RESEARCH ON NEW TRANSPORTATION METHODS

(GROUND EFFECT MACHINES)

HEARINGS

BEFORE THE

COMMITTEE ON SCIENCE AND ASTRONAUTICS U.S. HOUSE OF REPRESENTATIVES

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RESEARCH ON NEW TRANSPORTATION METHODS (GROUND EFFECT MACHINES)

WEDNESDAY, JULY 11, 1962

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C.

The committee met at 10 a.m., Hon. George P. Miller (chairman) presiding.

The Chairman. The committee will be in order.

This morning the full committee is beginning a series of hearings which will inquire into the research and development phases of new modes of transportation.

Our hearings at present will be limited to discussions of the progress made and the design concepts of hovercraft or aircushion vehicles. For the present we do not plan to call industrial witnesses. This will follow later, if and when the committee schedule permits.

The witnesses this morning are here representing the Army and the Navy. They will bring us up to date on the state of the art of air cushion vehicles as they are being developed by the military.

It may be that some questions will arise which will necessitate answers of a classified nature. If so, I will request the person asking the question to defer it until we are closer to the end of the session.

We can at that time go into executive session for a brief time to hear such information as may be of a classified nature.

Our first witness this morning is Capt. J. J. Stilwell, U.S. Navy, Director, Ship Design Division, Bureau of Ships, Navy Department. He will be followed by Brig. Gen. C. W. Clark, Office of Chief of Research and Development, Department of the Army.

Captain Stilwell, will you come up please.

Captain Stilwell. Good morning, Mr. Chairman, gentlemen of the committee.

The Chairman. Be seated, Captain.

Captain Stilwell. Thank you.

STATEMENT OF CAPT. J. J. STILWELL, U.S. NAVY, DIRECTOR, SHIP DESIGN DIVISION, BUREAU OF SHIPS, NAVY DEPARTMENT

Captain Stilwell. As you have stated, I am Captain Stilwell, Director of Ship Design, Bureau of Ships, of the Navy Department.

I may state for the record first, I have a prepared statement, which has been turned in to your committee, sir, and with your indulgence, in view of the fact that we have visual aids, I would like to follow the general tenor of this statement from notes.

The CHAIRMAN. All right, sir. This is not classified—this statement?

Captain STILWELL. That statement of itself is not classified.

The CHAIRMAN. The statement will appear in the record and you can summarize or go ahead on your own.

Captain STILWELL. All right, sir.

I might start by saying that in this particular program, as perhaps, opposed to some R. & D. efforts, we have enjoyed remarkable coordinative cooperation among the various agencies involved. We have an active coordinating committee among all Government agencies interested in this particular development.

Hence, the way we have set this program for you this morning, I will try to introduce the subject background and give the Navy position, and to be followed by General Clark, who will give the Army's summary of their work.

First of all, I would like to define some terms, since this particular field has as many different terms as you can imagine.

We have generally used in the program the term "GEM," to cover all of the various vehicles that are being developed, GEM representing a ground effect machine.

The CHAIRMAN. That is ground effect machine. Sometimes you hear it called ground environmental machine. I don't know how the "environmental" got in there.

Captain STILWELL. There are a number of names used—air cushion, hydroskimmer, air car, AquaGem, levapad, hovercraft—I think all of them refer in general to what we call a ground effect machine.

The technical definition of what a "ground effect" is is a little bit difficult to state, but, in essence, any flying machine as it approaches the ground increases its lift.

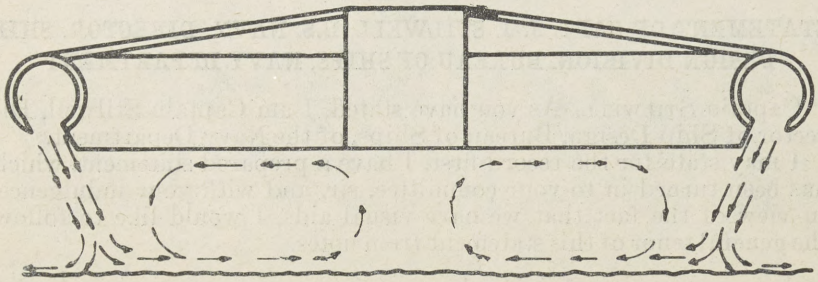
A very easy definition of this is, it is somewhat like the hydraulic pump analogy, where you have a small diameter piston at a certain pressure creating the same pressure in a larger vessel and then this same pressure across the larger area gives you a considerable mechanical advantage.

This is not precisely the principle involved, but it is very similar, the ground being the bottom of this container.

If I may, I will go to the podium so I can see while I am talking to the slides.

The CHAIRMAN. All right, sir.

SLIDE 1



Captain STILWELL. This [slide 1] is a very rough cross-section of a ground effect machine. This is the machine itself. This is the ground level. This is the classic ground effect machine, in which fairly high pressure air jet is blown out and tilted inward all the way around the periphery of the vehicle.

This jet does two things. It provides a curtain that seals the air beneath the machine and leaks off air to supply air to build up a pressure in this [indicating] area.

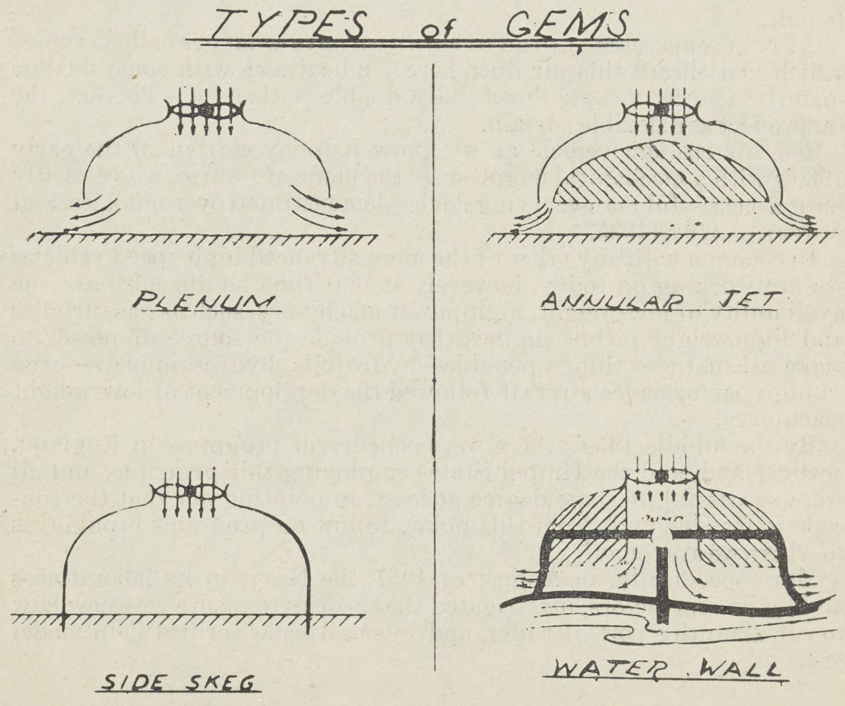
This is the mode in which the machine is lifted from the surface and supported. The propulsion is by any more or less conventional means of propulsion, such as aircraft propellers, water propellers, if you are over water, jets, or in some cases you can propel the machine by merely tilting these [indicating] curtains by rotating the jet itself.

The vehicle, as you can see, floating on a cushion of air, has to be controlled in attitude as well as course, so that there are various devices set up for controlling its attitude in space and its path.

Also the problem of sealing has from the inception been a rather interesting one. There are a lot of different ways to seal this cushion of air.

The simplest is probably what we call the plenum machine, which is an inverted bathtub, in essence, in which you blow air through a duct at the top, leakage is permitted under the bathtub, and the height of this leakage area is such that you throttle the flow and build up a pressure under the machine. [Slide 2.]

SLIDE 2



This is not quite as efficient as the annular jet, which I described previously, in which the air is set out through a peripheral jet, which not only seals but provides the air for the cushion pressure.

Another means of sealing, which can't be used all the way around but particularly in ships flown over water, is to provide solid side skegs, leaving only the bow and stern area to be sealed by some sort of a curtain of air or water.

This reduces the power required to lift the machine off the surface, but if you try to get above about 50 knots forward speed, the drag of these skegs in the water retards the forward motion of the craft making them undesirable in higher speed machines.

As I mentioned, we have also looked into using water as a seal for an over-the-water machine. In this case the black shows piping and water jets which seal the cushion and then you have a supply of air to provide air in the cushion. Water is a theoretically more efficient sealing device, it doesn't take as much power to seal with water as with air; however, the complications of extra weight and extra machinery has not proved too desirable to date.

Aside from these basic types, there are numerous devices under investigation to improve lift and to fly higher with the same power. These would include such things as flexible skirts. If you put a skirt from this [indicating] point down, then the important dimension is the gap, so if you have a skirt filling this [indicating] the whole machine will lift up the length that you drop the skirt.

This can be carried on to such an extent that as you get high enough you lose stability, because of the flexibility of the skirt, and you have to quit.

Also, in some cases, instead of skirts we have what are called trunks, which you encase this air duct here [indicating] with some flexible material and let it hang down like a double wall sheet. This has the same effect as a flexible curtain.

The air cushion vehicle as we know it today started in the early 1930's with a mechanical engineer by the name of Caario, who actually built a successful man-carrying device demonstrated over mud, ice, and water as early as 1935.

In common with any other of the more advanced high-speed vehicles we are working on today, however, at that time he did not have the availability of low-weight, high-power machinery, such as gas turbines and lightweight piston engines that provide the source of power to make all of these things possible—hydrofoils, hydroskimmers—even as high performance aircraft followed the development of low-weight machinery.

By the middle 1950's there were concurrent programs in England, Switzerland, and the United States employing this principle, and all were successful, to some degree at least, in pointing out that the concept is feasible and, from this point, follow-on programs brought us to where we are today.

More specifically, in August of 1957, the Navy, in its laboratories and by its contractors, investigated the theories to insure we knew how to calculate this sort of thing, and in small scale verified it in model test.

This very committee held hearings in April 1959 which did a great deal to help focus national attention on this principle and thereby to enlist quite a bit of attention from competent brains in industry and in Government, and gave the whole program a shot in the arm.

The Department of Defense held a symposium in Princeton in October of the same year, run by the Army, and this symposium did a complete review of the state of the art and published a lengthy summary report bringing up to date everybody's concept of the theory and developments to that date.

From this point on various agencies of the Government and some private industries have carried forward.

Since the 1957 to the 1959 era we have progressed quite far and rapidly in this field, in spite of a relatively modest but considerable expenditure of funds.

SLIDE 3

AIR CUSHION VEHICLE FUNDING SUMMARY

	NAVY/MARCORPS	ARMY	MARAD
FY 1958	$ 16,000	---	---
FY 1959	597,000		
FY 1960	1,135,000	$ 237,000	$25,000
FY 1961	1,124,000	920,000	---
FY 1962	1,391,000	436,000	370,000
	$4,263,000	$1,593,000	$395,000

TOTAL (ALL PROGRAMS) - $6,251,000

As you can see [slide 3] we start out very modestly in the early stages investigating theory, coming up with model tests. This is the symposium I mentioned. At this point we started testing out the various types and ways of doing the job. This [indicating] shows our expenditures to date, totaling just slightly over $6 million—total for Navy, Marine Corps, Army, and Maritime Administration.

As I mentioned at the outset, the program has been coordinated pretty much on a voluntary basis. At the current moment we have a voluntary and relatively informal coordinating committee of which I am the chairman, which includes membership from all of the naval activities interested, the Army and Maritime Administration, and the Marine Corps.

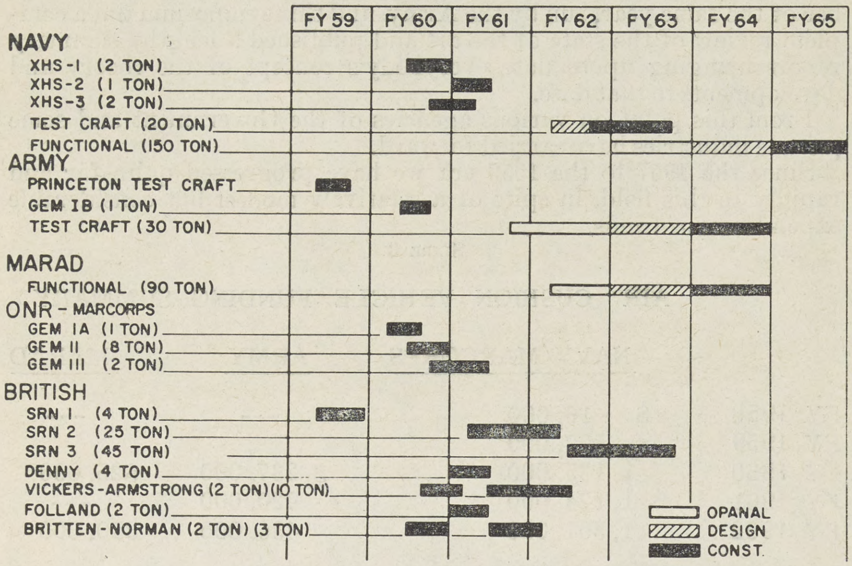
We review each other's programs for duplication and make known to each other the results of our individual pieces of research, so that each piece of it applies to the whole.

This [slide 4] slide shows perhaps a little better picture of just what we have been doing from the outset and some of the tentative plans. Everything from 1962 on is, of course, tentative, depending on firming up of our present plans.

SLIDE 4

AIR CUSHION VEHICLE PROGRAMS

SCHEDULES



In the early stages—1959 and 1960's—as I mentioned, we had a whole host of—actually about six—man-carrying small craft, which were required to check out the theories on the various ways of doing this job.

The principal activity going on in this country at this time is the 20-ton test craft, of which I will speak more later, which is currently under construction.

We have plans for going to larger sizes.

Of slight interest here might be the fact, that at least as far as hardware is concerned, it is apparent that the British are roughly 1 year ahead of us. As you can see [indicating], they are already testing a 25-ton operational craft—SRN–2.

My boss, Admiral James, Chief of the Bureau of Ships, is over in Europe now—just returning. He has just ridden SRN–2 and we expect some personal reports on his return.

If any of these are of interest to the committee, we will be happy to make them part of the record at a later date, sir.

The CHAIRMAN. I wish that you would, Captain.

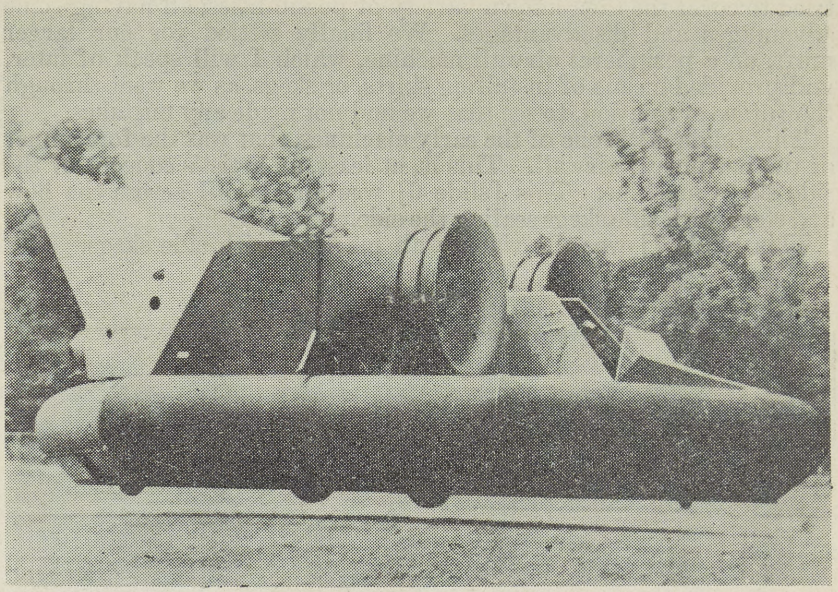
Captain STILWELL. Very well, sir.

(Slide off.)

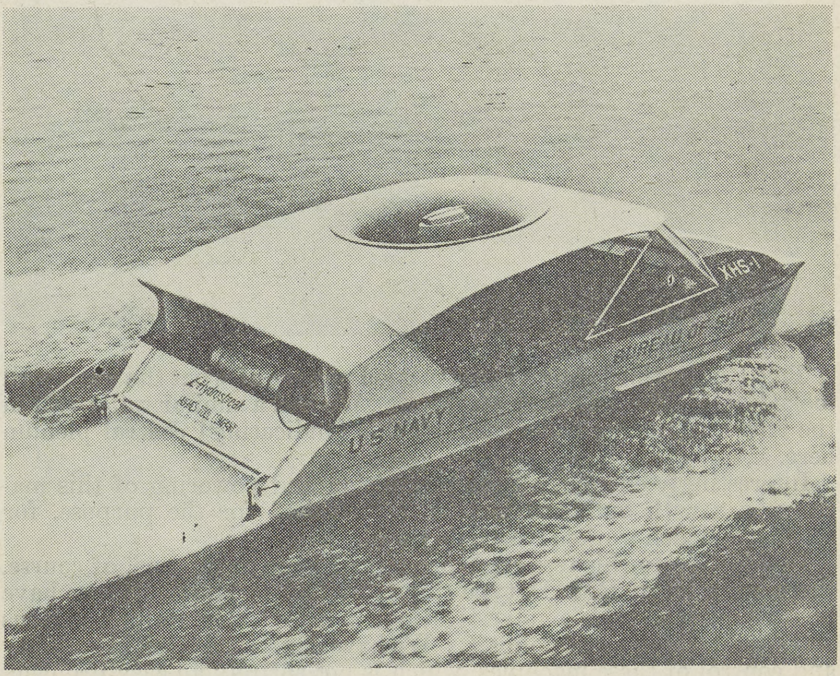
Captain STILWELL. The Navy's small test craft investigation, as I said, covered a wide range of variations. We tried out the full peripheral jet in which nothing touches the surface of the water, except the air cushion.

A full peripheral water wall machine of similar design except water was used as the medium.

SLIDE 5



SLIDE 7



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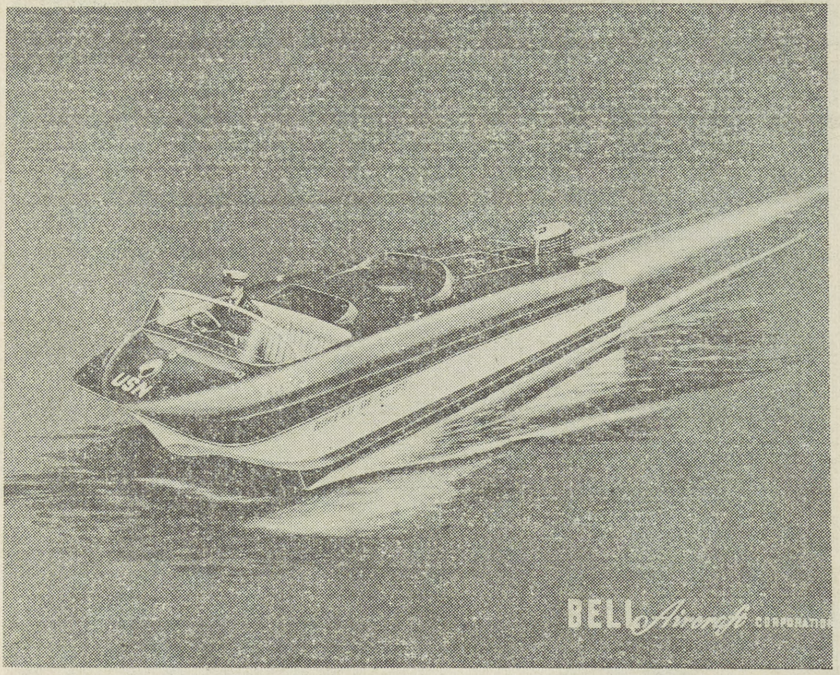
We tried side skeg machines with both air and water. So that we tried to cover the then known variety of possibilities, all having some advantages and disadvantages. We finally settled for our larger craft, on a peripheral airwall machine, which I will speak of later, and provided means of installing skirts, or skegs, as we went through the future evaluation, to see that we had not made any mistakes.

This [slide 5] is one of the early machines, that was the forerunner of the peripheral airwall. This is, at least, an artist's concept of the side skegs machine. This [slide 6] was an airwall across the bow and stern with side skegs sealing the side.

This [slide 7] was the water wall machine with side skegs.

SLIDE 6



This [indicating] shows a pretty good picture of what the waterwall looked like. The side skeg was solid. We had a similar waterwall in the bow and the air came through this [indicating] central plenum here.

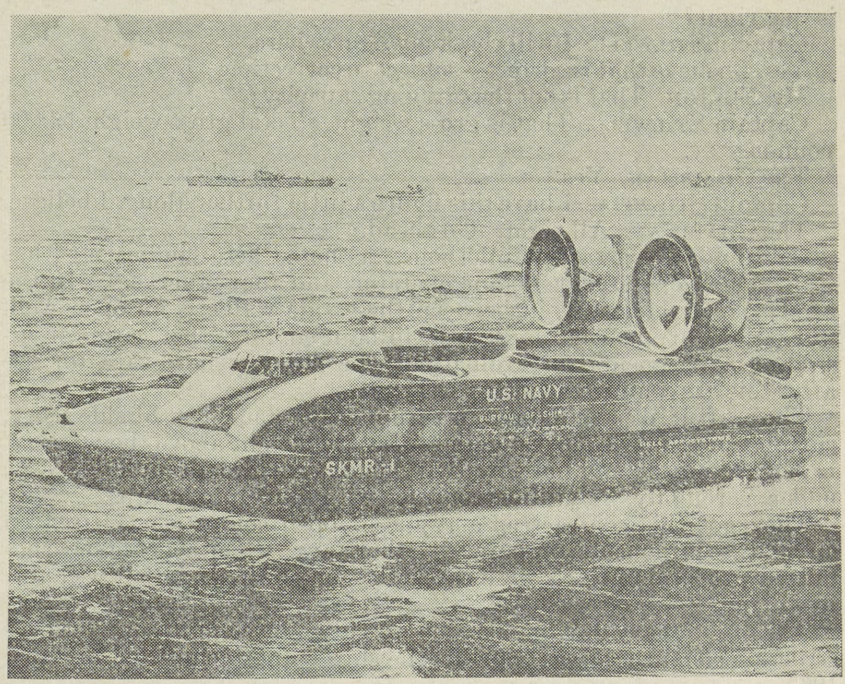
Interestingly enough, all the propulsion and powering of this machine was with outboard motors, refurbished for the purpose, for economy; which worked reasonably well.

In addition to this test craft program I have mentioned, of course, there are a lot of R. & D. type things we had to know. So we have been running a series of investigations in air cushion sealing, various ways and techniques of doing it. We have done some work in stability and control of these machines, which is not entirely an easy problem. We have looked into motion in a seaway, which may well be another critical problem. We have looked into resistance in powering, and are still looking into it.

Noise and the atmosphere in which the crew will operate in is a problem in these machines because of the large volume of air that is being handled, which is basically noisy. We have looked into this problem. Structural criteria require research and development because these machines depend for their lift and efficiency on a relatively large flat-bottomed area, as you perhaps have already noticed. And as you get into larger and larger sizes the problem is of providing a machine of this geometry and make it hang together, particularly in a seaway, which poses a structural problem of some note.

Lastly, we have been doing some operational analysis to see precisely what types of things these machines might be called upon to do. May I have the next slide, please.

SLIDE 8



I have spoken before of the 20-ton test craft. This is an artist's concept of it. [Slide 8.] We have a model here for anybody that cares to look at it after we are through.

As I said, it has this airwall all the way around. Air is supplied to the jets through these four fans. Propulsion is through the shrouded aircraft propellers. Control in course is through the rudders and swiveling of these [indicating] propulsion devices.

It is arranged so that power can be transferred from the fans or shared between the fans and propulsion, so that at slow speed, where you want to rise high, you can put most of your power in the air cushion, and later, if it is lower seas, or smoother riding, and you are getting some lift from going ahead, you can cut your other power in these [indicating] build it up on the fans, to get a greater speed.

