

the introduction to the hazard analysis section. A launch operator must track each identified hazard control separately.

(3) *Numbering.* A launch operator must number each hazard analysis form with the applicable system or subsystem identified. A launch operator must number each line item on a hazard analysis form with numbers and letters provided for multiple entries against an individual line item. A line item consists of a hardware or operation description and a hazard.

(4) *Hazard analysis data.* A hazard analysis form must contain or reference all information necessary to understand the relationship of a system, subsystem, component, or operation with a hazard cause, control, and verification.

(e) *Hazard analysis supporting data.* A ground safety analysis report must include data that supports the hazard analysis. If such data does not fit onto the hazard analysis form, a launch operator must provide the data in a supporting data chapter. This chapter must contain a table of contents and may reference other documents that contain supporting data.

PARTS 418–419 [RESERVED]

PART 420—LICENSE TO OPERATE A LAUNCH SITE

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APPENDIX E TO PART 420—TABLES FOR EXPLOSIVE SITE PLAN

AUTHORITY: 51 U.S.C. 50901–50923.

SOURCE: Docket No. FAA–1999–5833, 65 FR 62861, Oct. 19, 2000, unless otherwise noted.

Subpart A—General

§ 420.1 General.

(a) *Scope.* This part prescribes the information and demonstrations that must be provided to the FAA as part of a license application, the bases for license approval, license terms and conditions, and post-licensing requirements with which a licensee shall comply to remain licensed. Requirements for preparing a license application are contained in part 413 of this subchapter.

(b) *Equivalent level of safety.* Each requirement of this part applies unless the applicant or licensee clearly and

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convincingly demonstrates that an alternative approach provides an equivalent level of safety to the requirement of this part.

[Doc. No. FAA-2016-6761, Amdt. No. 420-8, 83 FR 28535, June 20, 2018]

§ 420.3 Applicability.

This part applies to any person seeking a license to operate a launch site or to a person licensed under this part. A person operating a site that only supports amateur rocket activities as defined in 14 CFR 1.1, does not need a license under this part to operate the site.

[Doc. No. FAA-2007-27390, 73 FR 73782, Dec. 4, 2008]

§ 420.5 Definitions.

For the purpose of this part.

Ballistic coefficient means the weight of an object divided by the quantity product of the coefficient of drag of the object and the area of the object.

Compatibility means the chemical property of materials that may be located together without increasing the probability of an accident or, for a given quantity, the magnitude of the effects of such an accident.

Debris dispersion radius (D_{\max}) means the estimated maximum distance from a launch point that debris travels given a worst-case launch vehicle failure and flight termination early in flight. For an expendable launch vehicle, flight termination is assumed to occur at 10 seconds into flight.

Downrange area means a portion of a flight corridor beginning where a launch area ends and ending 5,000 nautical miles from the launch point, or where the IIP leaves the surface of the Earth, whichever is shorter, for an orbital launch vehicle; and ending with an impact dispersion area for a guided sub-orbital launch vehicle.

E,F,G coordinate system means an orthogonal, Earth-fixed, geocentric, right-handed system. The origin of the coordinate system is at the center of an ellipsoidal Earth model. The E-axis is positive directed through the Greenwich meridian. The F-axis is positive directed though 90 degrees east longitude. The EF-plane is coincident with the ellipsoidal Earth model's equa-

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torial plane. The G-axis is normal to the EF-plane and positive directed through the north pole.

E,N,U coordinate system means an orthogonal, Earth-fixed, topocentric, right-handed system. The origin of the coordinate system is at a launch point. The E-axis is positive directed east. The N-axis is positive directed north. The EN-plane is tangent to an ellipsoidal Earth model's surface at the origin and perpendicular to the geodetic vertical. The U-axis is normal to the EN-plane and positive directed away from the Earth.

Effective casualty area (A_c) means the aggregate casualty area of each piece of debris created by a launch vehicle failure at a particular point on its trajectory. The effective casualty area for each piece of debris is the area within which 100 percent of the unprotected population on the ground are assumed to be a casualty, and outside of which 100 percent of the population are assumed not to be a casualty. An effective casualty area accounts for the characteristics of the debris piece, including its size, the path angle of its trajectory, impact explosions, and debris skip, splatter, and bounce. An effective casualty area also accounts for the size of a person.

Energetic liquid means a liquid, slurry, or gel, consisting of, or containing an explosive, oxidizer, fuel, or combination of the above, that may undergo, contribute to, or cause rapid exothermic decomposition, deflagration, or detonation.

Explosive means any chemical compound or mechanical mixture that, when subjected to heat, impact, friction, detonation or other suitable initiation, undergoes a rapid chemical change that releases large volumes of highly heated gases that exert pressure in the surrounding medium. The term applies to materials that either detonate or deflagrate.

Explosive division means the division within hazard class 1 of an explosive as defined in the United Nations Organization classification system for transport of dangerous goods, and as determined in accordance with 49 CFR part 173, subpart C.

