet agreement provides a basis for working out adequate procedures for notifying the Soviets of such launches.

One-time savings of up to \$1.0 billion in facilities costs and \$2.5 billion in operating costs over a 10 year period can be realized by launching all Shuttle flights from Kennedy. Planned facilities and manpower at Kennedy can handle over 40 Shuttle flights a year, thus providing a significant increase over past and present levels of space activity. This level of activity should contribute strongly to U.S. space leadership.

Sincerely yours,

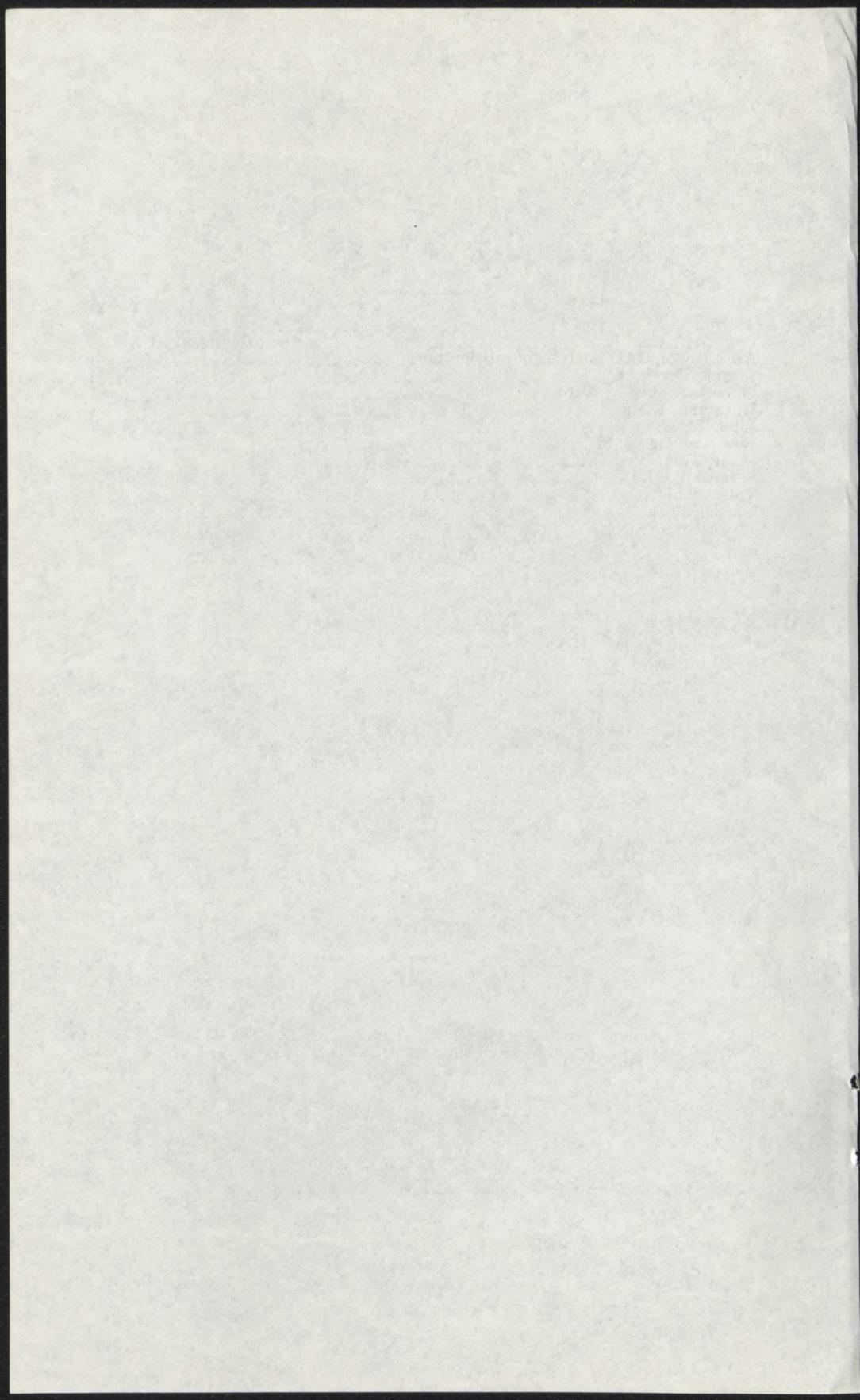


R. W. Gutmann
Director



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