This craft is basically capable of flying at a height of 1½ feet at a speed of about 70 knots with a weight of about 45,000 pounds. Its range under these conditions would be about 150 miles.

It will be capable of flying up to about a 55,000 pound gross weight. In this case the height would be reduced to about 1.25 feet, and it would still be capable of about 70 knots.

Length overall is 65 feet, beam 28 feet, powered by four Solar gas turbine engines, with a total power of 4,300 horsepower.

These engines are, one here [indicating], one here [indicating], in all four corners, with a shaft running between the two engines, with power takeoffs for all of the necessary fans.

All material is aluminum.

The CHAIRMAN. It can carry then about 22½ tons—45,000 pounds; is that right?

Captain STILWELL. I will check my figures here.

Yes, I believe that is correct—subject to correction.

Mr. FULTON. That is not the carrying capacity?

Captain STILWELL. That is gross weight. Total gross weight 55,000 pounds.

The CHAIRMAN. Yes.

Captain STILWELL. I have this figure a little further along, I believe.

The CHAIRMAN. All right. Go ahead.

Captain STILWELL. The pilothouse, as noted here [indicating] has seats for an operator, assistant operator, and four observers. In the afterpart of this craft, in between these side walls, is an open well, dimensions of about 40 by 9 feet, to be used for either cargo or installing experimental or evaluation type military hardware for use after this has completed its R. & D. type test.

The craft is also configured to permit easy attachment of side skegs, curtains or trunks to investigate raising the height above the water, it is being designed and built by Bell Air Systems Co. of Buffalo, N.Y., under a, roughly, $2 million contract with Bureau of Ships.

They got this contract as a result of open competition, based on circular requirements prepared by the Navy, seven contractors submitted proposals, which were carefully gone over, and Bell was able to win out.

The preliminary design phase has already been completed. The construction commenced last April. The ship will be completed in April 1963.

Working plans are about 50 percent along. The craft will be assembled in Buffalo. Initial trials, in April and May of 1963, will probably be carried out in Lake Erie. Subsequently the craft will be brought to Chesapeake Bay for military type evaluation.

The test program has been set up for the purpose of accumulating research information on the behavior of this craft and to formulate suitable design criteria for future vehicles.

Of primary interest will be testing of this craft in rough water. The reason I emphasize this is you find a lot of craft run around in smooth water, but our model tests indicate to us that the penalty of speed performance of these crafts may be somewhat higher in rough water than first anticipated. This is an area we were going to bring out very carefully with this craft to determine just how much slower you go in rough water.

Handling and maneuvering not only in calm but in rough seas is another problem which we are going to evaluate.

We are going to make detailed dynamic load tests to determine the loads put on the structure by operating this craft at these speeds over a seaway.

We are going to check out various devices of improving stability in control as opposed to each other.

And we are going to verify means of suppressing noise and spray, to make the craft a little more habitable.

And, as I have mentioned, we will evaluate the advantages of increasing flying height by the use of side skegs or skirts.

Following this program we, in the Chesapeake program, plan to look into beaching operations, running this on up over a beach, ASW operations; perhaps even with sonar high speed patrol operations, and some mine countermeasures operations, using this as a towboat.

We also will check out magnetic and acoustic properties to get some idea for operational evaluation of how this craft shows its presence in various detection devices.

In order to continue on from this point in the development and use of hydroskimmers or ground effect machines for open ocean application—as you note, this 20-tonner is a little small for open ocean, no matter what configuration you have—we are studying now within the Navy Department the most meaningful size. It appears now to be somewhere between 150 and 250 tons.

As I have mentioned, there is the structural problem as we get larger in size. From the aerodynamic and hydrodynamic aspects however, these craft become more efficient as they get larger in size so there is probably some optimum size that we will find out as we go along.

Among the various applications being considered for the next generation of these craft, as we have indicated, there is the high-speed communication or patrol mission, towing of mine counter measure gear, beaching operations, carrying wheeled cargo, and ASW operations.

(Slide off, please.)

Captain Stilwell. So, to sum up, the GEM's can fly a few feet over practically any surface. This is one of their main advantages. It can be ice, snow, land, swamp, water, and whatnot.

Its limitations are, it can't climb steep grades, it can't go over, say, trees or cliffs, things like that, it has to have a reasonably smooth grade to operate.

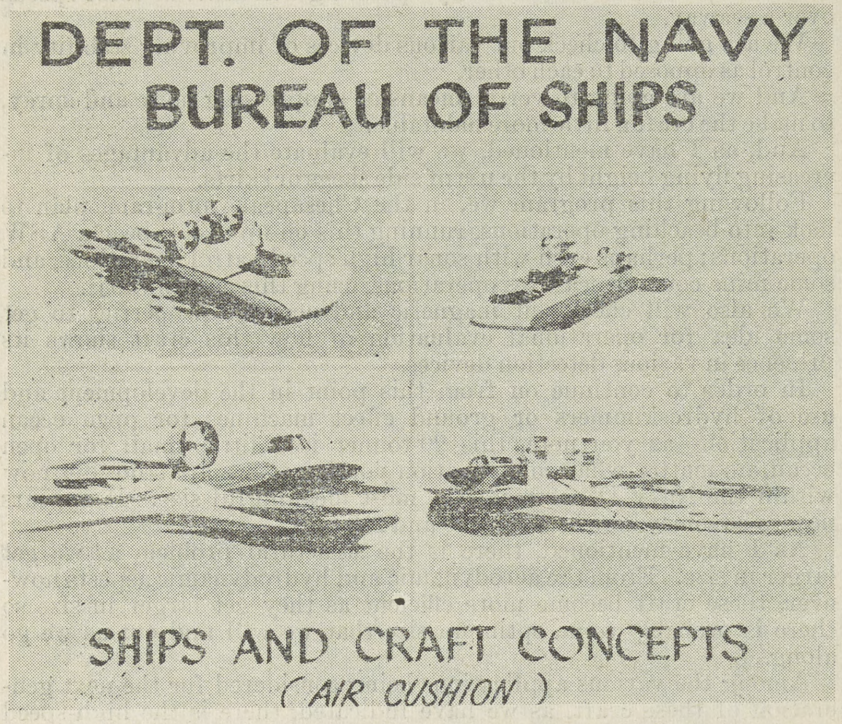
It can operate over rough water. We have yet to evaluate its efficiency and effectiveness in this medium, and just how much rough water it can take.

It is very fast for the power applied as compared to other vehicles.

We have, as I have mentioned, a problem, which we haven't the complete solution to, that of stability of craft, maintaining its flight attitude, and controlling it in course. However, we have interim answers to these problems.

The future will, of course, depend on an evaluation of this craft in comparison with a lot of other competitors. We have conventional planing craft, helicopters, low-flying aircraft. As some scientist wag mentioned during the development, we have to be very care-

SLIDE 9



ful in working on GEM machines that we do not reinvent the airplane.

It competes with hydrofoils and also with hydrokeels, a concept that is even newer than this one, which is, in essence, an air-lubricated planing hull.

Inherently, for a given load (military payload) the GEM will be very large in physical size compared to most of its competitors. Basically it is a low-density machine, because of this need to produce enough lift to keep it in the air. This poses, as I mentioned, not only structural but also transportation problems where you are going to carry this over the land, not under its own power, or in transporting it at sea—some such thing as breaking them down. It also presents a large tactical target, should be fairly easy to detect and hit.

It is very fast and efficient. By comparison, however, aircraft are faster, helicopters have a more versatile flight pattern—they can go up over anything they wish to but they are less efficient. Hydrofoils and hydrokeels have much higher volume density, hence are much handier craft to handle, transport, and, of course, give a smaller target and present a much lesser structural problem. All in all, each one of these has a unique set of advantages at certain speed and size ranges.

We are not sure we know the whole story on all of them yet. It is obvious that each deserves to be pursued to a point where its own niche in the military operational field is found, and it is quite apparent that to date no one of these concepts has shown an overall, overriding superiority, which would lead to the exclusion of any of the other candidates.

So to carry these GEM machines to a logical point of open sea evaluation and selection of suitable roles and sizes, the Navy intends to continue its program, and, if all goes well technically, we expect to spend about $35 million in the next 5 years in pursuit of this larger oceangoing craft and the supporting research program.

With that I would like to turn it over to Major General Clark, who will present the Army program.

(The statement of Capt. J. J. Stilwell is as follows:)

Mr. Chairman and members of the committee, I am pleased to have this opportunity to appear before you today.

The program to be presented to you will consist of three main parts: first, introductory remarks to set the stage so that all of you are familiar with the terms and general characteristics of the vehicles we will be discussing; second, a presentation of the Navy program; and, third, a presentation of the Army program.

I would like to start out by defining the field and the names used in conjunction therewith. The term "GEM," meaning ground effect machine, has probably received the most use in this country.

We will use it whenever referring to the entire field or discussing the phenomena of operation.

The term "air cushion vehicle" we will consider synonymous with hydroskimmer, hovercraft, aircar, AquaGem, or any other man-carrying self-propelled machine.

At this time I would like to describe briefly a typical air cushion vehicle.

(Slide 1.) The vehicle is lifted clear of the surface over which it operates by air issuing from the bottom of the machine to form a curtain and create the cushion beneath its base.

The vehicle is propelled by either standard propellers, ducted fans, or by directing the curtain air aft. The vehicle achieves inherent stability to remaining close to the surface and further by compartmenting the base cushion. The vehicle is controlled by standard aircraft-type controls in the operator's cabin moving either the propulsion means or reaction air actuators. (Slide off.)

In addition to the annular jet machine just described there are other types of craft which operate on the same basic principle.

(Slide 2 on.) These include—

(*a*) Plenum type, which is essentially an upside down bowl with air blown in at the center forming a cushion under the bowl as the air escapes around the periphery.

(*b*) Water wall type, which uses a curtain of water to retain the entrapped cushion of air under the craft.

(*c*) Side skeg vehicles, which use fixed side skegs to reduce the amount of power required to sustain the air cushion by cutting down the extent of leakage area. Side skegs are particularly effective at speeds below about 50 knots and can be used in conjunction with either water wall, plenum, or annular jet type.

Aside from these basic types, there are numerous devices currently under investigation and development which can be used to improve lift or flying height for the same power.

These include flexible skirts or trunks which increase the flying height of the main hull over the water and various recirculation schemes which attempt to reduce cushion power by recirculating the lift-producing air through a system of channels or passages built into the craft. (Slide 2 off.)

The air cushion vehicle as we know it today got its start in the early 1930's in Finland when a mechanical engineer by the name of Kaario built a small man-carrying device that he successfully demonstrated over land, ice, and water in 1935.

His efforts were not successful because of lack of funds, efficient lightweight power supply, and overall interest in his project.

In the midfifties concurrent and entirely separate projects were initiated in England, Switzerland, and the United States on vehicles employing the air cushion principle.

All of these were successful to the point of proving the feasibility of the concepts and in initiating follow-on programs that bring us to the point we are today.

In August of 1957 work was initiated by the Navy and its laboratories to investigate the theories involved and experimental verification thereof.

The hearings held by the Committee on Science and Astronautics of the House of Representatives on April 13–15, 1959, did much to help focus attention on this important problem.

The Department of Defense Symposium coordinated by the Army at Princeton in October 1959 made a significant contribution to this program by providing a complete review of the state of the art and publishing a summary report.

From this point on various agencies have continued a coordinated attack on the military and commercial feasibility of these machines.

Since 1957 we have progressed far in this field and there has been a significant expenditure of funds.

(Slide 3 on.) This slide shows expenditures to date by agency and by fiscal year. It was early recognized that vehicles such as these could service many functions for the several services. Coordination was, therefore, set up to make each program support the whole, thus achieving the maximum technical progress with the minimum time and funds.

This coordination is now carried on by a voluntary committee under Navy chairmanship to monitor all programs.

This next slide [slide 4 on] shows the scheduling of the various significant air cushion vehicle developments both in this country and abroad.

The Navy-Marine Corps program consists of six small vehicles purchased in fiscal years 1960 and 1961, a 20 ton R. & D. craft to be completed in fiscal year 1963 and a large oceangoing craft to be completed in fiscal year 1965.

The Army and Marad programs are shown along with the more important British developments.

It can be seen from this schedule that the British are about 1 year ahead of us in developments. My boss, Rear Admiral James has just ridden SRN–2, and will bring us a personal evaluation on his return to this country. Since the Marad and Army programs will be discussed separately, I will not dwell on these at this time. (Slide 4 off.)

The Navy's small test craft investigations covered a wide range of variations. These included full peripheral annular jet, an annular jet with side skegs, a full-peripheral waterwall, and a side-skeg waterwall.

The next two slides show three of these.

(Slide 5 on.)

This is the full peripheral annular jet craft.

(Slide 6 on.)

This is the side skeg annular jet craft.

(Slide 7 on.)

This is the side skeg waterwall craft.

(Slide 7 off.)

These test craft were not large enough to demonstrate military capability but they did demonstrate that simple theory, which was verified in model scale, could be extended reasonably well to large vehicles.

Their performance has been useful in orienting the R. & D. program. But their small size does not give the detailed information which we need to know before we can build large oceangoing vehicles.

The Navy and Marine Corps have conducted an extensive R. & D. program in conjunction with the Army. This program has included investigations into the areas of—

(*a*) Air cushion sealing.
(*b*) Stability and control.
(*c*) Motion in seaway.
(*d*) Resistance and powering.
(*e*) Noise.
(*f*) Structural criteria.
(*g*) Operations analysis.

Development of SKMR–1:

In order to further the Navy's air cushion vehicle program, a 20-ton R. & D. craft is being constructed. The purpose of this craft is twofold:

(*a*) To provide a vehicle which is capable of operation through a wide range of parameters and of sufficient size and speed to permit development of specification requirements in the areas of rough water control, stability, maneuverability, structures, spray, and noise.

(*b*) To provide a craft which can be used to evaluate the air cushion vehicle concept for military applications and which will hasten acceptance of these vehicles as military craft by successful demonstration of significant performance in different operational roles.

Description of SKMR–1:

(Slide 8 on.)

The slide shows an artist's rendering of SKMR–1 in flight. The craft has a design weight of 45,000 pounds and a maximum weight of 55,000 pounds. The length overall is 65 feet, and its beam is 28 feet.

It is powered by four Solar Saturn gas turbine engines with a total horsepower of 4,320. Propulsion is provided by two shrouded propellers located aft, and lift is provided by four fans. The propulsion and lift systems are tied together on each side of the craft.

The two lift fans and the ducted propeller on each side are tied to two Solar Saturn engines, one forward and one aft through common shafting and gear boxes.

The craft is capable of flying at a height of 1½ feet at a speed of 70 knots and a weight of 45,000 pounds for a distance of 150 miles.

At the maximum weight of 55,000 pounds the craft will be capable of flying at a height of 1.25 feet and at a speed of 70 knots. The hull material is aluminum.

The craft will be capable of withstanding loads encountered while proceeding at a speed of 50 knots in a state 3 sea.

The pilot house has accommodations for an operator, an assistant operator, and four observers. In the after part of the craft is located an open well approximately 40 feet long and 9 feet wide which can be used for transporting cargo. (Slide 8 off.)

Stability in flight is provided by segmenting the base cushion both transversely and longitudinally. Attitude control is provided by "butterfly" type vanes located in the air ducts around the perimeter of the craft.

A rudder, attached to the propulsion shrouds, provides directional control.

The craft is configured so as to permit easy attachment of side skegs and trunks. These will be evaluated during the testing program in order to determine their effectiveness in improving lift and performance in a seaway.

The craft is being designed and constructed by the Bell Aerosystems Co. of Buffalo, N.Y., under a $2.04 million CPIF contract with the Bureau of Ships. The propulsion engines, costing approximately $290,000, are Government-furnished. The craft is being funded out of the Navy's R.D.T. & E. program.

The Bell Aerosystems Co. was awarded this contract on November 29, 1961, after a competition conducted in the summer of 1961.

The contract consisted of a preliminary design phase, which was completed on April 5, 1962, and a fabrication phase which was begun on April 5 and which will complete on April 2, 1963. Working plans are approximately 50 percent completed, and production work has begun.

The craft will be assembled at the Bell Aerosystems Co. in Buffalo, and trials will be conducted in April and May 1963. Delivery is scheduled for May 31, 1963.

After the craft is accepted, the Bureau of Ships will begin an extensive test program to evaluate performance. This program will be conducted during the summer of 1963 with Lake Erie as the currently planned test site.

Test program: The program is primarily for the purpose of accumulating research information on the behavior of this type of craft in order to formulate suitable design criteria for future vehicles. The area of primary interest will be the testing of this craft in rough water.

The type of information sought in this program is—

(*a*) Speed-power and fuel economy as a function of vehicle loading and sea state.

(*b*) Vehicle handling and maneuvering characteristics as a function of speed and sea state.

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(*c*) Dynamic load tests as a function of speed and sea state.

(*d*) The effectiveness of various devices to improve stability, control, and lift.

(*e*) Verification of means taken to suppress noise and spray.

(*f*) Evaluation of side skegs and trunks as a means to increase flying height and improve performance in a seaway.

Following the R. & D. testing program, it is planned to bring the craft to the Chesapeake Bay area for demonstration of military applications.

Such demonstration will include beaching operations, ASW operations including performance with towed sonar, high speed patrol operations and mine countermeasures operations.

While in the Chesapeake Bay area, the craft will be operated to determine its magnetic and acoustic properties.

Future programs: In order to continue the development of hydroskimmers for open ocean applications, the Navy is planning construction of larger craft of this type.

Studies are now being conducted within the Navy Department to determine the most meaningful size for the next step in this development.

In arriving at this choice of size, consideration will be given to the logical mission applications and to the fact that the larger the craft, the more efficient is its performance.

(Slide 9 on.)

Among the various applications which are being considered for the next step in the hydroskimmer development are included mine countermeasures craft, landing craft, ASW craft and patrol craft.

It is planned to select that size vehicle which will give the widest range of possible applications. Although the exact size is not known, it is expected that the next craft in the Navy's hydroskimmer program will be in the size range from 150 to 250 tons.

The present schedule for development of this craft is to contract for design in fiscal year 1964 and contract for construction in fiscal year 1965.

Successful completion of a hydroskimmer of this size will demonstrate the ability of these vehicles to perform a useful military mission. It is expected that the techniques perfected in the development of this craft can then be extended to any reasonably desired size for open ocean application.

Conclusion: In summary, the GEM can "fly" a few feet over any terrain—water, land, ice, swamp, snow, etc. It cannot climb steep grades or pass over trees. Its performance over rough water is yet to be fully evaluated in reasonable size.

Another basic problem is that of maintaining stability and controlling the craft not only in attitude but also in course.

Its future will be determined as a result of evaluation and comparison with conventional planing craft, helicopters, low flying aircraft, hydrofoils, and hydrokeels.

Inherently, for a given load, the GEM will be very large in physical size which poses not only structural and transportation problems but also presents a large target. By comparison, aircraft are faster; helicopters have a more versatile flight path; hydrofoils and hydrokeels (an air lubricated planing craft) have much higher weight density and hence are smaller targets and handier.

All in all each has unique advantages in certain speed and size ranges and deserves to be pursued to a point where such selections can be made. None to date has shown overall superiority to the exclusion of any of the others.

To carry GEM's to a logical point of open sea capability in reasonable size, the Navy intends to continue the program and if all goes well will expend about $40 million over the next 6 years.

The next speaker, Major General Clark, will present a summary of the Army program in this important field.

The CHAIRMAN. For the sake of the members not here when we opened, we decided we would hear Captain Stilwell and Major General Clark before we start the questioning, and if some is also classified the last 20 minutes or so we will go into executive session.

General Clark.

General CLARK. With your permission, I would like to use the rostrum, and, if I may, take a moment to get set up with some slides.

The CHAIRMAN. Surely.

(The biographical sketch of Maj. Gen. Chester W. Clark is as follows:)

Maj. Gen. Chester W. Clark was born July 18, 1906, in San Francisco, Calif. He first entered the Army as a Reserve second lieutenant in 1927 and became a major general in July 1962.

In April 1962 General Clark was assigned as the Director of Army Research in the Office, Chief of Research and Development, Department of the Army.

General Clark has spent most of his adult life in education research, teaching, and in directing research. He attended the University of California, receiving a B.S. degree in chemistry in 1927 and a master's in chemistry and physics in 1929.

In 1935 he obtained the degree of Ph. D. in physics from the University of Leyden, in the Netherlands. For 6 years General Clark taught mathematics and chemistry at the University of California and San Francisco City College; and for 1 year following World War II was on the staff of the Johns Hopkins University where he did research in cyrogenics (low-temperature physics).

He was also consultant and physicist at the Naval Research Laboratory of Washington, D.C., where he helped to initiate the low-temperature research program.

From January 1941, to April 1946, except for his term at the Command and General Staff College, General Clark served at the Los Angeles regional office of the San Francisco Ordnance District and in the Legal Division of the Office, Chief of Ordnance, Washington, D.C.

His service since World War II has been almost entirely in research and development activities. From 1947 to 1954, he was, in turn, Assistant Director of the Ballistic Research Laboratories at Aberdeen Proving Ground, Md., and then Director of Research and Development activities at Picatinny Arsenal, Dover, N.J.

He was Deputy G–4 of the 8th Army in Korea during 1954–55, after which he joined the Research and Development Division Office, Chief of Ordnance, in October 1955. He served as Chief of the Guided Missile Systems Branch and its predecessors until he became Chief of the Division in June 1958. General Clark became Assistant Chief of Ordnance for Research and Development in January 1959.

General Clark is married to the former Miss Jessie May Clark, also a graduate of the University of California. They have a daughter, Adri, now Mrs. Jack Peacock, who is a graduate student and teaching assistant at the University of North Carolina, and a son, Anthony, who is now an engineer at the Jet Propulsion Laboratory, California Tech, Pasadena, Calif.

STATEMENT OF MAJ. GEN. CHESTER W. CLARK

General CLARK. Mr. Chairman and members of the committee, I am Maj. Gen. Chester W. Clark, Director of Army Research, Office of the Chief of Research and Development, Department of the Army.

It is my purpose to present the Army's air cushion vehicle program. This includes accomplishments, current status, and some potential applications that offer the Army improved surface mobility.

The Army's air cushion program has predominantly been in the research area. This program has purposely been designed this way so the Army could be assured that the technology was available before any large scale vehicle development was initiated.

The air cushion vehicle offers the Army an improved means of surface mobility and in the area of amphibious logistics the air cushion vehicle could well be our next generation of vehicles.

Also, in special or selected terrains, where a low-ground pressure is required, such as swamps, over snow and mud, the air cushion vehicle may be the vehicle to move men and supplies.

The air cushion vehicle has been a comparatively recent mobility concept to the Army. Although investigations of the ram wing

(Kaario, Finland, and D. K. Warner, United States) were carried out in the 1930's, little serious thought was given to the phenomenon until 1958 when Cockrell (United Kingdom) began construction of the SRN-1.

A symposium was sponsored by the Army at Princeton University in October 1959 to determine the state of the art and to assess the potential of the concept.

Scientists from all parts of the world representing industry, educational institutions, and governments responded and provided a comprehensive review of the art and contributed valuable data, much of which is the basis for performance prediction to the present time.

Subsequently, similar reporting sessions on the state of the art have alternately been sponsored by the Army and the Office of Naval Research. The last of these sessions was held at Fort Belvior in August 1961.

This slide shows the total funding for the Army's research program in fiscal years 1962 and 1963 and the projected funding for fiscal year 1964.

In fiscal year 1962 our program was $439,000, in fiscal year 1963, we are funded at $563,000, and a funding level of $643,000 is planned for fiscal year 1964.

Research during the preceding years has produced a significant advance. The results of the Army's research investigations are summarized as follows:

An analysis of the relation between aerodynamic and air cushion flow fields revealed a significant reduction in power required and higher speeds through the use of aerodynamic lifting surfaces with the air cushion vehicle concept.

These surfaces are not as aerodynamically efficient as wings or lifting surfaces of conventional aircraft, because of the size and platform of the surfaces being considered.

The review of stability characteristics reveals that control is more difficult to achieve than stability. Performance costs for maintaining inherent stability have been determined, and it appears that the costs are unacceptable in performance penalties to achieve the inherent stability needed as operating height is increased.

It may prove advantageous in the long run to accept the higher initial complexity of a stability augmentation device working through the control system.

In theory, a performance gain exists by sealing the ground cushion under a vehicle by means of a standing vortex. The ejector approach has been identified as a promising means of maintaining this vortex or a recirculation condition.

A comprehensive experimental program is currently being conducted to determine the performance characteristics of the recirculation concept.

The effect of transportability on air cushion structure has been analyzed. It was determined that a substantial weight penalty must be paid in order to sectionalize large rigid structure vehicles for transportation, indicating that either flexible structure or increased cushion pressure are necessary for meeting shipping constraints.

An experimental program to determine the performance of ejectors in an air cushion environment has been completed. This study indicated that a carefully designed ejector improves the overall efficiencies of a fan duct nozzle system.

An investigation of a method of producing lift by induced flow over external surfaces indicated that the pure Coanda effect is of little advantage, although by spacing between the nozzle and the surface increased thrust and mass flow augmentation will result.

The Army logistics-over-the-shore (LOTS) mission has been investigated for applicability of an air cushion amphibious vehicle and the optimum performance and payload of such a vehicle has been determined.

The Army's current research program involves contracts with industry and educational institutions as well as joint funding approaches with the Office of Naval Research.

The research carried out under these contracts is providing valuable research data and information. In some cases small scale vehicles are developed to verify a concept or a theory. The current contracts are briefly described as follows:

The Aeronutronic Division of the Ford Motor Co. is conducting investigations of stability and control characteristics of air cushion vehicles.

The Kellett Aircraft Corp. is investigating dynamic responses of the air cushion vehicle in overland operations.

The Grumman Aircraft Corp. is investigating the use of aerodynamic lift devices within ground effect or reduce power requirements of air cushion vehicles.

The Martin-Marietta Co. is investigating the use of recirculation of the air cushion as a means of improving the efficiency of air cushion vehicles.

The Bell Helicopter Co. is conducting a program in the use of controlled flow to improve the performance characteristics of the plenum type air cushion vehicles.

At Princeton University performance evaluations of various air cushion vehicles configurations are being investigated, particularly the configurations that will be used at higher speeds and higher heights.

Vertol and Convair are investigating various configurations to meet the Army's aircraft short-takeoff and landing (STOL) requirements and the Navy's requirements to reduce the hydrodynamic problems of seaplane operations.

Contracts that are jointly funded by both the Navy (ONR) and the Army are as follows:

The Aerophysics Corp. is conducting a theoretical analysis of the airflow for air cushion vehicles.

The Hiller Aircraft Corp. is conducting an experimental program to evaluate the annular ejector for use in air cushion vehicles propulsion systems.

The AiResearch Co. is conducting a study of various propulsion systems suitable for use in air cushion vehicles and is investigating stability and control for overwater applications.

The Vehicle Research Corp. is investigating the possibility of vortex recirculation to improve the internal efficiency of air cushion vehicles.

The Booz-Allen Applied Research Co. is investigating the effect of various environments of air cushion vehicles, particularly in overland applications.

The Army research program for the fiscal year 1963 is funded at $563,000 as shown on the first slide. This program is based on the results of the previous years' research.

From this research it has been recognized that four major problem areas exist. Three of these are problem areas because of high horsepower requirements and one an operational problem. The fiscal year 1963 research will emphasize study in these areas.

They are—

(1) To improve the inherent stability characteristics at higher speeds and higher heights.

(2) To provide effective and efficient control forces with a minimum of power.

(3) To improve internal flow efficiency, including inlets, fans, ducting, and the exit jet.

(4) To reduce operating noises and blowing of debris, dust, et cetera.

(Slide 2—Research spectrum.)

General CLARK. We have agreed with the Navy and Marine Corps on an air cushion research spectrum. Here are shown the values of h/D needed for various types of operation: ("h" is the operating height of the vehicle and "D" is the effective diameter of the vehicle). We are interested in the h/D range of 0.05 to 0.10 and higher.

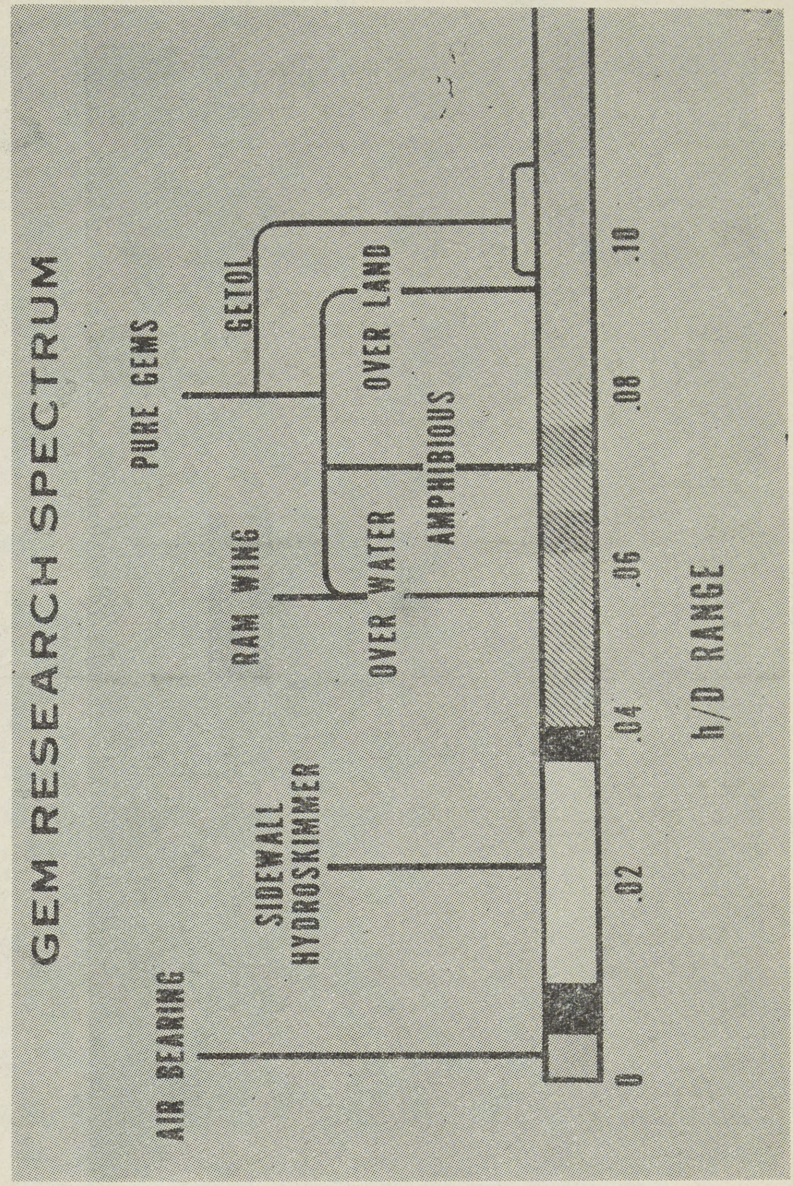
This is also illustrated by the next slide. At approximate values of h/D of 0.05 and above the inherent stability of the air cushion vehicles diminishes and it is necessary to include stability augmentation, such as compartmentation of the air cushion of the base or as I mentioned previously an augmentation device working through the control system.

The problem of control begins when the vehicle is not in contact with the surface and as illustrated by the different air cushion approaches of this slide, it is at a value of approximately h/D of 0.03.

The third major problem of internal efficiency is prevalent across the complete range of h/D. This basically involves taking air in by a fan and through a duct system or a plenum chamber to an exit nozzle. This must be done as efficiently as possible. This is why the ejector-recirculation concept I mentioned previously appears attractive, and that is the air is recirculated the form of a vortex and contains the air cushion under the vehicle at the periphery. (Slide 2 off.)

(Slide 3—Operational spectrum.)

General CLARK. Here is the area of operation that the Army is interested in using the air cushion vehicle—primarily amphibious with some overwater and overland application. The fourth problem area that I mentioned exists in the complete Army operational spectrum as shown on this slide. Reducing of noise and spray, dust blowing, et cetera, is essential before the air cushion vehicle can be optimumly used by the Army in the spectrum shown. (Slide 3 off.)


GEM RESEARCH SPECTRUM
AIR BEARING
SIDEWALL
HYDROSKIMMER
RAM WING
PURE GEMS
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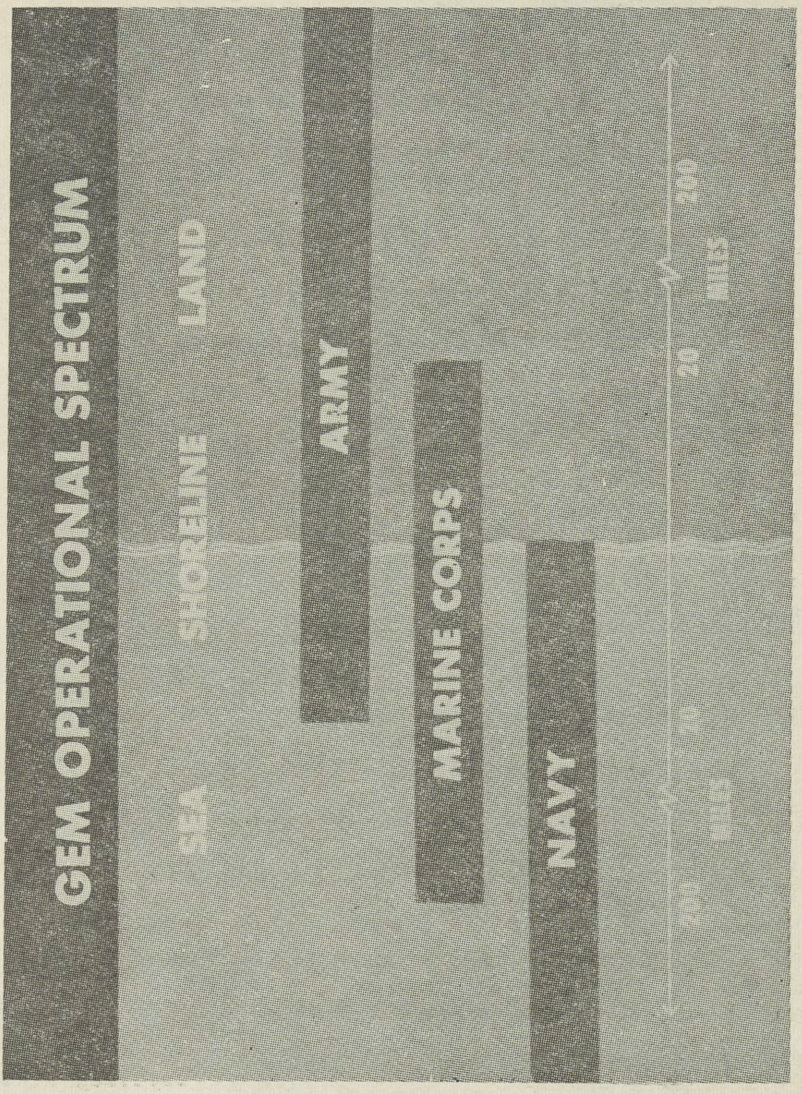
SLIDE 2


GEM OPERATIONAL SPECTRUM
SEA
SHORELINE
LAND
ARMY
MARINE CORPS
NAVY
20
MILES
200

SLIDE 3

Current studies that help in solving these four major problems will continue in fiscal year 1963, as well as new studies. One such study is that of investigating the use of skirts in conjunction with the air cushion vehicle. Skirting offers the potential of increased height, reduction in signature, and increased efficiency.

I would like to mention other applications of the air cushion concept that the Army is currently studying. Many of these applications will not be available for several years but all have potential.

The low vulnerability of air cushion vehicle to land mines has been recognized. An air cushion mine search head carrier is currently being designed to investigate its potential.

The Army's Surgeon General's office has recognized the potential increase in effectiveness of their corpsmen in evacuating casualties through the use of an air cushion litter.

An air-bearing jack has been designed and constructed to permit movement of the 5-ton Army-Air Force "Conex" containers in warehouses and shipholds, which utilize the high-lift efficiency of the air-bearing principle with 15 installed horsepower.

The air cushion assist type off-road vehicle may be desirable for specific missions and areas. This is a conventional wheeled vehicle with a kit mounted on it which lowers a skirt to lighten the wheel loading to permit travel through muskeg and similar-type terrain.

In the application of the air cushion concept to larger vehicles consideration is being given to an off-road carrier. However, the amphibious logistics-over-the-shore (LOTS) carrier appears to be the most attractive for future development.

I have several slides that I would like to show that illustrate artist concepts of possible LOTS carriers.

(Slide 4 on.)

General CLARK. Design and performance characteristics of such an air cushion LOTS carrier would be a 15-ton design payload operating at 3 feet height, and (slide 4 off), (slide 5 on) which would permit it to negotiate waves with significant heights of 5 to 6 feet and at a speed of 40 knots. (Slide 5 off.) (Slide 6 on.) The vehicle would have a 100-percent overload capability, when sea conditions permit operation at heights of 15 to 18 inches. (Slide 6 off.) (Slide 7 on.) (Slide 7 off.) Current investigations indicate that performance can be achieved with a platform of 30 by 60 feet and 3,500 installed horsepower. (Slide 8 on.) (Slide 8 off.) When we are completely satisfied that the technical problems I previously mentioned can be solved, a development of this type will proceed.

From most of the operational studies completed the Air Cushion Vehicle appears superior to any other form of amphibian.

Gentlemen, obviously such a brief period does not permit going into the details of our program. I have brought to your attention the significant accomplishments of our air cushion research program, briefly reviewed the Army's current contracts and indicated the technical areas the Army's research program in fiscal year 1963 will emphasize. I have shown you the type vehicle, the LOTS carrier, that appears to be the most attractive application of the air cushion concept for the Army.

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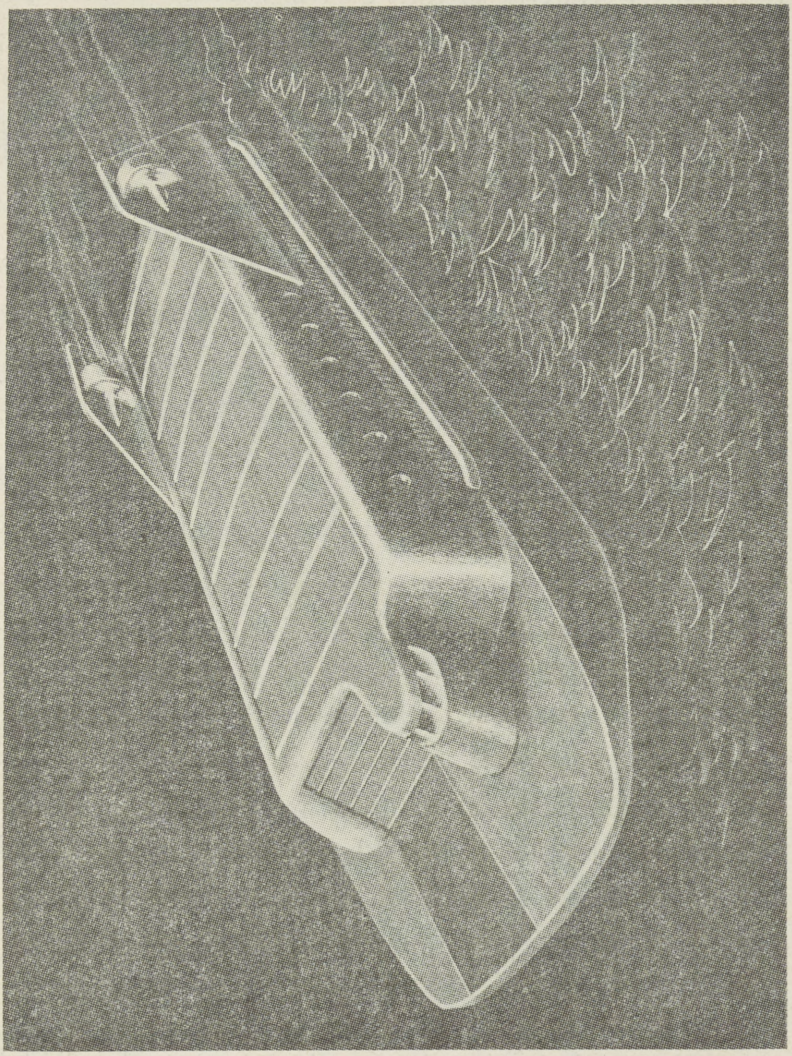
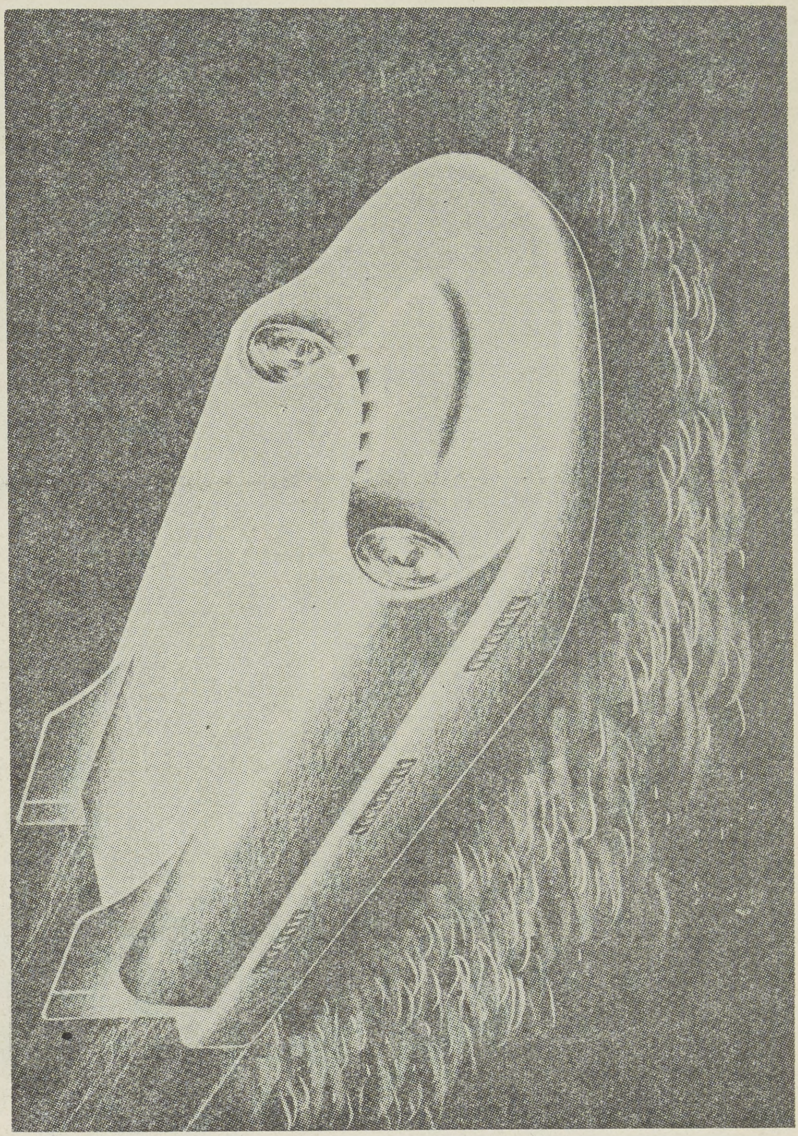
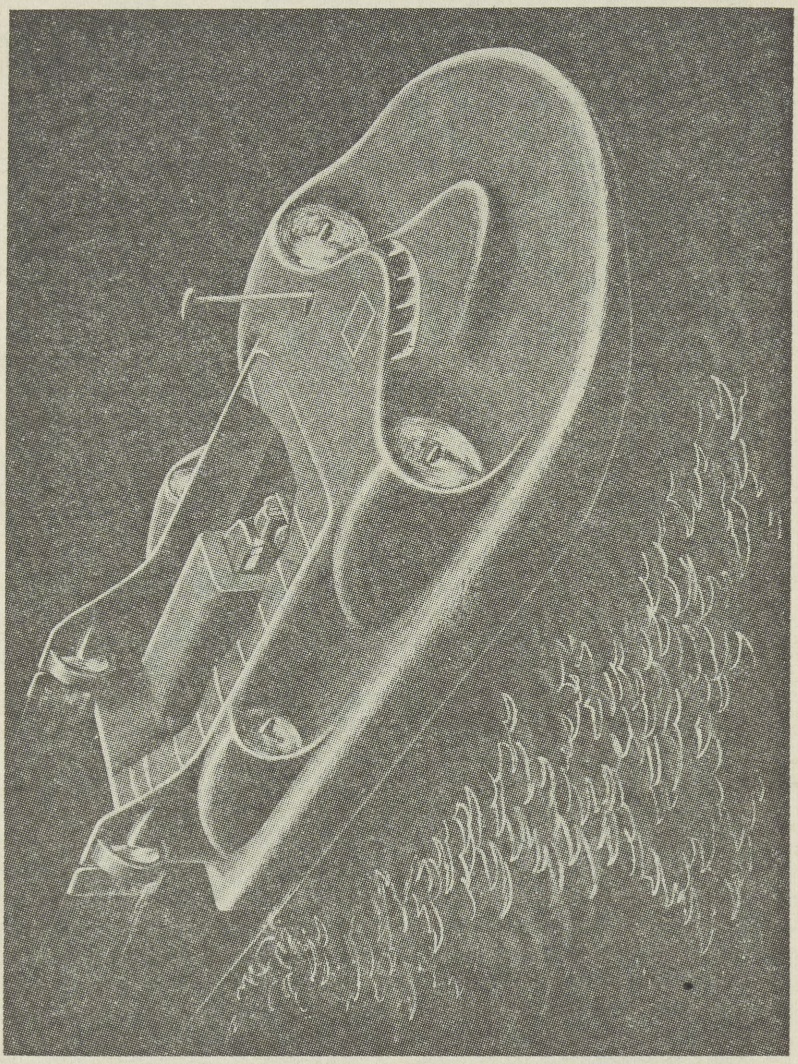


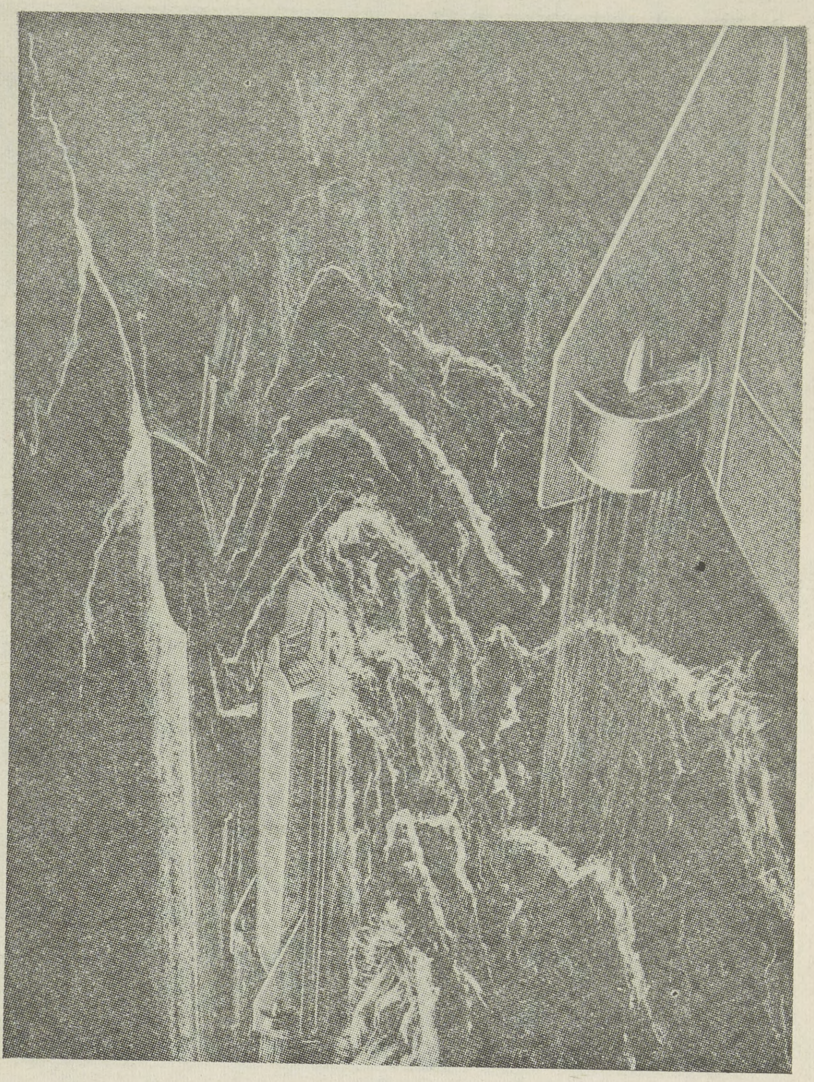
SLIDE 4



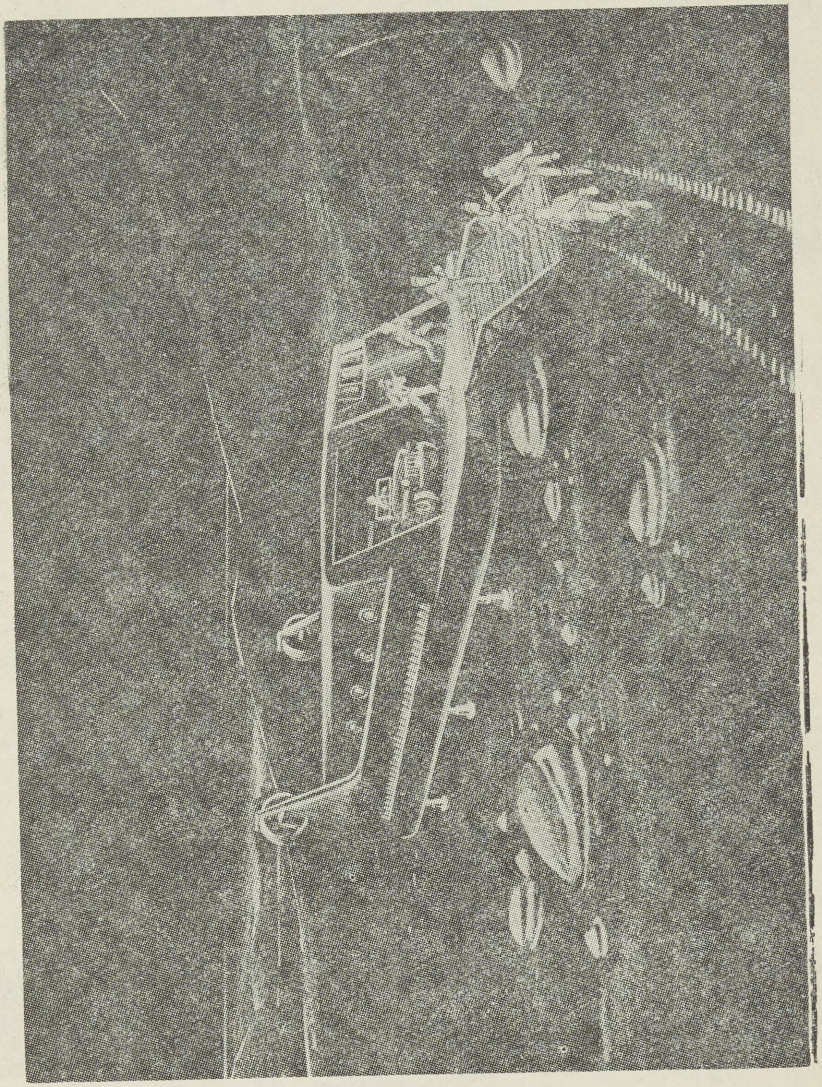
SLIDE 5



SLIDE 6



SLIDE 7



SLIDE 8

In closing, I wish to emphasize that this program is oriented to provide the Army with improved surface mobility.

Mr. Chairman, I thank you very much for this opportunity.

The CHAIRMAN. General, and Captain, there is then full cooperation between the Army and the Navy in development of this vehicle?

General CLARK. In my opinion, yes, sir, I think this is probably one of the better examples of excellent coordination. We have in the audience here today Major Robertson of the Army, who is right at ONR and has a desk there and he is here with his counterparts.

The CHAIRMAN. The Navy and its London office has a man who has specialized in it, or you continue to have people there who have followed this. Does the Army have anyone in Europe or in England who is following this, or is that part of the Navy's functions?

General CLARK. In our European research efforts we have a close tie-in with the Office of the Naval Research in London and similarly with the Air Force office in Brussels, and we have an office in Frankfort.

Our efforts in all areas of research there are well coordinated. We have one small plant down in Italy. We have access and take advantage of all of the information which the ONR provides there.

There are actually a series of meetings held at these different research offices in Europe between these people, who are specialists in certain areas at the working level.

The CHAIRMAN. Later on in the hearings Marad, or the Maritime Administration, will have a witness here. Is there a full cooperation with Marad in those areas where cooperation is possible with the Department of Defense?

General CLARK. Sir, I believe the Navy representatives can answer that better than I can.

Captain STILWELL. Yes, sir, the research and development people in Maritime have membership on our committee and we are in daily contact with them in their program, and they have complete use of our information as we develop it.

The CHAIRMAN. For the benefit of the members of the committee who came in a little late, at about half past eleven, we are going into executive session, to ask some questions, because some of the information is classified, but if there are any questions now that can be asked that are unclassified, the Chair will entertain them.

Mr. Fulton?

Mr. FULTON. How much money are the British spending on research and development in this field compared to ourselves? What is the relative comparison in size of the program?

Captain STILWELL. I do not have specifics on the monetary size of the British program in view of the fact that a considerable amount of this has been carried out in Britain by private funding and we are not privy to the books of some of the private British concerns.

Mr. FULTON. That is part of my question. I was in Britain recently and they felt they were already up to operational vehicles, while we are simply at a research and development stage. Can you comment on that?

Captain STILWELL. Part of my answer will be in the executive session, but for this session, I would say that, as was indicated on our progress chart, in specific hardware, the craft that we are delivering next spring is the equal, if not superior, to the present British craft just now operating.

So I don't think we are too far away from them hardwarewise, and how much they are up with us, or ahead of us, R. & D.-wise, on the specific answers to many of the problems, I wouldn't venture to guess.

Mr. FULTON. I couldn't help but notice, Mr. Chairman, that the Army calls theirs the air cushion vehicle and the Navy calls its machine a ground effects machine.

You ought to switch, because the Navy certainly ought not to be talking about the ground.

The CHAIRMAN. I would like to say, for the benefit of my colleague, that I think a rose by any other name would smell as sweet.

Mr. FULTON. I notice from the design chart that the Army is foresighted in selling its program, they have adopted the high-tailed fin approach, which goes on all the automobiles, and I could possibly imagine, adds greatly to the stability, or does it only add to appearance.

The CHAIRMAN. Any other questions?

Mr. FULTON. No, sir; that is all.

The CHAIRMAN. Any other questions on this side?

Over here?

I will say, for the benefit of the committee, that tomorrow I believe Commander Ditch comes before us. Commander Ditch has been on duty in ONR in London, and, I believe, is one of the specialists in this field—is he not, Captain?

Captain STILWELL. He is up to date on the field, yes.

The CHAIRMAN. He is returning from London. We will have him here tomorrow.

Mr. Waggonner?

Mr. WAGGONNER. Either the general or captain can answer this question—perhaps both:

The Navy has a projected figure for the next 6 years of anticipated expenditures on these hydroskimmers or ground effect machines.

Does the Army have a figure which approaches in the next 6 years the Navy expenditures, will they be comparable, or is the Navy to spend more money on the development of these craft than is the Army?

General CLARK. I don't have those figures available. We have plans out for 5 years beyond. I can get those figures. There would be no reason why they would necessarily match or balance because we are looking at different missions.

Mr. WAGGONNER. Thank you.

The CHAIRMAN. Mr. Randall.

Mr. RANDALL. General, did I understand—I came in late, but I want to be sure—that the United Kingdom started this first research, is that correct?

General CLARK. Yes. I think the first thing really put to large-size, practical hardware was by Mr. Cockrell in England, and that resulted in, I believe, he having the basic patents in this sort of thing, and he got together with some of the British companies, I think Saunders-Roe, and the first large vehicle put into the hardware—sort of a prototype construction, to test out the ideas—was the so-called SRN-1, which was Mr. Cockrell's ideas put into hardware.

Mr. RANDALL. That was one of the slides that had that enumeration on it the Navy was showing when I came in. It is commendable to see such good cooperation between them. We do a lot of talking about international cooperation, even to the extent of the Soviets.

What about the British, are they helping us on this, giving us the benefit of their research?

General CLARK. I would suggest we might discuss this a little later, if you don't mind, Mr. Randall.

Mr. RANDALL. All right.

Mr. RIEHLMAN. Are we going to get into the specific uses of this type of vehicle in executive session?

The CHAIRMAN. I think so; yes. In open session would you care to answer this: To what extent have the Soviets gotten into this field?

General CLARK. We know, from a very little bit of information, that I can mention here, because it has been published in some of the periodicals, they do have this type of machine in use.

As far as we can determine it is sort of an experimental one.

Do you have any more on that?

Captain STILWELL. Not for unclassified session.

Mr. FULTON. At the previous hearings there were several small businesses came before us and were interested in developments in this field.

I know some companies had some models. Their complaint was that at that time the Government agencies were not helping them much and they probably would not be able to continue. What has happened to those small businesses?

Captain STILWELL. One in particular—as I recall, the first slide I showed you was a model prepared by one of them. However, as we have come along in the R. & D. program I believe the record will show that at least two of those that were at that previous hearing are no longer in the business.

I can't testify as to why.

Mr. FULTON. The question is why not, and isn't the British Government doing better with their private industry in this new field than we are?

Captain STILWELL. I think part of the reason may have been the degree of technical background that was applied to the particular products. In one case the machine model worked but the technical backup for its working and the ability to extrapolate to anything bigger or different was not apparent. They were given opportunity, however, to participate in the program.

The CHAIRMAN. What other countries besides England and Russia have been interested in this?

Weren't the Canadians interested in it?

General CLARK. The Canadians had a related vehicle called the AVRO car. I believe that was discussed at a previous meeting. This has not lived up to expectations and we have withdrawn support from that.

The Swedes also have a vehicle that is flying.

The Swiss too, of course.

Mr. Weiland is one of the leaders in this field and they do have vehicles running in Switzerland, and I believe he has designed some vehicles that are being looked at over here.

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Captain STILWELL. He has come to this country.

The CHAIRMAN. One of the sad commentaries on this thing is that Switzerland gets into this. I believe on the patents that the Italians use for their hydrofoils they are licensees of a Swiss firm.

We have heard a great deal about the hydrofoils. They have used his foils now for some 5 years commercially, and one of them has been sold and is being used along the coast of America serving the West Indian islands. There have been applications by people for permission to bring Italian built hydrofoils to this country, but inasmuch as you cannot use a foreign bottom in intercoastal trade, the Committee on Merchant Marine and Fisheries has refused to recommend they be given this permission. I sat on that committee for a long time, as did Mr. Downing, who now sits on it. I think you remember the long discussions that we had trying to protect American development or American industry in this field. It is too bad these people have gotten out into this field.

For the sake of the record, I might say that when a subcommittee was in England last year—Mr. Van Pelt was along—we heard the plans of the British to commercially use hydrofoils in river traffic.

They were quite ambitious about replacing barges on the Rhine and barges in Europe on rivers. And later on I had a discussion with one of their people, who pointed out the great field that southeast Asia offered for such a vehicle, and how these vehicles could be used in these newly emerging countries where they had no railroads but did have waterways or swamps, and somehow or another the SN–1, as I recall, or an SN, not the "1"—I think it is the 5, isn't it?—was recently put into operation as a ferry on the River Dee in England.

Captain STILWELL. I don't know the designation of it.

Mr. FULTON. There is one, according to the press.

The CHAIRMAN. According to the press of this country. I have the clipping upstairs. It was an SN that was put into operation on the River Dee as a ferry crossing the Dee.

Captain STILWELL. Mr. Chairman, I could comment on your statement, if you would like.

As you know, we have been in the hydrofoil business for roughly 12, 15 years, of development, and all along the line the European developments have been watched very carefully and looked at for possible application, obviously, to save our own R. & D. money, to our problem.

However, there are two things that enter in. First, the popular concept that the European hydrofoil people are way ahead of us is fallacious in that you will find most of the hydrofoil designs in operation in Europe are direct descendants of the early German work in about 1933–34—in that era.

They have not changed too much. In fact, in our evaluation they were not sufficiently seaworthy for most of our purposes, so that we had to develop beyond that, to get a craft that we felt was adequate for all-weather operation.

Secondly, their popularity and use in Europe, as you perhaps have alluded to, I think, is a case of supply and demand. Where you have an excellent road transportation system and air transportation system to all parts of your country, the competition with the hydrofoil is pretty stiff; whereas in some areas, such as southeast Asia, and in portions of Europe, the established transportation systems are not nearly as fully developed or as competitive, and the hydrofoil is a little more of a crying need in these areas.

The CHAIRMAN. Of course, I recognize this. I also recognize the fact that there is a great deal of testimony before another committee as to the use of a hydrofoil as a ferry between two parts of Puerto Rico and the only reason it was not put in was because they can't use the hydrofoil—they can use the hydrofoil that now operates between Puerto Rico and the Virgin Islands because the Virgin Islands are exempt from the provision of the law that says you cannot use the foreign bottom in those ports—because of their peculiar position.

So this boat is being used between them. It was well brought out by the Puerto Rican representative of the Puerto Rican Commonwealth and our own people that the use of a hydrofoil would cut down the time that it takes a ferry to operate in that country, but the committee did not see fit to go beyond the law that requires American-made ships to operate between American ports.

There was quite a tendency to do it. There are bills pending in Congress now for the granting of this permit, to use these between, for instance, Catalina and the mainland. I am not too sure that if the hydrofoils were established here that there wouldn't be some places on the Great Lakes they can be used.

When I was at Fort Lewis in World War I—or Camp Lewis, General—the best means of transportation between Takoma and Seattle was by ferry. This has long gone out because we have good roads. But I think a hydrofoil over this same area could even beat the railroad or the other modes.

Mr. DOWNING. In connection with that, I am sure the chairman will recall we asked the applicant why he did not try to get an American hydrofoil, and he told us that the American industry had not reached the state of the art where they could produce one.

I believe that company gave an astronomical figure to come up with this Italian hydrofoil, which was available at a fair figure.

The CHAIRMAN. I wasn't in Italy to use this thing. Had I stayed on the committee I would have gone on it. A former member of the staff did go down and ride it. His report is that it operated in rather heavy water.

Mr. RIEHLMAN. Mr. Chairman, I had the experience of riding on a hydrofoil from Naples to the Isle of Capri. We did meet with some very rough seas and had a very, very, rough ride. In fact, we were not permitted to come back on it because of the weather conditions. That was the only experience I have had. I am not so sure that they are at this time—at least the hydrofoil that we had to ride on—a very dependable ship in any kind of severe weather.

I don't know what the captain would say about that.

Captain STILWELL. I have probably extended my remarks further than I should in the commercial area already, but, of course, these areas are closely related. Actually there are two basic types of hydrofoil. One is called the surface piercing hydrofoil, which you will find all the European types are.

Mr. RIEHLMAN. Would you explain that?

Captain STILWELL. Yes, the principle of the surface piercing hydrofoil is that you design an underwater wing that has roughly twice as much lifting area as you need to support the craft. Put it up in a V form wrapped around the hull. The waterline is halfway up the foil. If the wave comes by, or if you get too heavy, the foil raises or lowers, so just enough is wetted to keep the ship afloat.

This is fine in relatively calm waters and in head seas. However, there is only, as you can see, a two to one lift variation available, so when you get into a relatively rough following sea there are several effects happening. The wave reduces your angle of attack. The oncoming rush of water in the waves reduces your relative flying speed so that what happens is there is a size wave for any given size surface piercing foil boat that will cause it to stall out and fall, just as an aircraft would fall when it is stalled out. This is not catastrophic in the craft. The hull comes into the water and you decelerate rather rapidly as you perhaps experienced in your ride, sir.

The other type of craft is known as the submerged foil craft, which is configured very similar to a monoplane aircraft with the wing entirely submerged and struts coming through the surface to the craft. The difference between this and the surface piercing boat is that this foil, or wing, has no idea where the surface is so you must apply electronic or mechanical means to keep this at the proper angle of attack, and hence the proper distance below the surface.

However, by varying angle of attack you can change the lift a matter of four or five times, rather than the two to one ratio you have in surface piercing foil. Hence you can, for all practical purposes, design a submerged foil craft that will fly absolutely level, or very close thereto, in practically any sea state from any direction. This has taken considerably longer development and is actually a technical breakthrough in the form of a sensing device that would rapidly measure and integrate the water surface and tell the foil exactly what to do reliably.

The CHAIRMAN. Captain, with your permission we will go into this hydrofoil later and perhaps you will be up here then. I may say though, in closing, before we get into this, just for the information of all concerned, my good friend, Mr. Downing, just called my attention to the fact, something I have known, that the man who trains astronauts and is in charge of the program of getting people into space, Bob Gilruth, built a hydrofoil and used it to study the effect of the angle of attack and the same dynamic features in water down at Langley.

I asked him if he was going to take it down to Texas with him, and he told me he didn't know.

We are going into executive session.

Mr. HECHLER. General Clark, I noticed Captain Stilwell gives some dates, when various craft will be delivered between 1963 and 1965.

Can you pin down your general timetable a little more specifically on some of these things that they are working on?

General CLARK. We had expected our first models, or prototype model of the LOTS carrier would begin to be available somewhere in 1964. However, I think we are forced to postpone that 1 year beyond that as we see it at the present time.

Now, on some of these others we are talking about, like this litter type thing and others that I mentioned, these are sort of breadboard type models to test out the feasibility of them.

We are going into that now. After we have more information on them, and find out whether they are of value—I mentioned this mine search lead carrier which we think might be quite important—a prototype is being made to determine whether it is feasible.

After we get more information on them, we will have a specific timetable.

Mr. HECHLER. Thank you.

The CHAIRMAN. Before we go into this, I might say the ground effects machine and hydrofoils have been more or less orphans of Government. No one has taken a great deal of interest in them—pressing them in Congress.

I want to assure you that from now on out this committee is going to take them under its wing and sponsor them and try and see if we can't help you gentlemen out. I want to congratulate you on the job you have done with this great lack of interest being shown, on the Hill at least.

Now, I will ask those people who are not qualified to remain to leave the room, because we are going into executive session.

(Whereupon, at 11:30 a.m., the committee went into executive session.)

We are going into executive session.

Mr. Hechler. General, [illegible] Captain [illegible] give some dates when various craft will be delivered between 1963 and 1965.

Can you run down the [illegible] a little more specifically on some of these [illegible] they are working on?

General [illegible]. We had started our first models, or prototype model of the [illegible] earlier would [illegible] to be [illegible] sometime in 1964. However, [illegible] we are forced to postpone that a year [illegible] that as we [illegible] at the present time.

Now, on some of these others we are talking about, like this latter type thing and others that I mentioned, there are sort of breadboard type models to test out the feasibility of them.

We are going into that now. After we have more information on them, and find out whether they are of value—I mentioned this more [illegible] which we think might be quite important—a prototype is being made to determine whether it is feasible.

After we get more information on them, we will have a specific timetable.

Mr. Hechler. Thank you.

The Chairman. Before we go into this, I might say the ground effects machine and hydrofoils have been more or less [illegible] of this committee. We have taken a great deal of interest in them—pressing them in Congress.

I want to assure you that from now on this committee is going to take them under its wing and [illegible] we can help you, gentlemen [illegible]. I want to congratulate you on the job you have done with the great [illegible] being shown on the Hill at least.

Now, I will ask those people who are not qualified to remain to leave the room, because we are going into executive session.

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RESEARCH ON NEW TRANSPORTATION METHODS (GROUND EFFECT MACHINES)

THURSDAY, JULY 12, 1962

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C.

The committee met at 10:30 a.m., Hon. George P. Miller (chairman) presiding.

The Chairman. The committee will be in order.

We will resume the hearings that we had yesterday with respect to Hovercraft or ground effects machines and others.

I want to welcome Commander Ditch here, whom I had the privilege of meeting and working with in Europe last year, and who in my estimation is one of the best informed people in this country on this particular problem.

So Commander Ditch, will you proceed with your statement and we will question you afterward.

Mr. Fulton. May we please have Commander Ditch give his educational background.

The Chairman. Commander Ditch is presently on duty at the Office of Naval Research in London. He, among other things, has specialized in this particular field. I can't give you all of the details of his service.

Will you, Commander, tell us of your education and background.

STATEMENT OF COMDR. WILLIAM E. DITCH (ONR LONDON)

Commander Ditch. I have a master's degree from California Tech and a professional aeronautics engineering degree from Cal Tech both earned in postgraduate school under Navy sponsorship.

The Chairman. All right.

Commander Ditch. Mr. Chairman, members of the committee, a Finn, Mr. T. J. Kaario, is given credit for the European invention of the ground effects machine (GEM) by some workers in this field.

Mr. Kaario patented "GEM's" in the 1930's, and he has continued to build and test experimental vehicles in Finland. Perhaps Kaario's machines should more properly be called "ram wing" vehicles or low aspect ratio airplanes designed to always operate within ground effect.

Nevertheless, his work has included the basic principle inherent in all GEM's. That is, the creation and retention of a shallow supporting air cushion between the bottom of the vehicle and the surface over which it operates.

Although he has concentrated on the ram effect to pressurize his air cushions, some of his machines rise off the surface when tethered in place.

Mr. Kaario's work went largely unnoticed, and the disclosure of the British invention by Mr. Christopher Cockerell was responsible for the current upsurge of interest in air cushion vehicles.

Cockerell had worked on his invention since about 1953, and applied for a British patent on December 12, 1955.

The unique feature of Cockerell's work was the retention of the air cushion by a curtain of air around the periphery of the vehicle.

In 1956, the British Ministry of Supply (now the Ministry of Aviation) became interested in Cockerell's invention, and classified the work Secret. Saunders-Roe Limited was given a government contract to test models in their hydrodynamics facilities.

This contract was later expanded to include feasibility studies. The tests and studies proved the principle to be theoretically practical. However, requirements for military vehicles did not develop, and the Ministry of Supply terminated work on the project and declassified the invention.

The CHAIRMAN. Commander, would you just in a word describe the British National Research and Development Corporation.

Commander DITCH. We have no similar organization in the United States. It is an organization, corporation, I should say, a government-sponsored corporation, and it operates as a business, NRDC receives its funds from the Board of Trade, and its major task is to develop promising inventions into salable items, items used in British production and to create new industry.

The moneys NRDC receives from the Board of Trade are a sort of rotating funds. They make a profit on these inventions and therefore hold their funds at a supposedly fixed level. Actually it fluctuates.

The CHAIRMAN. The closest approach we have to it, although it does not approach it very closely, would be the Small Business Administration here, where it could make loans to business, and it not only makes loans but it encourages new types of inventions and new business with public funds.

Commander DITCH. Yes.

The CHAIRMAN. It must be repaid to the corporation?

Commander DITCH. Yes, it is not just repayment of the basic amount but they continue to make a profit over the years on it.

Mr. DADDARIO. Don't they also seek out patents for the purpose of developing for commercial advantage?

Commander DITCH. Yes. They don't seek them in the sense they advertise for them, but they are an organization widely known and inventors do come to them frequently for this kind of help.

Any other questions on that point?

The CHAIRMAN. Fine.

Commander DITCH. In July 1958, Cockerell approached the National Research Development Corporation for support of his invention. NRDC accepted the application in September 1958 and agreed to sponsor a development program. Two simultaneous approaches were selected:

(1) The conduct of supporting research, and (2) the construction of a man-carrying prototype. Because of the company's previous ex-

perience, the NRDC contract for both phases of the program was given to Saunders-Roe.

The now famous SR–N1 made its first public appearance on June 11, 1959, having been completed in less than 8 months.

During this same period, Mr. Carl Weiland, of Zurich, Switzerland, was also working on an "air boat" supported on an air cushion, and had proposed the labyrinth seal principle to reduce the power required to generate and maintain the air cushion.

Weiland's second machine was purchased and sent to the United States where it was used in experiments conducted by the U.S. Marine Corps.

A small research contract with Weiland was issued to further explore his labyrinth seal concept. Weiland came to the United States shortly thereafter and has figured in the GEM work of the Reynolds Aluminum Co.

Although Weiland's machines appeared in the newsreels and popular press, the emergence of the SR–N1 seemed to act as the catalyst for the greater part of the noteworthy investigations in Europe.

Sweden, France and the United Kingdom were most prominent in independent research and theoretical investigations which had some Government or quasi-Government support, and the Netherlands Ship-model Basin has done some excellent work on GEM's in waves patterns for the U.S. Navy.

In the United Kingdom the development has proceeded toward commercial applications. NRDC and its subsidiary organization, Hovercraft Development, Ltd. (HDL), entered into agreements with four firms for the development of salable machines.

The four companies were: Saunders-Roe Ltd., Vickers-Armstrongs (South Marston), Ltd., Folland Aircraft, Ltd., and the shipbuilding firm, William Denny & Bros. Ltd. A fifth company, Britten-Norman, Ltd., undertook an independent program.

Folland Aircraft withdrew from the GEM field in February 1962, but the remaining companies are conducting active programs.

Saunders-Roe, now a division of Westland Aircraft, Ltd., has constructed the SR–N1 (June 1959) and the 27-ton SR–N2 (December 1961). Vickers-Armstrongs (South Marston) has flown their experimental VA–1 (September 1960), the 12-ton VA–3 (April 1962) and the smaller 3-ton VA–2 is nearly ready to fly.

Before withdrawing from the field, Folland Aircraft constructed and tested the GERM or ground effect research machine (September 1960) and a series of light plenum vehicles.

William Denny & Bros. built and put their D–1 into operation in mid-1961. And Britten-Norman constructed and flew the CC–1 (May 1960) and the 3½-ton CC-2 (September 1961).

Britten-Norman and J. Samuel White & Sons have formed a joint company named Cushioncraft, Ltd., for the production of the CC–2 vehicles.

The prototype CC–2 was sold to the British Ministry of Aviation for use as a test vehicle, and the second and third machines are under construction. Preliminary design is progressing on a CC–3 vehicle of about 14 tons all up weight.

William Denny & Bros. have formed a subsidiary company called Denny Hovercraft, Ltd., and the new company is constructing the

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first of a series of 25-ton D–2 sidewall craft, called Hoverbuses, with a capacity of 70 passengers for use on inland and sheltered waters.

Saunders-Roe Division of Westland Aircraft is doing the detail designing of a new 36-ton GEM called the SR–N3, but the decision to commence construction has not yet been taken. Design studies of a still larger 150-ton craft, the SR–N4, have been conducted. Saunders-Roe believes vehicles in the 150–200 ton range are the most competitive size for commercial use.

Vickers-Armstrongs is conducting preliminary design studies of two craft nominally called the VA–4 and VA–5, weighing about 100 tons and 250 tons, respectively.

In Sweden, experimental and theoretical work was undertaken by the S.A.A.B. Aircraft Co. (Svenska Aeroplan A.B.) and the Armed Forces Research Establishment.

This work has culminated in an order for a four-place experimental machine called the SAAB 401 recently placed by the Swedish Navy in cooperation with the Swedish Air Force and the Armed Forces Research Establishment. Delivery of the SAAB 401 is expected in December 1962.

The aerodynamics group of the French Aeronautical Research Establishment (ONERA—National d'Etudes et de Recherches Aeronautique) has conducted theoretical studies and some experiments; however, full scale Government-sponsored construction has not been undertaken.

Nevertheless, the Bertin Co. has constructed a 3½-ton experimental plenum vehicle called the Terraplane. The French Army R. & D. Command is monitoring the Bertin project and will test the Terraplane later this year.

The French Army experiments will investigate performance as a missile and ordnance carrier over rough roads. Sud Aviation has reportedly ordered a second machine from Bertin.

Undoubtedly the efforts in the United Kingdom are the most advanced in the Western European countries. Vickers-Armstrongs 25-passenger VA–3 will be put on experimental service by British United Airways later this month (July 1962).

The service will span the mouth of the Dee estuary in Wales and will continue for trial period of about 2 months. Saunders-Roe hopes to put their SR–N2 into a similar trial ferry service later this year—probably from the Isle of Wight to a port on the south coast.

Cushioncraft, Ltd. have applied to the Ministry of Aviation for permission to carry passengers in their model CC–2 on joyrides in sheltered waters near Hayling Island.

Four British transportation companies have made statements on future GEM services.

(1) P. & A. Campbell, Ltd., have applied to the Air Transport Licensing Board to operate hovercraft in the Bristol Channel. This service is probably intended to cover the Weston-to-Cardiff route.

(2) Townsends Ferries & Shipping, Ltd. are intending to operate hovercraft on the cross-channel Dover-to-Calais route.

(3) Southdown Motor Services, an associate of British Electric Traction Co., has applied to the Air Transport Licensing Board for permission to operate regular services along the southern coast of England. The company believes these services are a practical alterna-

tive to their bus routes along the coast, particularly in the summer months when the roads are crowded.

(4) Starways, Ltd. have also applied for permission to operate hovercraft.

At this time, the United Kingdom's classification of the class of vehicles has not been completely settled. The current road traffic bill does contain a brief clause to amend the basic act to permit the Minister of Transport to exercise control over air cushion vehicles which are operated on public roads.

The terms of the clause are very general to permit the final decision on regulations and requirements to be made at a later date.

If there are any questions, I am at your disposal.

The CHAIRMAN. Commander, the British have then made a great effort, apparently, to develop this along commercial lines as well as, perhaps, for military application.

Commander DITCH. The entire development under NRDC has been run for a commercial vehicle—for a series of commercial vehicles I should say.

The CHAIRMAN. What other countries of Europe have tried to develop this commercially?

Commander DITCH. As far as I know, sir, no other commercial developments are in progress.

The CHAIRMAN. The people who are doing this, do they seem to be convinced and satisfied that they have a new vehicle of transportation, that can be made and developed successfully and made to pay off for the money they are putting in, from your knowledge of it?

Commander DITCH. I would say they went through quite an extensive market analysis exercise as they started out to determine this possible commercial market for such kinds of vehicles. In fact, it appears the market is developing along similar but slightly unexpected lines to that anticipated by companies. I think they are pleasantly surprised at the number of people wanting to operate the vehicles.

The CHAIRMAN. Any questions?

Mr. HECHLER. Having seen the British commercial development and interest there, would you say that the market would be comparable in this country?

Commander DITCH. Their development is not geared entirely for their own country. They are hoping for a world market for these vehicles. I think they envision they have a greater world market than we do.

Mr. HECHLER. They are hoping to take over the American market?

Commander DITCH. I think that was their initial intention. I believe now this is not so firm in their minds perhaps.

Mr. RANDALL. Mr. Chairman——

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. How do you brake a machine like this, how do you stop it?

When going 140 miles an hour, for example, how do you stop it? You have no ground contact.

Commander DITCH. The braking systems on most of the machines—I say "most" because each has a different control method—involves applying an opposite thrust, in effect reversing the thrust on the machine as a braking effort. Those operating over water entirely expect also to ditch, if you will, at some reasonable speed, actually drop the vehicle into the water for additional braking effort.

Mr. FULTON. Secondly, what is the cost on your development of your energy and your velocity, what is the cost factor there compared to an ordinary land vehicle?

Commander DITCH. Probably we should say this is still to be determined. All of these vehicles are built in different ways with different control systems, different type of construction.

It is almost impossible to make a vehicle-by-vehicle comparison. I would say though that the companies themselves have used and published figures on what they think these machines will cost to operate and it comes down to a figure of about 2 cents per passenger-mile.

Mr. FULTON. Would the future of this type of which be competitive with other forms of transportation?

Commander DITCH. Yes, this is a competitive figure. It will be a premium form of transport in that you will pay for the additional speed and quick service, but it will compare favorably with, say, aircraft or high speed shipping.

Mr. FULTON. In your opinion could these GEM vehicles be used on the internal river system of the United States or in swamp areas?

Commander DITCH. I think the river systems, yes. They have a very nice quality, these vehicles, in that they leave very little wake and don't tear down your waterway system as they move about. The economy is such that I would say it would probably compare with truck charges for similar routes.

Mr. FULTON. In the vehicle performance chart of the various other types of transportation vehicles we now have in operation, where would this fit, in your estimation, in the transportation program of the United States?

Commander DITCH. Well, I am not quite familiar—could you clarify the "chart"?

Mr. FULTON. We have passenger cars, trucks, low-flying planes, high-flying planes, buses, river boats, and individual river transportation.

Where does this fit into our present transportation system in the United States?

Commander DITCH. I think we have to say it will spread over quite a bit. I think in general you can say they are, on waterborne transport, somewhere between a helicopter and a slow boat for overwater application. In other applications, as a straight land vehicle over a good surface, I don't think they will be competitive.

Mr. FULTON. For example, could you use it instead of a bridge across the Chesapeake Bay, would it be better to have a fleet of these GEM's operating?

Commander DITCH. I am not familiar with the cost of bridge work, sir, I am afraid.

Mr. FULTON. It is high.

Commander DITCH. Undoubtedly it could replace a ferry service.

Mr. FULTON. We have resorts up and down the coast. We have thousands of miles of coastline and thousands of miles of riverways in this country. Would it be better to use this type of equipment to go between coastal areas rather than land transportation, or will this do both water and beach?

Where can we use the GEM system in the United States? I might say to you, I have been very interested in them, so much so that I ordered one of them in 1959, but the company never fulfilled the order.

Commander DITCH. Well, I think their primary use will be in those areas where you can actually shorten the route by the kind of terrain this vehicle covers. If you can go across the estuary mouth, for instance, or in areas of swamp, bog, and so forth, where you can take a straight route, there is probably their biggest application.

Mr. FULTON. Therefore you think GEM's are competitive as to cost with other transportation methods in the United States, and, secondly, you think there is a real place within our vehicle and transportation setup for this type of an approach.

Why then is the United States, both military and civilian, development so slow in this field when so many other countries have gone so far?

Some of my British friends laugh at me, saying they are learning while doing, while we are trying to do so much on drafting boards and ideas that we never get down to operations on this GEM development.

Will you answer that to me?

Commander DITCH. I wish I could, sir. I have been on the other side.

The CHAIRMAN. Will the gentleman yield?

I think we are flatfooted. It is one of the reasons I was anxious to hold these hearings. Perhaps we can take hold of it and might put some life in it in private industry or into the military.

Unfortunately it is not too glamorous a thing and I don't think the military has sufficient money to do the job. We have been doling it out in small bits, when you look at the program we had yesterday, where you had about $600,000 a year on it.

Apparently it has merit and should be gone into.

Mr. FULTON. Will you answer the question?

Commander DITCH. I am sorry, sir, but I have been stationed in London for 3 years, so I have not been familiar with the workings of the programs here.

Mr. FULTON. From a Navy eye view from London, what does it look like, why does it look as though the United States is just left at the dock on this particular development? Our British friends and European friends, Italy, Switzerland, Sweden, are moving ahead so fast.

Commander DITCH. I am afraid these are my own personal observations, sir—not speaking for the Navy. It would appear that a large part of the impetus has come from the commercial application that they have placed on this. This is a commercial venture as far as they are concerned, in Great Britain in particular, and they have therefore pursued it in a different line than we have.

As you heard yesterday, I believe our programs are largely military.

Mr. FULTON. Then the question comes—I am in the Navy Reserve myself, so this question is asked with all kindness—Why is it then that the U.S. Marine Corps has to purchase a British vehicle to see what to do on our landing type program?

Commander DITCH. That was a Swiss vehicle.

The CHAIRMAN. Yes.

Mr. FULTON. Why does the United States go abroad and purchase one of these vehicles, take it apart and take it down and see what makes it operate?

Commander DITCH. I am not familiar with the program the vehicle was subjected to, sir.

Mr. FULTON. Why is it that we have not in the United States progressed far enough militarily or commercially on our plans that we ourselves can have more than just research?

Commander DITCH. I think the military interest should be reserved for a closed session.

Mr. FULTON. I hate to put it that bluntly, but would more money help? Maybe the committee, as the chairman said, should take an interest and push this program for you on the basis of research.

It is really a new chapter, Mr. Chairman.

The CHAIRMAN. I can understand how Commander Ditch, stationed abroad, having nothing to do with Navy projects, and what they are, being a technical man, would hesitate to answer this question.

Mr. FULTON. I won't press it, but if money would help us get going and really set a program up that we can make progress on in the United States, I would be willing to look into it.

The CHAIRMAN. I am hopeful that whoever in the Department of Defense reads this record—and they have people who read them—will take cognizance of the question you asked.

Mr. FULTON. Yes, thank you.

The CHAIRMAN. And get someone on the proper level sometime to answer the question.

Mr. FULTON. I want to compliment the witness on his good appearance and on his broad knowledge and background.

The CHAIRMAN. I am sure if you had the privilege of knowing Commander Ditch like some of us who worked with him in London you would say that with a great deal more emphasis.

Mr. Daddario?

Mr. DADDARIO. No questions.

The CHAIRMAN. Mr. Van Pelt.

Mr. VAN PELT. No questions.

The CHAIRMAN. Mr. Waggonner?

Mr. WAGGONNER. I think the obvious answer to Mr. Fulton's question—which the commander didn't answer—and probably would have liked to have said a minute ago—is the fact that the British have given commercial application to this proposed development and have attached more significance to it than we have, and the Italians likewise, and most of the other countries have done the same, because their transportation is not as complex and well developed as ours, and they are further behind, and there is more to be gained by pursuing this course.

If their transportation systems were as fully developed and comprehensive as ours are, they wouldn't feel quite the need.

So there is some experimentation to be done there and something for them to gain by, maybe, pursuing something that is new.

As far as our buying one of the Swiss boats, if we are buying, and I guess we are, from the testimony we have, that is probably the cheapest and best way to get it.

The CHAIRMAN. That is true.

Mr. WAGGONNER. Cheapest and best. Maybe we used our noggin there for a change.

The CHAIRMAN. I would say, Mr. Waggonner, if I may make this observation, you are right, when it comes to talking about the transportation network, perhaps, of this country, but this country is always looking for business in other parts of the world, and there are new emerging nations who have no transportation networks today, who have waterways on which these could be used, and I think this is the thing that British industry has its eye on a great deal. Isn't it, Commander, as far as you know?

I don't expect you to be expert in this, but in your discussions isn't this one of the places they are looking to?

Commander DITCH. Certainly, Mr. Chairman, this is exactly what they are looking at. They have, they believe, a tremendous world market in the underdeveloped countries, who have not yet established a fully going transportation system. We would hesitate to accept it, however. If you started from nothing you might really prefer this kind of vehicle.

Mr. WAGGONNER. I guess one of the first things we are going to decide is how we are going to tax these people.

The CHAIRMAN. Maybe if we get them in business we will get some taxes.

Mr. FULTON. In all good humor I was going to suggest when the Army was here yesterday and called them air cushioned vehicles the British called them Hovercraft, that the Navy, peculiarly, calls them ground effect machines.

I think I would drop the "ground effect", if I were talking as a Navy man, hereafter.

Isn't that rather limiting to a Navy man?

Commander DITCH. It is indeed. They have been called air cushioned vehicles or air cushion craft. The term ground effects machines is probably my own fault. It is the most worldwide term and they recognize it when I talk overseas. The word "Hovercraft" itself is a copyright name belonging to NRDC-developed vehicles. The British say "hovercraft," uncapitalized, but it is a trade name.

The CHAIRMAN. Off the record.

(Discussion off the record.)

Mr. WAGGONNER. Commander, is there any possible future use of these craft—Hovercraft, ground effect machines, air cushion machines, whatever you want to call them, to replace tugs and still continue barge tows?

Commander DITCH. Not as replacement for a tug, sir. I don't believe this would be it. It is a replacement for a cargo type vessel.

The Denny machines we talked about are relatively low-speed machines, around 25 knots speed, and their only attribute is low power required to make the 25 knots with considerable load.

Mr. WAGGONER. At this point can you evaluate the nature of products which could best be transported through this type craft?

What type products?

Liquid, bulk products, package?

Commander DITCH. I would say package products would be the logical answer. They are relatively lightly constructed structurally and therefore don't take a very dense cargo.

Mr. WAGGONNER. We are not getting down to something that will change the pipeline picture then in any conceivable time in the future?

Commander DITCH. No, sir. Maybe I misled the committee on the economics. I said it is a premium-type transportation.

Mr. WAGGONNER. Something to compare with monorail system maybe.

Commander DITCH. Yes, or helicopter. You wouldn't use helicopters to carry oil. It is a premium-type transportation at the moment.

Mr. WAGGONNER. When you gave your 2-cents-per-mile passenger figure you meant per passenger?

Commander DITCH. Yes, unfortunately the British have found the insurance rate will run this up probably.

Mr. WAGGONNER. What type fuels have they found to be at this point most satisfactory?

Commander DITCH. For the vehicle?

Mr. WAGGONNER. Yes, sir.

Commander DITCH. The two largest machines SRN–2 and VA–3 are turbine powered using the conventional turbine fuels.

Mr. DADDARIO. What are the elements which have affected the rate of insurance—premium rate of insurance?

Commander DITCH. Unknowns, I think, is the way to answer that. This is a new form of transportation. Unfortunately it has to operate as of the moment, at least, in areas already occupied by other forms of transportation. That makes it quite a complex problem in deciding how these vehicles will be operated within shipping lanes and small craft areas, and even sailing areas. A high-velocity vehicle mixed with low-velocity devices.

Mr. DADDARIO. Are there any dangerous elements that have shown themselves?

Commander DITCH. No, the vehicles have been actually rather docile. It compares to a ship of the same size and weight, braking effort about the same, and braking distance very good. Just the actual fact of velocity. Really it is unknown. I think with a little practice we will find these are more attractive insurance risks.

Mr. DADDARIO. Everything said up to now would indicate it is a relatively safe means of transportation, just you have more flexibility and more speed, and if this is so, and it is safe, insurance companies would necessarily come down?

Commander DITCH. Well, we, for instance, would have a lot of trouble insuring an aircraft if we wanted to fly the aircraft through the valleys continuously as an air transport line, and this is analogous to what we are doing here.

If you have a barren area, no other forms of transportation in that field, you have a different problem. I think it is a safe vehicle in that element.

Mr. HECHLER. Would you expect these will replace all cross-channel sea operations?

Commander DITCH. No, sir. I think you will always have the need for a highly economical slow transport across the channel, for instance.

Mr. HECHLER. I was thinking of passenger transportation when I asked the question.

Commander DITCH. There again it will depend upon the man's pocketbook, which form he will take. If it is worth it to him to save the hours, he will pay the premium.

Mr. HECHLER. You don't anticipate these will be mass produced to run the price down so it will no longer be a premium form?

Commander DITCH. Mass produced only in the sense that you mass-produce vessels or anything of that size. A 200-ton coaster, you don't exactly mass-produce. You do in a sense, but not in large quantities rolling off every month.

The CHAIRMAN. Is that all?

Mr. WAGGONNER. One other question.

The CHAIRMAN. All right.

Mr. WAGGONNER. What has been the experience with the various small experimental craft, which might haul three or four or five or six people. Might this at some conceivable date in the future reduce the cost of highway construction repair, where these might be put down on the highways to hover over the highway and travel? Can they be maneuvered to the extent safety would not be a problem, there, or do they think this would ever, for instance, preclude the possibility of repairing highways by just having Hovercraft travel the highways?

Commander DITCH. I don't think there is any plan of that nature. There are some basic limitations. They would prefer a flat terrain. Even the crown of the road causes it to want to slide off. If you build a powerful enough control system into the craft to operate as a car its economics become disappointing.

Mr. WAGGONNER. Would you say the longitudinal jetstream of air by which they now in England are attempting to hold the water pocket and the air pocket there to lift the machine has proven successful rather than the stable sidefins?

Commander DITCH. Actually we still have the full complement of vehicles. Some of the machines are built—or principal machines, I should say—are built on the sidewall effect—I mean the airwall effect.

The Denny machines do have sidewall with airwalls fore and aft. The SRN–2 and VA–3 have complete airwalls. The little CC–2 has a complete airwall system.

On the other hand the machines that Folland built, little plenum machines I mentioned, are also in use and are very economical, they use them on building sites as wheelbarrows. Small machines with handles—as wheelbarrows. This is actually one of the reasons the road traffic bill brought up this thing, because contractors were operating them and somebody had to decide what to do with them.

The CHAIRMAN. Mr. Randall.

Mr. RANDALL. Somewhere in your testimony, Commander, it seemed like there was a departure, you had been talking about air cushion and then you said some light plenum vehicles. Actually this is an air cushion also; isn't it?

Commander DITCH. Yes.

Mr. RANDALL. Describe what you meant. I am advised by some of your associates it is an inverted bathtub.

Commander DITCH. That is roughly a good description. I am not familiar with whether the committee had an explanation of the machines.

The CHAIRMAN. Some, not too much.

Commander DITCH. Basically there are three fundamental types of these vehicles. The so-called levipad system that Ford developed in this country, which is a high pressure device—nothing but a flat pad with air bleed operating at very low clearances.

Then we come to the lower pressure machines, which are the plenum and air curtain machine, if you prefer to use that term.

They are identical in that the problem is to retain the air bubble beneath the machine. In one case you invert the bathtub, if you will, and let the air leak out around the low clearance at the edge. It is analogous to having a flat tire and pumping in air as fast as it leaks out.

The so-called plenum vehicles are nothing but a very low clearance leak around the edge of the vehicle.

That has been modified in recent years by making the lower part of the bathtub a flexible skirt so it can be pushed aside as it goes over obstructions and the actual clearance remains quite low, in the order of an inch or two from the ground.

The other way to retain the air is to use an air curtain. It captures the air beneath the machine and prevents it from escaping.

Mr. RANDALL. Captures air?

Commander DITCH. I want to use the blackboard. I have trouble doing this without my hands. The air is inclined inward toward the machine and as the pressure builds up beneath the machine the jet of air is bent back out until the air is escaping as fast as it is being forced under the machine. This provides a moving air wall that holds the air bubble beneath the machine.

We have also water versions of that same thing, where we use a water wall to capture the air bubble.

Mr. RANDALL. Commander, quite a little bit has been said about the uses, and so forth.

What are we talking about in terms of cost here?

Commander DITCH. Unfortunately we are not privy to the costs involved in the building of these machines. I can give the rough cost of purchasing a SRN–2, their largest machine. They have quoted prices in the press of about £650,000.

Mr. RANDALL. British pounds?

Commander DITCH. Yes. Pounds sterling.

Mr. RANDALL. Not cheap.

Commander DITCH. No. That is for a 68-passenger vehicle.

Mr. RANDALL. Thank you, sir.

Thank you, Mr. Chairman.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. These machines, they can be very small or they can be very large.

About 3 years ago I had ridden an Army-type scooter that was a ground effect machine and was able to handle it in a small space.

Couldn't we have scooters that would be very easy to operate in our civilian life—or military scooters—that could be used so that they are not only cheap but give you quick and easy transportation?

Commander DITCH. A whole range, I think, of vehicles can be covered with this type of machine.

Mr. FULTON. Having served on a U.S. carrier in World War II I remember the difficulty we had. Wouldn't it be possible to use this type of an air cushion vehicle for transportation between two Navy vessels?

Has that been gone into?

Commander DITCH. Yes. Maybe I should say one thing first here. The smaller the vehicle the less economy is realized in terms of pounds carried per pound of gasoline or fuel.

But as you well know, we do afford this kind of thing when we want small craft carrying a limited number of people. Yes, you can have small vehicles. But in a seaway there is probably a limiting effect by the sea itself, on how small you want to get with this.

Excuse me, sir, I have a card laid on my desk here from the West Aircraft, Ltd., representative and he says the cost of the SRN–2 is £317,000 now.

Mr. FULTON. When you have a plenum type of configuration, and when the vehicle gets more efficient, the larger it is, why shouldn't large Navy vessels, and likewise large passenger steamships, each one have a plenum type configuration, so that in the future all our big ships will be riding on an air egg under them? Wouldn't that be more efficient, and has it ever been tried?

Commander DITCH. This is what we are all striving toward, I think, those that are interested in the field, are the larger and larger vehicles.

Mr. FULTON. Has anybody looked to see about having your passenger ships sitting on an air egg, go across the ocean with this captured air to sit on, and having a concave instead of a convex hull?

Commander DITCH. These are all problems of design when you are talking of shapes of hulls. Unfortunately, you would like to make this passenger vehicle, or freighter, whatever you like to call it, as economical as possible. The higher you require it to ride over the waves the more power it costs you to form the air curtain, or to provide the clearance between the edge of the craft and the water.

Mr. FULTON. You are missing my point.

I am saying, suppose you had just captured air in a plenum configuration, which you just then retained, and the ship sits down in the water and does not have a very high free board.

Commander DITCH. The drag, if you actually allow it to touch, gets very high quickly, sir.

Mr. FULTON. The drag of the air on the water surface.

Commander DITCH. The skirts themselves in the water, you should not let it actually touch.

Mr. FULTON. Nothing further.

The CHAIRMAN. Mr. Yeager has a couple of questions.

Mr. YEAGER. Commander, as you know, there are a number of American companies which are developing these craft, some for military purposes and some, they hope, may have some commercial purpose sometime.

Can you tell us whether, from your observation, or as an engineer, whether the British in concept, design, and theory, are advanced over what we have, or whether the gain is primarily one of actual practice?

Commander DITCH. I would answer that by saying that the gain is probably actual practice. They have concentrated on developing vehicles as such, a particular vehicle. They have gained a lot of research and technical knowledge in overcoming the problems of a particular design, which are, in some cases, applicable to other designs, but their effort was toward a definite end object each time.

Mr. YEAGER. There is no basic theory or knowledge which has been developed which they have which we don't have; is that true?

Commander DITCH. Not to my knowledge. This is difficult to say because these companies each treat their data as proprietary and we have not had access to it. The applications I have seen appear to be within our capability too.

Mr. YEAGER. In regard to the problem which arises in speed and control, stability, efficiency, from your observation of the British craft, are these particularly good, is this superior to model types that we have?

Can you give us any comment on the performance of the British type?

Commander DITCH. This is a very hard question to answer. We are talking about too many different types of machines. In fact, in the British applications there are no two craft which have the same kind of control or propulsion system.

They too are still looking for the best way, I think. Actually, the amount of control you get is the function of how much control power you provide in the vehicle.

It is provided in various ways. The SRN–2 has control propellers that swivel on pylons, one forward and one aft, from which they get a thrust by changing the pitch of the propeller. The VA–3 has two fixed air propellers aft, for propulsion and some control, because by changing the power in each engine we get rudder or yaw control, but they develop the side forces necessary a different way; by tilting the vehicle to get some side thrust from the cushion itself.

They also have a system of controllable vanes in the air curtain which gives them side forces. I don't want the committee to get the feeling that this is the end, we are at the end of development in these vehicles. We are just starting. Everybody is still looking for the best way. This is why we can't compare one vehicle directly against another or one development against another. There are still too many models and kinds. We haven't finally honed this process to a science yet.

Mr. YEAGER. Can you say anything about the performance of the SRN–2 in rough sea?

Commander DITCH. I have ridden the SRN–2 in seas to about 2, 2½ feet, 14 feet between peaks. That is a rather sharp chop.

It normally would give a small craft a problem. It was like riding a train. It is not uncomfortable to sit and ride. If you get up and move around you have a tendency to grab for things. It is not like riding a ship. It is more like riding a train. There is probably no serious problem of seasickness with the machines.

Mr. YEAGER. How about control at high speed?

Commander DITCH. It is very good. As I mentioned, that for a particular machine, compared to a ship of the same size and weight, and braking effort about the same too.

Mr. YEAGER. Thank you.

Mr. FULTON. Does the patent situation, for example, in any foreign country, hold us back on our development here commercially or militarily?

Commander DITCH. I don't see that it holds us back.

There has been no indication, that I know of, they would not be willing to license us, or companies of ours, to use these items they have developed.

Mr. FULTON. You would have this type of a vehicle operating maybe 1 foot to 6 feet above the surface of the sea. Who should run that vehicle, the Army, because it starts on shore and goes down to the beach——

The CHAIRMAN. Let's not get into that.

Mr. FULTON. Navy or Air Force.

The CHAIRMAN. Let's not get into that.

Mr. FULTON. Should the Navy operate these vehicles?

The CHAIRMAN. We won't get into that; I think you have ended it.

Mr. FULTON. Just note laughter on the record.

The CHAIRMAN. I want to thank you, Commander, for coming here.

I think this has veen very helpful.

Haven't you a question?

Mr. DAVIS. No, Mr. Chairman.

The CHAIRMAN. I think it has been very helpful. It has been more than helpful. I hope that we can stimulate a little more interest. Maybe we can take it upon ourselves to consider this more fully, to press for more action on the part of the Government, perhaps encourage industry.

Very happy to see you again, sir.

With that, the committee is adjourned until tomorrow morning.

(Whereupon, at 11:45 a. m., the hearing was recessed, to reconvene at 10 a.m., Friday, July 13, 1962.)

RESEARCH ON NEW TRANSPORTATION METHODS (GROUND EFFECT MACHINES)

FRIDAY, JULY 13, 1962

House of Representatives,
Committee on Science and Astronautics,
Washington, D.C.

The committee met at 10:30 a.m., Hon. George P. Miller, chairman, presiding.

The Chairman. The committee will come to order.

Mr. Potter, we are very happy to welcome you here from the Maritime Administration.

I know of some of the interest which the Maritime Administration has in this matter because of my activities on another committee for many years, and I happen to have played a part in some of those interests which were stimulated in it.

Will you either summarize your statement or you may just go ahead and read it as you desire, and then we will ask you some questions.

STATEMENT OF W. T. POTTER, ACTING CHIEF, DIVISION OF PLANNING AND DEVELOPMENT, OF THE MARITIME ADMINISTRATION'S OFFICE OF RESEARCH AND DEVELOPMENT

Mr. Potter. All right, sir.

Mr. Chairman and members of the committee, I will substantially read my statement, and perhaps you can stop me any time I get onto something that you feel you would like explained.

The Maritime Administration became actively interested in ground effect craft in the spring of 1961.

At that time, it was decided to pursue the design of a commercial version of the craft which had been the subject of an Office of Naval Research solicitation in January 1961.

This was mentioned the other day in this room. If you will recall, the Office of Naval Research had a solicitation for a 35-ton amphibious vehicle. We were to pick up the results of this solicitation, and, of course, design it on the basis of a commercial craft rather than an amphibious craft.

Permission was granted by the Maritime Administrator on August 2, 1961, to negotiate a contract with the Vehicle Research Corp. of Pasadena, Calif., who had won the ONR solicitation.

I may say here that this method of choosing a contractor has been a very happy one for us. The Vehicle Research Corp. is headed by Dr. Scott Rethorst, who is here today.

He is a doctor of physics, I believe, and is very eminent in the field of aeronautics. In fact, I understand he is the man who did the basic design of the B-58, and we are very, very pleased to have his ingenuity as part of this program, which has already paid off.

The contract which was finally concluded envisaged a four-part program lasting 1 year, with three of the four parts funded.

The fourth part, the final design, was to be pursued if the testing program proved the design to have sufficient merit.

Part 1 of the contract was short, 1 month, and required that the Administration be provided with expert advice in deciding on a size, speed, and range.

Vehicle Research, with its extensive background in GEM research, (which, incidentally, has been going on for 3 years, primarily under ONR contracts), set forth in this period the controlling conditions for the design, including the exterior configuration [indicating figure on easel] of which this is a picture, here.

Having provided the expert advice, and Maritime having decided upon a 100-ton design, the work moved into Part 2—Preliminary Design, and Part 3—Developmental Testing, where it is at the present time.

These parts are to be completed at the end of August 1962 and steps are being taken to provide money for further work.

The Maritime GEM, in response to its primary mission of working in conjunction with the American merchant marine, has been designed around a cargo compartment large enough to carry four 8 by 8 by 20 foot containers.

You probably remember, Mr. Chairman, that the Maritime Administration has recently, in connection with its container standardization program, said that all American ships which are built under subsidy should be designed, if they are to carry containers, for 8 by 8 foot sections, in increments of 10, 20, 30, and 40 feet.

The most popular container turned out to be the 20-foot container. That size happened to fit perfectly into the craft which we have here, because, as you will see, the upper surface of the craft is being designed as a curved surface. In order to get sufficient headroom on the cargo deck to carry this 20-foot container, you are happily given a nice sized cargo space into which four containers will fit.

We originally had two containers in there, but the wind tunnel tests have changed the configuration a little bit so that we can carry four, making it possible to carry partially loaded containers.

Alternatively, the cargo compartment can be altered to carry 150 passengers, their baggage, and break-bulk premium cargo.

This entails the installation of a false deck underneath the passenger compartment, which of course precludes the carrying of containers.

Operating speeds for best performance is 100 to 120 knots, with a maximum of 150 knots. Due to the relative simplicity of commercial operation, the craft is designed for continuous cruise using supplemental aerodynamic lift from "channel flow," a concept believed to be unique in GEM design. And I will get to that in a minute.

Preliminary wind tunnel results indicate that the stability questions inherent in low aspect-ratio wings flying in ground effect have been solved without sacrificing the ability to hover or climb beaches.

The point of that is, there have been several designs proposed in the past which were for high speed craft, and they had some pretty severe problems—one of which was the high speed landing and taking off problem.

However, this craft combines the features of hovering ability and high speed translation.

The design which is being developed is for a 100-ton craft carrying 40 tons of payload plus 10 tons of fuel.

It will operate at a nominal height of 7 feet; 4 feet to the bottom of the flexible jet extensions, 7 feet to the hard structure (which should enable it to negotiate at least 10-foot waves) .

The measurements are taken to the bottom of the hard structure, and, while it does not show in this particular picture, this is actually a semicatamaran shape with two large skegs on either side which are there for both hydrodynamic and aerodynamic reasons. The 4 feet just mentioned is there to the lowest part of the jet extension. To the actual underside of the hull, will be 7 feet clearance.

This should enable it to negotiate at least 10-foot waves.

Now, I am trying to be conservative there. I understand our British colleagues give a rule of thumb that a craft will negotiate waves which are twice the height of the nominal operating height, so if you operate with a 7-foot clearance, you should be able to negotiate a 14-foot wave.

However, having had some experience in waves, I don't believe in 14-foot waves as being a regular thing.

Our modern theory of wave propagation says these waves are an infinite collection of different sized waves.

Occasionally you will get all the crests coinciding, and this makes a sudden, monstrous wave, and, unlike a ship, this is the wave which is going to give the most trouble. We cannot afford to go around skipping over the top of 10-foot waves, and then have a 14-foot wave confront us, so we must be on the safe side.

Power will be supplied to two mixed-flow fans and two thrusting propellers by six engines having a total of 10,000 horsepower.

At cruise, using the flexible extensions, the craft will use about 4,000 horsepower.

This is at an operating height of 4 feet to the hard structure, and might appear a little confusing. Under ordinary conditions, by maintaining our original 4-foot height, which is the normal operating height, we can now subtract the flexible 3-foot extensions which puts the jets down 1 foot off the deck, so this gives us the 4,000 horsepower at cruise. At the maximum height, which will be the full 7 feet, it still takes 10,000 horsepower, which is the power you put into hover.

It is very much like the hydrofoil. This craft has the happy quality that, if you put in enough power to hover (just as you put enough power in the hydrofoil to get it up on the foils), you automatically put in the capability to reach a high speed. The hover power will eventually equalize out at a higher speed, which in this case, is 120 knots.

I say 10,000 horsepower there, but if we go into construction, we would end up with 14,000 horsepower, because there is no engine exactly hitting 10,000 h.p., and we want the increased reliability of the higher power in a research craft.

The principal point of difference between the Maritime GEM and other designs, lies in the use of the Vehicle Research "Channel flow" concept.

By deriving supplemental lift from the flow of air around the hull, the craft is permitted to proceed at speeds greater than those of air cushion craft, as opposed to the true ground effect craft.

Now, just to confuse the issue a little more, I'm afraid I can't use the words, "ground effect" and "air cushion" vehicles interchangeably.

We use this in the sense that true ground effect is found in an airfoil flying close to a surface. In doing so it has greater lift than it does when it's flying away from the surface. That augmentation to lift is the ground effect.

A craft down close to a surface and supported by an air cushion underneath it, is operating on a slightly different principle.

So this craft is called a ground effect ship. Actually, Marad calls it a surface effect ship, but GEM is becoming a very handy word. We use "ground effect" basically, and this, as I say here, differentiates it from the slower craft.

Mr. FULTON. Mr. Chairman may I ask a question?

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. What about an airflow on the configuration of this type, on such a vehicle as you have here, what would you call that?

Mr. POTTER. That is ground effect. It is actually flying very close to the surface and depending upon this augmentation of lift, this ground effect, to keep it up.

I should explain that a little more. When starting off in this craft, it operates as an air cushion vehicle. A peripheral jet provides the air cushion until 80 knots, at which time you get lift. Then, turning off the jets forward and aft, the craft goes on into "channel flow" which provides full lift, and then the ship is a true ground effect vehicle.

The GEM's which have thus far been built are supported only by the air cushion beneath them, limiting their speed to about 80 knots.

A low aspect-ratio wing in ground effect, on the other hand, has no immediate limit to speed, but does exhibit instabilities which have been, until recently prohibitive.

It is the belief of Vehicle Research Corp. that they have solved the stability and the lift problems.

This immediately makes it possible to improve efficiency by an order of magnitude.

We do not pretend that this company is the first one who has had the idea of getting aerodynamic lift, but the normal airfoil shape has a very peaked pressure distribution, across the top and bottom surfaces.

This makes for very great problems in stability. What Dr. Rethorst has done, has been to develop the configuration of the underside. What it really is, is an enormous inlet, and this gives a uniform pressure distribution all over the botton. The top side is ogival in shape, as opposed to airfoil shape, which gives a uniform pressure distribution over the top. Now we have equal support all over the bottom of the craft just like a ship.

Mr. FULTON. How do you get it at the sides? How do you get your lift at the sides? Would you explain that?

Mr. POTTER. All the lift is developed in between these two pontoons. This inlet shape with two pontoons that come down on the side is to channel the air down through the middle and this is where the lift occurs.

Mr. FULTON. I see. Thank you. And not at the top, at the bottom of the airfoil.

Mr. POTTER. Two-thirds of the lift is developed underneath the craft and one-third is developed on the top. I believe this is the reverse of a normal airflow. And you gentlemen are familiar with the ratio of lift to drag as a quantitative expression of performance.

Normal transport aircraft, having a lift-to-drag ratio of about 14, will be surpassed in an economic comparison by a craft which can achieve higher values, other factors remaining the same.

Air cushion craft have lift-to-drag ratios ranging from 2 to 8. Jet transports have values as high as 18.

Wind tunnel tests of the maritime GEM have reached lift-to-drag ratios of 24. These values, after further work, should be capable of improvement.

[Indicating with small chart.] Mr. POTTER. I have another chart, but I think it is too small for the chairman and members of the committee to see. If I can just hold it up here a minute. This illustrates what we are talking about in this case.

These are the pressure bubble vehicles or the air cushion vehicle here. As their growth increases, they will increase in efficiency along this line.

The CHAIRMAN. Would you turn around and show it to Mr. Casey, please, Mr. Potter?

Mr. POTTER. But the craft which has aerodynamic lift will be able to go along this line [showing]; below this point here, it is too small to carry any useful cargo, in our sense. You can't get the containers in. This is what fixed the 100 tons for us, but what Dr. Rethorst is basing his design on, is a jump in efficiency of this magnitude here.

He is going up from values, lift-to-drag, of about 10 (at 100 tons) up to about 26, at the same size. For comparison we have put the SRN–2 at this point on the bubble curve.

Mr. FULTON. Mr. Chairman, may I ask a question?

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. What does that do on the fuel ratio, Mr. Potter?

Mr. POTTER. It makes it lovely, sir. It extends the range a great deal. You can, of course, make this trade-off any way you want.

You can go farther with the same fuel or carry a lot less fuel, or you can change the cargo-to-fuel ratio.

Mr. FULTON. And what about——

Mr. POTTER. Excuse me, sir, and it changes the range from 400 miles to approximately 1,100 miles for the same amount of fuel.

Mr. FULTON. And aerodynamically, at each of those points, what is the comparison between the use of fuel to the aerodynamic lift?

Mr. POTTER. It is in the direct ratio of lift-to-drag: if you triple the lift-to-drag ratio, you get that much change in the fuel consumption.

The CHAIRMAN. Mr. Bell.

Mr. BELL. What kind of fuel do you use?

Mr. POTTER. These are gas turbines, and I believe gas turbines operate on JP–4, and then there is a less refined fuel which they will use. It's the same fuel that the commercial airliners use.

Mr. FULTON. Could you use any old Snark engines on this, Mr. Potter?

Mr. POTTER. Which ones are those, sir? I don't believe I know them.

Mr. FULTON. You know these missiles, the 9.4's moving on the speed of sound. I think the bottom of the Atlantic Ocean is pretty well covered with these things, and there is high production on them, and the program is in between, you see, and it was one of those things that turned out as a step in advancement. I thought maybe you might take some of those old configured missiles and use them.

The CHAIRMAN. Lash them alongside, perhaps.

Mr. FULTON. And perhaps you could use those. Actually, it's an inland single engine plane.

Mr. POTTER. Oh, yes; I think I know that one. Yes, I think we ought to investigate that, sir. We are a little fast for jet propulsion—I beg your pardon, a little slow for jet propulsion.

Anyone who is giving away free engines, sir, I am sure will be welcomed with open arms.

The work completed thus far, which includes the first wind tunnel tests, and a computer program, has verified the theory for this type of craft.

The results, in fact, appear so promising that hopes of a breakthrough have been excited.

Plans are being made to extend the testing program to include a 20-foot, man-carrying model to check control, stability, and Reynold's number determinations.

One of the problems of testing this craft in a wind tunnel is that, when it is a short distance off the ground board of the wind tunnel, the air passing underneath is disturbed. Effectively, if you view the wind velocity as zero, these two surfaces, model and ground board, move together. To get a really true representation of what is happening, we have to try to test the thing so the ground board is moving relative to the craft, or vice versa, which will change the airflow underneath. That is why we have to have a man-carrying model: to make the air go underneath it in the proper way.

Another, simpler model, using the same frame and engines, will, hopefully, be built for testing over waves.

It will be necessary to test the first model over dry lakebeds to get the required speeds over a "moving ground board," as opposed to the stationary ground board of a wind tunnel.

If these tests are also successfully, the way will be clear, technically, to build a full-sized, stripped-down, test vehicle which can later be converted for commercial operation.

Unlike the military vehicles which must satisfy a variety of requirements, the commercial GEM enjoys a relatively simple mission. It must carry cargo as far as possible, as fast as possible, as cheaply as possible.

While commercial GEM's may, in the future, be adapted to many missions, the maritime GEM is intended to be part of the new marine transportation system.

In such a system, an automated ship, carrying 20-ton containers at high speed, would be linked by river networks to inland ports through a local distribution system of GEM's and hydrofoils.

I know this committee is interested in hydrofoils. Let me say one thing here, we do not hold the view that GEM's and hydrofoils are competitive with one another; they are complementary to one another for two reasons:

First of all, the speed regime is entirely different. We talk about GEM's cruising at 150 knots, but they are effective between 80 and 150 knots.

The hydrofoils are best from 45 to 75 knots. They can extend this for military purposes, using supercavitating foils, but I don't think for commercial purposes this will be economically feasible.

Secondly, there is a difference in the growth potential of the craft. The hydrofoil is faced with the same thing the aircraft people used to be faced with.

The weight is going up as the cube of the difference in length, while the lift is going up as the square. Eventually, the hydrofoils get so big that their foils would not be able to carry them.

The aircraft people have licked this problem, and quite likely the hydrofoil people will also. But at the moment, indications are that with the GEM, the bigger you make it, the greater is its efficiency. The hydrofoil, which is limited, does not have this potential.

We anticipate that a container ship, coming down off the coast of a country which does not have highly developed transportation system, can transfer containers into GEM's which can take them inland, or up and down the coast. From the secondary points then, hydrofoils will be the logical craft for light passenger and cargo carrying in the immediate vicinity.

The CHAIRMAN. Could this be used then, say, in southeast Asia?

Mr. POTTER. Yes, sir.

The CHAIRMAN. When they begin to develop it will replace the old system where they have ships now discharging cargo, say, at Singapore and then junks would come in from all over India to carry their limited parts, and take it away.

Mr. POTTER. That is correct, sir. It's about a three-part job to get anything up some of these rivers today.

You have to send the ship all the way down the coast to some town, unload the cargo and put it in a warehouse. Take it out of the warehouse and put it in a coaster, and then take it back up the coast, and put it in another warehouse. Finally, take it out of that warehouse, and put it on some small *African Queen*-class launch which takes 7 days to the destination, where the cargo arrives rained on, mildewed, with half the cargo spread among the inhabitants of both banks.

Using the new system, the automated container ship has only to heave to at the mouth of the river and lower the containers into a waiting GEM. These, carrying for example, frozen foods, can be as much as 300 miles inland in a matter of hours, and the cargo is quite safe.

Mr. FULTON. Mr. Chairman.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. Mr. Potter, could the local inhabitants on the local estuary use these, too?

The CHAIRMAN. We'll be happy to try, if you are going to make that many transfers, because I understand out in some of these countries, each time you take the goods out and put them in a warehouse, there is a certain amount of chicanery.

Mr. POTTER. That's right.

Mr. FULTON. The chairman is from the Oakland estuary.

Mr. POTTER. There is a problem with the containers, too. You know the American steamship companies are using containers, and these things are rather expensive. They lost one one time, and they sent a man down from the local office to try and trace it down, and they finally found it with a family living in it.

The CHAIRMAN. For the record, it might be well to show, as long as the Oakland estuary has been introduced, that one of the first companies to use containers is the Matson Navigation at their port at the terminals in Alameda; and, why not, they also want to put up a big derrick and handle them in Los Angeles.

Mr. POTTER. They are very progressive in that. And their research people have written some papers that are a guide to the whole industry, on how to carry containers.

The CHAIRMAN. It presented a lot of problems even when we got into the terminal usage of these containers because I don't know whether you have ever seen them or not, but they look like great big vans, and they are taken off and then put on semitrailers, and the trailer motor comes under them and it takes them out and delivers them wherever they are going.

But you have regulations as to the terminal areas in which this can be done without violating some trucking lines' franchise.

This presented a lot of problems that had to be worked out here.

Mr. POTTER. Yes, sir, that is a very intricate question.

Maybe we can help you out on that when you get around to it, too, because we are deeply interested in containerization.

The Maritime Administration, as promoter of the marine industry, and as part of the Department of Commerce, has an excellent motive in aiding the development of GEM's: Stimulation of marine transportation; which is to say, stimulation of oversea trading.

It is Maritime's earnest hope that, by providing a means of economical transportation in countries deficient, at present, in highway and rail networks, the growing trade with new nations will, in appreciable measure, be assisted.

The vehicle is thus viewed as an exportable item which, in turn, will stimulate exports and promote economic growth.

The GEM is not considered to be a panacea for all the ills that transportation is heir to, but it is a new tool of considerable promise.

Once developed, and their potentialities shown, it will be up to American entrepreneurs to find the profitable uses for these vehicles.

In this connection, it should be mentioned that, on their own merits, and not as feeder craft to the merchant marine, GEM's have other uses.

Firstly, it is believed that safe transportation at 120 miles per hour will prove popular for short haul intercity passenger traffic.

Between cities linked by water, downtown to downtown service by GEM's could be faster than by air.

The tendency for airports to become more remote will be a growing factor in this, as well as the fact that many medium-sized towns must use the airports of distant cities.

Secondly, interisland or coastal traffic, both passenger and freight, can be carried at less cost than in aircraft, and much more quickly than in small vessels.

In summary, the Maritime Administration's program in ground effect craft consists of a single contract with Vehicle Research Corp. to design, develop, and if warranted, to build, a 100-ton commercial craft.

The preliminary design and developmental testing has been funded for $370,000.

Planned extensions to the testing program will cost $300,000. Construction of a 100-ton craft will, it is estimated, cost $5 to $6 million.

I have a note here, and I would like to mention one other thing. That is, we are in very close contact with the Coast Guard, so that the development of these craft will be done along lines acceptable to the Coast Guard. We hope to pave the way and get the regulations set up for any commercial company following later who wants to build them.

The CHAIRMAN. You may be interested in, and perhaps you already know, that the British already have in the House of Parliament passed certain laws governing the use of hover vehicles.

Mr. POTTER. Yes, sir.

The CHAIRMAN. Commander Ditch as sitting right behind you there. He brought over a copy of that bill from England, and he gave it to me, but, unfortunately I didn't bring it down today, it's up in my office.

Mr. POTTER. We had a conference the other day between Mr. Miller of Westland Aircraft, the Coast Guard, the Federal Aviation Agency, and ourselves to talk about these problems.

We would like to keep the thing well coordinated. Already there are little differences showing up. The British feel that it is an aircraft; we feel very strongly that it is a marine craft.

The GEM is operating in a marine environment. If it gets into trouble, it will be trouble with marine objects and not trouble with aircraft, so we feel the Coast Guard has the primary cognizance over it.

The CHAIRMAN. As I remember Commander Ditch—Commander, didn't the British in the bill itself, or in the hearing, say that it was an expedient, but that they called it a motor vehicle, or applied the same motor vehicle?

Will you speak up, please, Commander, so we may get it for the record?

Commander DITCH. Yes, sir. The bill that I brought to you, sir, was their annual review of their road traffic bill.

The problem facing them was the operating of small land vehicles, even though they admitted they were not intended to operate on roads, they actually traversed roads in going from one place to another, or in building roads and bridges and so forth, and they felt that these must be controlled.

The CHAIRMAN. In the equivalent of what would be the report of the hearing on the bill which is attached, they say this is purely an expedient; that this is not final, but it has to start someplace, so we are starting it right here so we can exercise some control in effect.

Commander DITCH. Yes, sir.

The CHAIRMAN. So the British Parliament has gone that far. I just didn't know whether you knew that, Mr. Potter.

Mr. POTTER. I understand there have been some regulations made up for the Government on hovercraft in the marine atmosphere also, sir.

The CHAIRMAN. Then Marad has given very serious thought to the use which can be made of GEM's in commerce?

Mr. POTTER. Yes, sir.

The CHAIRMAN. This is part of the economic study which you have made, some economic studies?

Mr. POTTER. We have done some very, very rough economic studies, sir.

The ones which I have seen up to now, Dr. Rethorst keeps making obsolete. I have, therefore, delayed until he decides just what the lift-to-drag ratio will be. I expect to start a study similar to the hydrofoil study, as to the economics of this.

The CHAIRMAN. Now, this committee, as you know, is charged with research and development in any branch of the Government.

It is not limited to NASA, and it is not limited to the Defense Department.

I do not know whether you know of all the rules creating it, so we have called on you from time to time.

It is very much concerned with the research and development of this, and we want you to know that we want to do anything that we can to stimulate interest in advancing his new form of transportation, because I feel that unless we do it, some other country may beat us to this.

As I see it, this offers a new field of activity here which could be compared with the automobile industry, where we pioneered the truck and sold many trucks all over the world, or the start we got one time in the airplane industry, where most of the airplanes throughout the world are still coming from the United States.

I think in the future, the same kind of a market can be developed for ground effect machines and this committee is very much interested in seeing that the spinoff or fallout from the $10 billion a year that the Government spends in research and development testing in engineering can be injected into the economy of the country to get a payoff from this thing.

I want you to know we are interested, very much interested, in this, and I was going to suggest for the record there has been some confusion in the use of terms, that if you have a glossary or definitions we would like to have it, and perhaps it might be a good place here to put this into the record.

We have had to do this in the past with NASA which came before us, with their new scientific terms which many of us have never heard of, and we have asked for glossaries and we got them.

Do you think Commerce could put together a sufficient glossary?

Mr. POTTER. Yes, sir, but it will have barnacles all over it, because we keep using ship terms and confusing our aviation colleagues, but it might be a good time to standardize on a glossary that we all can use.

The CHAIRMAN. We invite you to submit a glossary, Mr. Potter, and we would like you to be the first to submit such a glossary. Maybe we can help bring about this standardization.

Mr. POTTER. May I suggest, sir, that we have a GEM coordinating committee and we are in close contact with one another.

Maybe this would be a good job for that committee to do, and we can all work on it and get it out together.

The CHAIRMAN. Could the committee do it? Who is chairman of that committee?

Mr. POTTER. Captain Stilwell, sir.

The CHAIRMAN. Captain Stilwell. Suppose, Mr. Yeager, you contact Captain Stilwell and see whether this would be the place to do it?

The committee can furnish us with a glossary of terms.

(The information requested is as follows:)

THE GROUND EFFECT FIELD GLOSSARY

Ground effect

The change in lift of a body operating in the proximity of a surface.

Pressure lift

Ground effect whose presence is not dependent on motion of the body.

Ram effect

Ground effect which is obtained by conversion of velocity head into static head as a result of motion of the body.

Ground effect machine (GEM)

The generic name for machines, vehicles, and craft utilizing the phenomenon of ground effect.

Cushion

The pressurized air contained between the GEM and the supporting surface.

Air cushion vehicle

A GEM operating on a relatively thick cushion, excluding, in particular, one which utilizes the air bearing principle.

Hullborne

The condition of a GEM when operating as a displacement craft in water.

Cushionborne

The condition of a GEM when operating on a cushion.

Hovering

Cushionborne with no velocity in any direction.

Cushionborne height

The height of the lowest rigid part of the vehicle from a solid surface over which it is operating cushionborne.

Diffuser cushion
Channel flow cushion

A type of a GEM which is augmented in lift by a combination of both pressure lift and aerodynamic lift.

Curtain

The fluid (air or water) or solid wall which contains the air cushion or reduces the rate of cushion leakage.

Water wall

A water curtain.

Air wall
Jet flap

An air curtain.

Flexible bottom

A cushion using flexible solid curtains.

Plenum cushion

A type of air cushion which is maintained by the throttling of air under the sides of the vehicle, and which uses no curtains.

Nozzle

The long narrow exit from which the fluid flows to form the fluid curtain.

Skirt

A solid curtain, normally flexible, mounted on the outboard side of the nozzle.

Flaps

A solid curtain, flexible or rigid, used only normal to the direction of motion and mounted on the outboard side of the nozzle. Sometimes used interchangeably with "Skirt."

Skegs

A solid curtain, normally rigid, used only parallel to the direction of motion to prevent leakage or crossflow of air. The skegs may, in the case of overwater operation, pierce the water.

Sidewall

A skeg used only at the sides of the vehicle.

Trunks

A flexible extension of the nozzle.

Recirculation seal
Vortex seal

A type of air curtain in which a major part of the air used in the curtain is recirculated.

Labyrinth seal

A means of sealing the cushion by means of multiple air curtains or standing vortices.

Cushion area

The area of the bottom of the ACV contained within the outboard side of the nozzle opening or the solid curtain.

Effective diameter

The diameter of a circle whose area is the same as the cushion area.

Base pressure
Plan form loading
Platform loading

The weight of the vehicle divided by the cushion area; i.e., the average cushion pressure plus any lift (per unit area) developed by the curtain (or other) jets.

Cushion lift

The lift developed by a GEM due to ground effect; i.e., the base pressure times the cushion area.

Ducting

The passages through which the fluid is transmitted to supply the fluid curtain.

Control ports

Vents in the sides and ends of the vehicle from which fluid from the ducting is bled for the purpose of reactively controlling the vehicle.

Integrated propulsion

A combined lift-proplusion system utilizing control parts and/or deflecting vanes in the nozzles for both proplusion and control.

Compartmentation
Segmentation

The division of the cushion by secondary curtains for stability and control purposes.

Hydroskimmer
Skimmer

The U.S. Navy designation of a GEM for naval application.

Hovercraft

The trade name for a GEM of the British firm of Hovercraft Developments, Ltd.

Cushion craft

The trade name for a GEM of the British firm of Britten-Norman, Ltd.

Aircar

The trade name for a GEM of the U.S. firm of Curtis-Wright Corp.

Aqua GEM

The trade name for ACV of the U.S. firm of National Research Associates.

Hydrokeel

The trade name for a craft similar to an ACV of the U.S. firm of Anti-Friction Hull Co., the vehicle concept uses side skegs and bow flaps. This craft is basically an air lubricated planing boat.

Hydrostreak

The trade name for ACV of the U.S. firm of Hughes Tool Co. This concept uses water walls.

Leva-Car
Leva-Pad

A GEM of the Ford Motor Co. utilizing the air-bearing principle.

Hybrid GEM

A GEM utilizing a supplementary system(s) to aid primarily in control and handling; e.g., wheels or planing surfaces.

Mr. Downing.

Mr. DOWNING. Mr. Chairman, you brought up a very interesting point which troubled me. If this is a ship, why isn't it more properly handled by the Merchant Marine and Fisheries Committee?

The CHAIRMAN. I don't think we are trying to encroach upon the activities of the Merchant Marine and Fisheries Committee; and I see you and Mr. Casey are here, and with respect to confusion, if this is an airplane which properly belongs in another committee—I feel this is a sort of hybrid.

I was going to use another word, but I see Mrs. Weis is here with us.

Mrs. WEIS. Thank you, Mr. Chairman. I appreciate your attention.

The CHAIRMAN. But this is a hybrid, and it is in the research and development field and I think that we properly can take jurisdiction over it without violating the jurisdiction of the Merchant Marine and Fisheries Committee.

Mr. DOWNING. To its exclusion?

The CHAIRMAN. Not necessarily to the exclusion of it.

Mr. FULTON. This committee has jurisdiction over science, research, and development, wherever it is, whether it is in the Department of Defense, in peacetime, or on the moon, or in the air, so that our jurisdiction is not an operational jurisdiction, but a research jurisdiction; therefore, even if the Navy comes up here, and explains to us what they are doing on science, our job, I believe, and the chairman has stated this very well previously, is to correlate science, research, and development, even to test in engineering, within the Government, and to correlate it with private industry at home and abroad, as well as with other governments; so that we do have a very broad jurisdiction in this committee, which I do not think in any way impinges upon the Merchant Marine and Fisheries Committee, who are primarily interested in operation and production.

Mr. DOWNING. I agree, if we know at what point to let this go, because it is more properly a Merchant Marine and Fisheries Committee function. I think it is proper for us to see it through R. & D. phase and then cut it off.

The CHAIRMAN. That is the distinction. I may say with respect to NASA and Defense, as soon as we can. But as far as DOD is concerned, exercise concurrent jurisdiction over their R. & D. along with the Armed Services Committee. As soon as a weapon is declared into inventory and it is accepted, we no longer have interest or control and we do not care where they put the Minuteman, for instance.

Mr. CASEY. Does this broad field cover new types of processes in foods and everything else?

The CHAIRMAN. I presume if we want to go into it, it does, yes. I think we can go into items like that.

If you read the rules, I think it says that.

Mr. CASEY. It is that broad?

The CHAIRMAN. Oh, yes.

Mr. CASEY. We can take on an awful lot of work.

The CHAIRMAN. I imagine the best thing to do is get the rules. Would you go out there and ask for a copy of the rules?

Mrs. WEIS. Where does the funding come from for this operation, the $370,000?

The CHAIRMAN. The funding, I presume, came through Commerce, out of the Commerce Committee, out of the Department of Commerce budget. That is where it should be.

Mr. POTTER. Yes, sir.

The CHAIRMAN. I want to congratulate you, Mr. Potter. I think you have made an excellent statement, and an excellent case for this. I think you will agree with me, that this is something which has been lost pretty much as far as the Congress and the public are concerned. We are getting somewhere, but there are some earthbound developments that are highly important to the country and the economy of the country, and we should give more attention to, and this committee will give it attention.

Are there any other questions?

Mr. FULTON. I have a question, Mr. Chairman, on the use of this vehicle for inland waterways.

The speeds which you mentioned, of course, will be too much to operate in casual traffic, or for unexpected turns and bends, and it would seem to me that your speed factor would be somewhere between 15 to 50 miles an hour for inland waterways.

Has there been any research and development done in those areas?

Mr. POTTER. Not so much on ground effect machines, sir, because this is the natural field for the hydrofoil.

With respect to rivers, a craft this size is going to be confined to the big rivers, where there isn't a lot of opposing traffic.

This vehicle can't operate where there is a lot of traffic and craft such as sailboats because, as you say, when the GEM comes around a sudden bend in the river, if the driver isn't careful, it might slide across the river and get into trouble.

When coming in from a long run, and entering into crowded waters, the GEM is probably going to sit down and operate as a planing boat.

Mr. FULTON. That was to be my next question. What close proximity can it come to any sailcraft on an ordinary river, where the ordinary little bugs that you see scooting around these islands and coastal waters are?

Mr. POTTER. Well, sir, the British are running into this problem down near the Isle of Wight, where everything that floats, as soon as the SRN-2 comes out, comes over to look at it, and they are talking about setting up hoverways which will be marked off, with navigation lanes specifically for hovercraft.

I don't think that that is going to be too effective, because you cannot keep the little boatowners out of these lanes. You are going to have to slow the GEM down and go carefully whenever you enter crowded waters, because you cannot get close to a sailboat or any small craft.

Mr. FULTON. Supposing it is operating 7 feet over the surface, and likewise suppose you are operating over 10-foot waves, you mean to say the waves, that is, from the trough to the crest of the wave?

Mr. POTTER. That is correct, yes, sir.

Mr. FULTON. How do you then operate on an ocean surface such as that?

Mr. POTTER. Well, sir, it would be tremedously bumpy, it would be like going over cobblestones or what have you. But as I say, the rule of thumb is, that the wave height permissible is twice the operating height.

So, of course, this measures the operating height from the mean height of the wave.

When traveling at this sort of speed, the gem will tend to follow the mean height of all the waves.

However, you cannot go over a corrugated surface in any kind of craft where it depends for its support on that surface, without having a pitching movement and heave movement induced into the craft.

If it comes at the resonant point, then you get in serious trouble, of course, but this is the reason there is a horizontal fin for pitch control at the back.

My personal belief is that, when you are operating in heavy sea status, you are going to do the same thing you would do with your automobile on a winding road in the woods at night.

You are just going to slow down. If the waves get so big that you start hitting them and you finally can't go over them, then you just sit down on the water and ride it out.

However, the range of these craft is such, and the uses of them are such, that you should be cognizant of the weather which lies between you and your destination, so that you do not get caught in a hurricane.

Mr. FULTON. On fuel use and on range, would this be competitive with other means of transportation, or would it require Government subsidy?

Mr. POTTER. This is a very difficult question, Mr. Fulton.

The lift to drag ratios of this craft are such that if you could get—now, as I said a few minutes ago, I have not made an economic study yet, so I don't know precisely what I'm talking about. The following is just my opinion.

I believe that the GEM could operate self-supporting right now, because it can carry a ton of cargo cheaper than an airplane can, and it does not need a big, expensive airfield; it doesn't need an expensive roadbed, or any of these other things which the other modes of transportation have.

However, the Maritime Administration's view of the best use for GEM's could conceivably be on a Government to Government basis, where nobody pretends that they are actually going to make money.

If another country has towns in its interior, linked by large rivers with the coast, if that country wants these towns to grow, wants to stimulate industry in those towns, this is the craft that can do it, but at the beginning I don't think that it's going to make money on such a service as that.

The service will probably have to be subsidized in such a case, because at the outset, the intention is to stimulate growth and so, before the growth has occurred, you don't have the business for it.

Eventually, I would like to think, this would be a highly profitable operation.

Mrs. Weis. Will they ever get the cost of operation down, Mr. Potter? I mean the cost of building these down from $5 to $6 million in production, or will it always cost $5 or $6 million?

Mr. Potter. Well, this is a big vehicle, although it's not as heavy as a 707 or a DC–8. If you were able to get tooled up to build them, I believe that with the continuing orders for 30 or more over a period of years, you could construct these at a considerably lower cost than the $5 or $6 million.

The Chairman. I was going to say, in following out your theory, that this would be a Government operation to stimulate the growth in a country.

Isn't that what we did over a hundred years ago in establishing rail lines to the West?

Didn't we very heavily subsidize the railroads by giving them every other section of land—perhaps not done today—but didn't we give them 6 miles each side of the track, as a subsidy, besides very heavy grants in the purchase of their bonds, and contributions by the Federal Government in building the first transcontinental railroad lines, to open up the West.

This is the theory of opening up the West, and it is part of that. As a matter of fact, within the last 10 years we took back the unused lands and we cancelled certain conditions of this contract that called for the carrying of troops and materials of war at a 1-cent-a-mile base, and it was contemplated when this was done that the railroads would be taking care of the Indians in the West, and if you had to take a cavalry troop on a train and with the horses, you would have to take them say 40 miles. Well, this would be done at a very low rate.

And then when we got into World Wars, and we started shipping troops and freight across the country, why, you had to take this into consideration, and I am sure any number of you, before this was repealed, who traveled on military orders, if you wanted to protect yourself, you always had to make sure you got transportation requests when you got into the western lines, because you could only get reimbursed for 1 cent a mile instead of the 7 cents which you could draw.

So, you lost money heavily if you did not know how to take care of that.

Mr. Roudebush has a question he wants to ask. Mr. Roudebush.

Mr. ROUDEBUSH. I would like to ask just a couple of quick questions.

Mr. Potter, does the depth of the water underneath this craft affect its operating efficiency?

Mr. POTTER. No, sir, the depth of the water under the craft, well, it doesn't have to be water. It can be swamps; it can be quicksand; it can be anything flat; it can be rushing, moving water so that even along rapids, it would not be a bar to the passage of such a craft.

Mr. ROUDEBUSH. What is the speed of this craft as a surface craft when it is operating on the surface?

You mentioned the fact that on certain river conditions it would probably be wise, I believe, to operate as a surface craft.

What would its speed be as a surface craft, and how slow can it operate?

Mr. POTTER. If you get the side pontoons down—well, it can go all the way down to zero. With respect to the upper limit for surface operations, we are talking about 35 knots, now, which would be in a semiplaning condition.

Actually, I believe that you would be able to blow a little bit of air out of the jets, decreasing the draft a little bit, and get better than 35 knots.

Mr. ROUDEBUSH. Sort of a hydrofoil effect in that case, would it be?

Mr. POTTER. Yes, sir. Actually, more as an air-lubricated boat.

Mr. ROUDEBUSH. One other question. We mentioned the cost and the subsidization, and so forth, of this craft, and the ability of this type of craft to compete with conventional-type transportation.

The success of this craft would be in using select cargo I believe. Is that not correct?

I mean, in other words, a craft of this type even in the foreseeable future can never transport, let's say, iron ore successfully, could it?

Mr. POTTER. It is no bulk carrier by any means. If it will carry 40 tons, it will carry 40 tons of anything, but it would never compete with the more efficient methods of bulk transportation.

Mr. ROUDEBUSH. Thank you very much, Mr. Potter.

The CHAIRMAN. Mr. Karth.

Mr. KARTH. I want to congratulate Mr. Potter. He seems to be much more confident and rather sure of himself than the testimony which has been given in the last few days.

This is my opinion in evaluating the testimony which has been given up to this point, Mr. Chairman.

I have sensed considerable equivocation on certain problems which other people foresee with this kind of craft, and I certainly do want to congratulate you, Mr. Potter, for what you are doing with the small amount of money which you said you had, I believe I recall $600,000 before you get into actual construction.

It seems to me that is a very insignificant amount as opposed to what we generally get into when we talk here about higher medium and craft of this type.

I understood from the previous testimony that there is considerable doubt about the stability, involving almost insurmountable problems; at least the problem up to this point which had not been answered. Do you care to address yourself to this instability with other seacraft of this kind—when it gets up to this maximum height, up over the surface; that is, its tipping effect and therefore crashing into the surface?

Mr. POTTER. Yes, sir. This was the normal airfoil shape flying in ground effect. It has a pressure distribution across the top of the wing which is highly peaked, both sides, top and bottom.

This means that the resultant of the pressure is spread over a very small range, and when you change speed, if the center of pressure changes suddenly, and the center of gravity does not, you suddenly go out of equilibrium, and that is what Dr. Rethorst has been working on for 4 years.

This channel flow idea gives pressure distribution across the bottom which is virtually the same as a ship. It is also uniform all the way across the top. In the last few months the top has been changed to what you see here. This is not an airfoil at all; it's an ogive shape which is just an arch, and this gives a similar pressure distribution across the top where it is nice and even.

So, now, we have uniform support all along the craft, and we don't depend upon just one big vector at the bottom.

Mr. KARTH. As far as you are concerned, on a craft of this kind, you don't see this as a very knotty problem?

Mr. POTTER. Well, that is the thing, sir; this is what I am hoping is the genuine breakthrough: that by changing this pressure distribution picture, he has made it possible now for us to get into a higher speed range, and by getting down close to the surface we get these tremendous efficiencies, which were not possible before.

Mr. KARTH. Thank you.

The CHAIRMAN. Are there any other questions?

Mr. DOWNING. I have one more, Mr. Chairman.

The CHAIRMAN. Mr. Downing.

Mr. DOWNING. What industry will construct this, the aircraft or the shipbuilding industry?

Mr. POTTER. Well, sir, we are ship people and I would like to get the shipbuilding people interested in this.

Mr. DOWNING. Mr. Potter, I am glad to hear that. I am with you 100 percent.

Mr. POTTER. In fact, we have shipbuilders right here today, and it pleases me to see them here, because up to now, the marine industry hasn't been too much interested in them.

And may I amplify my previous remarks which tie in with what we are saying as to whether it will pay its way? Remember, Mr. Fulton, that the GEM would be operating in conjunction with the American merchant marine, and whether or not these craft, operating along a coast or between islands, are making a profit, is relatively unimportant.

What we are trying to do is to get the steamship lines carrying more cargo. If, for instance, we can stimulate the carriage of more cargo, we might do it in three ways:

No. 1, the craft itself is an exportable item; No. 2, it should help the American merchant marine to sell its products better because there is now a better and more diversified product to sell; and, No. 3, everybody with a product to sell or to export should be interested in it. In all three ways, we hope the GEM will stimulate the carriage of more goods overseas; as it's really this big mass of operating cargo ships that the benefits are aimed at, rather than just the inland leg of the trip.

The CHAIRMAN. Mr. Fulton.

Mr. FULTON. The name, "ground effect machine," brings to my mind the question of transportation, so that you actually do transpose it to your operation, on the ground, or on land?

Could you, maybe by putting down a level way, as a concrete highway strip, or configuration like a conic section, that would be the equivalent of a guide rather than a track, operate this kind of a GEM over terrain; that is, of course, not mountainous, but within feasible limits?

For example, might this kind of approach, a GEM approach, supplant canals that might be talked about that run into billions of dollars, whereby putting a concrete strip in it might look like a continuous tent, or a configuration that might look like a steel rail?

Mr. POTTER. Or a grassy strip.

Mr. FULTON. Just a grassy strip, yes. You would be able to accomplish the same results, and likewise it brings to mind the St. Lawrence River and Canal, where if you simply had long incline planes over the dams, you would have readily gone right down the canal without ever touching a drop of water?

Mr. POTTER. That is true. This is perfectly possible, sir. I wouldn't swear to the economics of the thing over many years, but it is technically quite possible.

Mr. FULTON. My point is really on the use of it possibly as a high-speed intercity transportation system. Or a high-speed suburban transportation system out to 50 miles.

Mr. POTTER. There you will need a rail to guide the vehicle, because, remember, you are going 150 knots on something quite like slick ice, and this will be real nervous when other objects are nearby.

Mr. FULTON. But on the other hand, you can see without friction, and without much traction, you will get the same L–D ratio as you would over water.

Mr. POTTER. No, sir; you get a much higher one, because over rail, you don't have to be at 7 feet; you can be at an inch or less, and then you get L over D's that are fantastic.

Mr. FULTON. Maybe on the President's plan for this fast transportation, and revising our types of transportation around cities, from automobiles, we might look into something like this?

Mr. POTTER. Well, sir, it would be quite interesting.

The CHAIRMAN. Mr. Corman, and this is the last question.

Mr. CORMAN. Do you think this might operate in the Los Angeles River?

Mr. POTTER. Yes, sir.

Mr. CORMAN. Well, that is an answer to your question, Mr. Fulton.

Mr. POTTER. We were speaking of names a minute ago, and I would like to apologize for the name which is written on the bow of this craft.

This is Dr. Rethorst's idea, and I told him not to put it on there, as we don't have the prerogative of choosing names, but he just cannot resist it every time he has one of the pictures done. He likes it so much that he wants the first seagoing GEM called the "Columbia"—the GEM of the ocean.

The CHAIRMAN. Thank you, Mr. Potter, we appreciate your being here today.

Mr. POTTER. Thank you, sir.

The CHAIRMAN. And we would like to have you back again sometime.

Mr. POTTER. May I ask, Mr. Chairman, what can we do to keep you abreast of these developments?

The CHAIRMAN. Well, I think we will ask you—let me ask Phil: Mr. Potter has asked what he can do to keep us abreast of these developments.

Mr. YEAGER. We will be in contact with him.

The CHAIRMAN. Mr. Yeager says the committee would be very happy if you would keep it advised on this thing.

Mr. POTTER. All right, sir, thank you.

The CHAIRMAN. And thank you very much.

Now, the question came up before with respect to our jurisdiction.

We have jurisdiction, and I won't read this, but it mentions the Bureau of Standards and so forth and on down to "H," "Scientific Research and Development," period.

Mr. ROUDEBUSH. That gets everything.

The CHAIRMAN. Yes.

Now, we have Dr. Robert B. Sleight, president, Applied Psychology Corp., before us, and, Doctor, will you give us a little bit of your background.

Well, I see it's at the back of the doctor's statement. All right, we will include that in the record then.

Doctor, we are very happy to hear from you. Would you proceed, please?

STATEMENT OF DR. ROBERT B. SLEIGHT, PRESIDENT, APPLIED PSYCHOLOGY CORP.

Dr. SLEIGHT. Mr. Chairman, and members of the Committee on Science and Astronautics, I want to thank you for the opportunity of meeting with you.

I am here today to talk about the nature of user acceptance for vehicles which may become an integral part of a future U.S. transportation system. These vehicles have been called ground effect machines, ground and air cushion vehicles, or even flying cars.

To me the term "aircar" is a useful general term with which to refer to all of these types of vehicles.

I know that this committee has conducted hearings and completed considerable study on these vehicles, so I will restrict my remarks to matters related to their use and acceptance.

The utilization of the aircar involves many problems directly related to functions or capacities of people in the transportation system.

There is more to acceptance, however, than the immediate satisfaction of the operator or the profit gained by those who use it.

Using a product—especially one with the broad implications of an aircar—creates many intricate relationships to existing interests, people, and activities in our economy, and even in our society as a whole.

Unless anticipated and dealt with, any of these new relationships can so evolve as to hamper rather than improve the transportation system.

Now, you may ask, How can we foresee and study problems of a futuristic mode of transportation that does not even exist yet?

This is a challenge, of course, but it is not one that cannot be met.

Many problems can be predicted, and appropriate designs or procedures to facilitate acceptance can be developed.

This is achieved by the logical and scientific application of established techniques and methods for investigating expected user reactions.

These methods involve the techniques and knowledge of a variety of psychologists, life-science investigations, and associated specialists.

Market problems can also be attacked by applying methods of market research, motivation research, and product evaluation.

Some fundamental and applied research—not much—has been initiated with regard to the problems of the operator of ground-effect machines.

Concerning other acceptance areas—the economic impact, safety, regulations, and so forth—I would say that there is very little research in progress.

Before discussing some of the typical acceptance problems to be met, a word about aircar feasibility and the sponsorship of development is in order. There is, in the development of a new product, very frequently a serious financing problem.

Typically, the inventors or promoters of an item are completely engrossed with something which exists and "works" at least on a demonstration basis.

Often, these people exhaust their limited funds on this "physical product," and have none left for essential market analysis, including the suiting of the product to the user and integrating it into an existing system.

Some support at this crucial phase may mean success for a worthwhile product that otherwise would fail.

The product in question here, the aircar, must meet demands that exist not only in the transportation system but that arise from the desires of the individual user.

There are two primary categories of satisfactoriness for a product: (1) Economic aspects; and (2) social and psychological factors.

The dollars and cents matter should not be minimized in our economy. An item must pay and it must compete to be successful.

The economic feasibility of an aircar such as the GEM is presumably dependent on competitiveness with existing modes of transportation and ways of getting work done.

The word, "presumably" is used here to acknowledge that major subsidizing of the vehicle and of associated facilities may be appropriate for a period of years.

Also, because the judgment of some strategists is that the aircar may be of considerable military potential in the not distant future, we may anticipate that the Department of Defense will provide large subsidy in the form of research and development aid.

Federal, State, and local governments may even support operational phases of civil use.

Therefore, it is fair to answer the question, "What cost is acceptable?" by saying that acceptable cost will depend on the vehicle's ability to perform unique functions.

For example, a unique capability frequently mentioned for GEM's, but not yet fully established, is their use over marshy and muskeg-type terrain, and over light snow and powdery sand.

Such an application would have great military value. Also, a product after meeting an initial military demand may next be used for some specialized purpose in a certain industry.

Thus, an acceptable cost is still only specifiable for a special case.

However, for any vehicle to displace a conventional one such as a ferry—or even a camel—it must make sense economically.

Intimately associated with the questions of feasibility are the kinds of acceptance problems I will detail now.

The following five areas are typical of use and acceptance problems of many devices used by me in complex systems.

For the system that involves aircars, these five problem areas should be of more than casual interest to developers and planners. These five categories have to do with: (1) The operator; (2) the internal environment of the vehicle; (3) safety; (4) reliability and maintenance; and (5) legal constraints.

Consider first the job that an operator of an aircar must carry out successfully. The developmental goal will be to obtain an operator task of maximum simplicity.

Simple operation can best be described as that which uses the operator's ability to an optimum degree, that is, neither underutilizing nor overtaxing him.

If man is to be given manual control of the aircar, in contrast to more or less automatic control, then we will want to assess carefully the sensory imputs to the operator in order to be sure that they can be perceived and interpreted with adequate speed and accuracy.

Fundamentally, we need to provide visual, auditory, and touch cues which are of sufficient magnitude for detection and which are so constituted that proper meaning is readily apparent.

The next step, of course, is to be sure that these cues, employed in combination with learned skills, will result in correct decisions and thus will elicit muscle response for actuation of proper controls in the appropriate manner.

The physical characteristics of the devices with which the operator is confronted can to a large extent determine the quality of his responses and thus they should be designed in conformance with his capabilities.

Regardless of what else he does, the human is left with the task of directing the air cushion vehicle or flying car along a prescribed path.

To so guide the vehicle, there must be provision for adequate visibility—especially visibility directly ahead.

However, the objective of completely unobstructed forward vision often conflicts with the need for readily observable information from instruments.

These need to be near the central line-of-sight or the operator will soon weary of head-swiveling in order to read them and perhaps ignore them with disastrous consequences.

Completion of an analysis of the human control requirements will lead to the establishment of visual information requirements. As a result, a guide to the design of instruments for quick and easy reading can be specified.

The second primary problem area is the nature of the environment with the aircar. To be acceptable as a voluntary mode of transportation the aircar should provide the so-called "shirtsleeve" environment. This condition includes temperate heat and moderate humidity levels.

Also, it involves acceptable levels of noise and motion, including vibration. It is clear that the present high noise level of many GEM's must be modified.

Normal conversation should be possible as well as easy reading of ordinary printed matter.

In certain situations as, for example, in military operations, some of these ideal comfort requirements can perhaps be relaxed.

However, when we are dealing with human operators and passengers, any reduction in comfort requirements will have some adverse effects such as premature fatigue, lessened sensory acuity, retardation of responses, and even sickness.

Such effects are usually detrimental to human performance—a fact that should never be overlooked in any system of men and machines.

In the long run, comfort cannot be compromised because it is highly correlated with efficiency.

The third typical acceptance problem to be met is safety. The establishment of criteria more appropriately described by the term, "efficiency" will embrace those also often included under the heading of safety.

Deserving of special mention as fundamental to efficiency is the objective of all-weather operations, independent of such adverse climatic conditions as dense fog and snowstorms.

Such all-weather operation at high speeds assumes a refined control based on external guides.

Technological developments in guidance and control which can utilize the full flexibility potential of the aircar represent a severe but rewarding challenge.

It goes almost without saying that it is highly desirable for the aircar to have many fail-safe features.

These would include fall-breakers, collision-avoidance devices, and means for flotation.

A fourth problem area concerns reliability and maintenance. The objective of high reliability of components, and of the complete vehicle, invariably conflicts with economy.

Low reliability means the maintainer of the vehicle is required to repair or replace elements in order to continue operability.

A vehicle which demands an unwarranted high degree of skill for maintenance will usually be objectionable because of excessive "downtime" and high cost of maintenance.

Design for ease of maintenance is a worthwhile objective. The design which takes into account the strength, body size, dexterity, and problem-solving ability of the human, will be easy to service and maintain, and therefore desirable.

Not all aircar applications will meet problems of the last area, legal constraints. However, implementation of any sort of aircar in the public transportation system must give attention to legal aspects that will arise as a result of aircar use.

Traditionally, legal constraints have lagged behind technological advances. Consideration of the regulatory aspects of such a radical new mode of transportation as the aircar should be carried out at the same time as technological research and development in order to obviate a later unnecessary arrestment of its progress.

We can assume that some policing will be essential, once the aircar is in actual use, in order to protect the rights of individuals, to insure standards of performance, and to avoid a chaotic traffic situation.

The logic of regulation can be augmented by a thorough study of the proper role of the Federal, State, and local agencies with regard to such a new transportation mode.

The protection of the public's rights can be dealt with in terms of establishing acceptable rights-of-way and routes for travel over land or over water.

A very important point here is that only maximum freedom to move over uncharted areas will exploit the full potential of the aircar.

Still another facet of the legal matter are those vehicle characteristics of possible annoyance to the public.

Such characteristics as noise and dust will not require regulation if they are at an acceptably low level as judged by persons in the vicinity.

In summary, it is fair to say that we may expect a high degree of consumer acceptance only if the aircar offers as much comfort, speed, economy, safety, and operating ease as the automobile.

It is reasonable to hope for an improvement over the automobile in many respects.

It is unreasonable to think such problems as discussed here cannot be dealt with.

Considering such a radical change in U.S. transportation as integration of aircars can be a rewarding activity.

With regard to possible skepticism, a relevant question appeared in an article I wrote for the July 1961, issue of Industrial Research, entitled "Aircars and the Terresphere." I asked, "Will the automobile driver who sees a stalled aircar—5 or 10 years hence—shout his advice to the stranded driver to get a car, as automobile drivers were told to get a horse two generations ago?"

A few months later Johnny Hart, creator of the cartoon strip, B.C., made the same point much more effectively. In the first panel of this cartoon strip we see our caveman-period character, B.C., riding along "Bumpity, Bump, Creak, Creak" while standing on a shaft of his invention, a single stone wheel. The next panel shows a friend yelling to him, "Get a Dinosaur!" The final panel shows B. C. continuing along on his wheel and saying to himself, "There's an expression destined for immortality."

On the basis of prototypes already flown, or driven if you wish, the aircar warrants development as a means of private and public transportation. Its use will necessitate expert attention to a number of pressing research problems. We can be confident, though, that this new form of transportation can be brought into being properly with adequate planning. This committee is to be commended for its part in such planning.

Mr. Chairman, that completes my prepared statement. I thank you.

BIOGRAPHICAL SKETCH OF ROBERT B. SLEIGHT

Dr. Sleight was born in 1922 in Hemlock, a small town near Rochester, N.Y.

Dr. Sleight received his undergraduate training at the State University Teachers College, Geneseo, N.Y.

In 1949, he was awarded the Ph. D. degree by Purdue University, following a major course of study in industrial and experimental psychology.

For 4 years he was on the faculty of the Johns Hopkins University as a research psychologist and assistant professor; and he served also as a research scientist at the Naval Research Laboratory.

Dr. Sleight has been engaged in research and consulting in the field of human engineering for the past 14 years, and has received national recognition in that field. He is the author of many scientific papers in the area of industrial and engineering psychology.

He is a fellow of the American Psychological Association and of the American Association for the Advancement of Science, and is active in the Institute of the Aerospace Sciences, Eastern Psychological Association, International Association of Applied Psychology, American Ordnance Association, District of Columbia Psychological Association, Society of the Sigma Xi, and the Human Factors Society.

His biography is listed in several directories including: "American Men of Science."

As a naval aviator in World War II, Dr. Sleight flew high-performance aircraft. He holds commercial and instructor pilot ratings.

Since 1962, Dr. Sleight has been president of the Applied Psychology Corp. In recent years he has been especially concerned with the application of the methods and principles of human factors engineering to the design of aviation and electronic equipment.

Also, major effort has been applied to long-term trends in product development and to factors in research methodology and research administration.

BACKGROUND OF APPLIED PSYCHOLOGY CORP.

The Applied Psychology Corp., a research and consulting firm, specializes in the experimental approach to man-machine systems and provides expert services in such other fields as safety, personnel, public opinion, communications and intelligence systems, and product and equipment design. Since its establishment in 1952, it has specialized in research work, based on quantitative analytic methods.

The staff of the Applied Psychology Corp. is made up of highly qualified professional persons with a wide range of capabilities in the physical and psychological sciences.

The professional staff consists of 25 specialists, supplemented by clerical personnel and technicians.

Typically, in performing a research project, Applied Psychology Corp. specialists analyze the problems, review the existing information, conduct laboratory and simulator experiments, and make actual field tests.

Many research projects are unique and frequently require the development of special apparatus, techniques, and methods to arrive at reliable and practical solutions.

Clients include leading large and small firms in American industry and commerce, as well as numerous agencies of the Federal Government.

Administration and research headquarters are located in Arlington, Va.

The CHAIRMAN. Thank you, very much, Dr. Sleight.

That was quite interesting. It opens up some new avenues. Perhaps had we had research in the past at the time the automobile was introduced, we might have gotten some little better acceptance of it, and, as I remember, in the early days of commercial air transportation, it took quite some time to get acceptance as we have full acceptance today.

Dr. SLEIGHT. A good point.

The CHAIRMAN. There are lots of people who do not fly and who will not fly and they do not like to admit to it.

Now, in other facets of industry, has thought been given to applying the type of psychology which you apply here?

Had you tried to obtain acceptance?

Dr. SLEIGHT. Mr. Chairman, so far the studies of acceptance have dealt almost exclusively with small items such as consumer items that the housewife might purchase.

These sorts of problems are far more simple to approach than the problem with which we are faced here—the integration of an entirely new item, a very large one, into such a complex system as our U.S. transportation system. The answer is that the techniques are available for thoroughly studying in a scientific manner the probable consumer reaction to a product that he will have available in the future.

The CHAIRMAN. Of course, a great deal has been done in the retail field in this on the consumer acceptance of food packaging, that they can almost tell how successful a product is going to be by the type of package it is contained in.

Dr. SLEIGHT. There has been some notable success and there have been some failures in the effort to assess the marketability of products.

The techniques are not foolproof, as all techniques are open to challenge. But there is a way of going about assessing the likelihood of acceptance and effort should be made in this direction even though the results may not be 100 percent accurate.

The CHAIRMAN. Well, it's part of this whole new era of sciences into which we are entering.

Dr. SLEIGHT. I think it is definitely a part; yes, sir.

The CHAIRMAN. It is the human sciences which cannot be overlooked for the physical——

Dr. SLEIGHT. As long as man is going to be a part of the system, regardless of whether it be a simple small system, or whether it be a very large one, such as our space program, or large as the aircar program may become in the future, then we have to assess, starting fundamentally with the individual himself, his place in this complex system.

The CHAIRMAN. Mr. Chenoweth.

Mr. CHENOWETH. I really enjoyed listening to your statement, Doctor, and you have aroused my curiosity as to just when you think now the public is going to be ready to accept this aircar as an integral part of our transportation system.

How far away is it? Is it a matter of a decade, or two, or shorter than that, or longer?

Is this something that is imminent; or something that will take a lot of education on the part of the public?

Dr. SLEIGHT. Congressman Chenoweth, I believe the answer is that the public will be ready, providing we are ready to give something to the public.

That is, if we can assure the public we have an item that is efficient, from the standpoint of carrying things or people, if we can assure the public that we have a vehicle which is safe, and at a price that he can afford, then I believe the public will be ready to accept it.

Certainly those people who are interested in somehow overcoming the challenge of our chaotic traffic situation would be interested in participating.

Mr. CHENOWETH. How long have you been giving some thought to this proposal, Doctor?

Dr. SLEIGHT. Well, sir, I certainly can say I have been in this field for something like 14 years now, and specifically with regard to the aircar we have been studying this for 3 years.

Mr. CHENOWETH. For 3 years?

Dr. SLEIGHT. Yes, sir.

Mr. CHENOWETH. And how did you happen to get into this study? Just what attracted you to it?

Dr. SLEIGHT. Well, simply futuristic look. I feel this is a mode of transportation which has considerable potential, and, therefore, went into it strictly because I thought it was something where our type of services were required.

Mr. CHENOWETH. As I understand it, you have given no thought to the economical or physical features of the aircar; you are assuming there is an air vehicle which can be successfully operated in an efficient manner?

Dr. SLEIGHT. This is fundamentally true.

Mr. CHENOWETH. You are accepting that as a thesis on which to start? You have not gone into the background whether it is possible to have such a vehicle or not?

Dr. SLEIGHT. That's right. Our starting position is somewhere along the line that if indeed such a vehicle were available, would people buy it, and would they use it?

Mr. CHENOWETH. You think there is a demand for any such vehicle right now?

Dr. SLEIGHT. I think there certainly is a demand, yes, for carrying people on inland waterways, possibly for interurban travel, and for the carrying of cargo, select cargo. And I would concur with the comments made to the committee in the last few days in that regard.

Mr. CHENOWETH. You have not gone into the military aspects of this? This is purely on civilian use, is that right?

Dr. SLEIGHT. I think they have a lot in common. In a military situation, if you are interested in transporting personnel, in a similar fashion to transporting personnel intercity, it is a similar situation.

Mr. CHENOWETH. But I mean the military might not have use for it, using it for the same function?

Dr. SLEIGHT. If you take the use of the vehicle in limited warfare over the beaches, let's say, this is a military application which might have potential. There certainly would be parallels on the frontiers of industry, Mr. Congressman, from the standpoint of offshore oil developments, let's say, or in mining operations in some of the muskeg territory of Canada.

I think there would be parallel applications in the civilian world to those that have apparent potential in the military.

Mr. Chenoweth. I am not sure that I recall the answer which you gave me now in the time element. How far are we away from it?

Dr. Sleight. I would say the public could be ready to utilize this vehicle in the form of personnel transportation analagous to bus transportation, as soon as it is available, in reasonably large numbers, providing the cost was comparable to the cost of current bus transportation.

Mr. Chenoweth. You studied it from the psychological standpoint, and you think the public is ready to accept such a vehicle?

Dr. Sleight. I think so.

Mr. Chenoweth. Although there is no vehicle available yet?

Dr. Sleight. That's right.

Mr. Chenoweth. You are not sure how soon it will be?

Dr. Sleight. That's right, sir.

The Chairman. Mr. Bell.

Mr. Bell. What type of a roadbed would you use if you were going to use a method of transportation for the public, say, downtown to an urban area?

Would you use a certain type of roadbed or just use the type of common roadbed that we have today?

What route would you have?

Dr. Sleight. The people who are concerned with the engineering design indicate that vehicles can be constructed to utilize almost any existing roadbed; there is also considerable indication that a very rough roadbed which has been sometimes called a clearway will be satisfactory for these vehicles.

This would be merely a matter of removing the trees and large objects, and then the clearway would be usable and it would be safe.

There has been discussion of the potential of using these vehicles down the median strip of some of our country's superhighways, because these are there, and minor modifications in the roadbed would make them safe and efficient.

Mr. Bell. Your immediate plan would of course be to continue the automobile and so on, but that you would have to set up another side roadbed, I assume, for immediate public acceptance to this, assuming there was one?

Dr. Sleight. There would have to be a compatibility of speed.

There is some thought in certain remote areas where there is very little obstruction, such as perhaps some desert areas, that it would be possible to use the vehicle over uncharted regions, and then when coming into towns, so to speak, settling down on the roadbed on wheels, more or less like our conventional automobiles and then moving around the city in the same way as automobiles now move.

Mr. Bell. Then you wouldn't be really thinking of it this far as close in, downtown movement?

Dr. Sleight. Well, I see no reason why the aircar which is primarily exemplified these days by the ground effect machine couldn't be utilized as a substitute for existing city buses.

And there could be certain benefits in terms of reduction of cost and perhaps even enhancing speed providing, as I say, again, it were compatible with existing traffic and special bus lanes would permit higher speeds.

The thought of using this vehicle in essence on the monorail, seems to have merit. However, in that situation, you have a considerable expense of building the monorail.

Mr. Bell. That is what I was thinking. I thought of the expense you would have to go through.

The Chairman. Mr. Yeager has a question.

Mr. Yeager. Do you think the type of research which you talk about going into, what might be called the human factors involved, could have some influence on the design and concept of these cars actually?

In other words, it would have—could have a physical effect?

Dr. Sleight. Very definitely, from the standpoint of the operator crew station, as we say, the operator's position. That should be designed for safety from the standpoint of increasing visibility and so on.

I don't know that it would necessarily have much change, that it would cause much change in the passenger compartments necessarily.

Mr. Yeager. But if it were carried on concurrently, it might save some money in the long run in that these factors might be built into an operating craft in the first place, without having to build certain models and then find because of vibration, noise, or dust factors, such as those, it would have to be redesigned——

Dr. Sleight. I see your point, sir. Indeed, the application of the knowledge of the human factors engineering, would be desirable in the earliest phases of design.

That is, designing in terms of those characteristics which the public will tolerate with regard, for example, to vibration.

Mr. Yeager. Could you give us any idea how much the cost might be in a research of this type as compared with, say, the overall R. & D. necessary to bring the craft to issue in the first place; as a factor of, say, 10 percent or what?

Dr. Sleight. Having had a fair amount of experience in this field, we have seen many cases where something on the order of 20 percent of the overall R. & D. effort can profitably be put into the human factors engineering.

This can vary, of course, 5 percent up or 5 percent down, depending upon the particular situation. In this case I think it might run even up to 25 percent.

Mr. Yeager. Thank you very much, that is all.

The Chairman. All right, thank you very much, Doctor.

The meeting will stand adjourned at the call of the Chair.

(Thereupon, at 11:45 o'clock, the meeting was adjourned at the call of the Chair.)

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