Explosive equivalent means a measure of the blast effects from explosion of a

given quantity of material expressed in terms of the weight of trinitrotoluene (TNT) that would produce the same blast effects when detonated.

Explosive hazard facility means a facility or location at a launch site where solid propellants, energetic liquids, or other explosives are stored or handled.

Flight azimuth means the initial direction in which a launch vehicle flies relative to true north expressed in degrees-decimal-degrees.

Flight corridor means an area on the Earth's surface estimated to contain the hazardous debris from nominal flight of a launch vehicle, and non-nominal flight of a launch vehicle assuming a perfectly functioning flight termination system or other flight safety system.

Guided suborbital launch vehicle means a suborbital rocket that employs an active guidance system.

Hazard class means the class of an explosive as defined by the United Nations Organization classification system for transport of dangerous goods, and as determined in accordance with 49 CFR part 173, subpart C.

Impact dispersion area means an area representing an estimated three standard deviation dispersion about a nominal impact point of an intermediate or final stage of a suborbital launch vehicle.

Impact dispersion factor means a constant used to estimate, using a stage apogee, a three standard deviation dispersion about a nominal impact point of an intermediate or final stage of a suborbital launch vehicle.

Impact dispersion radius (R_i) means a radius that defines an impact dispersion area.

Impact range means the distance between a launch point and the impact point of a suborbital launch vehicle stage.

Impact range factor means a constant used to estimate, when multiplied by a stage apogee, the nominal impact point of an intermediate or final stage of a suborbital launch vehicle.

Instantaneous impact point (IIP) means an impact point, following thrust termination of a launch vehicle. IIP may be calculated with or without atmospheric drag effects

Intraline distance means the minimum distance permitted between any two explosive hazard facilities in the ownership, possession or control of one launch site customer.

Launch area means, for a flight corridor defined in accordance with appendix A of this part, the portion of a flight corridor from the launch point to a point 100 nautical miles in the direction of the flight azimuth. For a flight corridor defined in accordance with appendix B of this part, a launch area is the portion of a flight corridor from the launch point to the enveloping line enclosing the outer boundary of the last debris dispersion circle.

Launch point means a point on the Earth from which the flight of a launch vehicle begins, and is defined by its geodetic latitude, longitude and height on an ellipsoidal Earth model.

Liquid propellant means:

(1) A monopropellant on a launch vehicle or related device; or

(2) Incompatible energetic liquids collocated for purposes of serving as propellants on a launch vehicle or a related device where the incompatible energetic liquids are housed in tanks connected by piping for purposes of mixing.

Maximum credible event means a hypothesized worst-case accidental explosion, fire, or agent release that is likely to occur from a given quantity and disposition of explosives, chemical agents, or reactive material.

Net explosive weight (NEW) means the total weight, expressed in pounds, of explosive material or explosive equivalency contained in an item.

Nominal means, in reference to launch vehicle performance, trajectory, or stage impact point, a launch vehicle flight where all launch vehicle aerodynamic parameters are as expected, all vehicle internal and external systems perform as planned, and there are no external perturbing influences (e.g., winds) other than atmospheric drag and gravity.

Overflight dwell time means the period of time it takes for a launch vehicle's IIP to move past a populated area. For a given populated area, the overflight dwell time is the time period measured along the nominal trajectory IIP ground trace from the time point

whose normal with the trajectory intersects the most uprange part of the populated area to the time point whose normal with the trajectory intersects the most downrange part of the populated area.

Overflight exclusion zone means a portion of a flight corridor which must remain clear of the public during the flight of a launch vehicle.

Populated area means a land area with population.

Population density means the number of people per unit area in a populated area.

Position data means data referring to the current position of a launch vehicle with respect to flight time expressed through the X, Y, Z coordinate system.

Public area means any area outside a hazard area and is an area that is not in the possession, ownership or other control of a launch site operator or of a launch site customer who possesses, owns or otherwise controls that hazard area.

Public area distance means the minimum distance permitted between a public area and an explosive hazard facility.

Public traffic route means any highway or railroad that the general public may use.

Public traffic route distance means the minimum distance permitted between a public highway or railroad line and an explosive hazard facility.

Trajectory means the position and velocity components as a function of time of a launch vehicle relative to an x, y, z coordinate system, expressed in x, y, z, \dot{x} , \dot{y} , \dot{z} .

Unguided sub-orbital launch vehicle means a sub-orbital rocket that does not have a guidance system.

X, Y, Z coordinate system means an orthogonal, Earth-fixed, topocentric, right-handed system. The origin of the coordinate system is at a launch point. The x-axis coincides with the initial launch azimuth and is positive in the downrange direction. The y-axis is positive to the left looking downrange. The xy-plane is tangent to the ellipsoidal earth model's surface at the origin and perpendicular to the geodetic vertical. The z-axis is normal to the xy-plane and positive directed away from the earth.

ϕ_0 , λ_0 , h_0 means a latitude, longitude, height system where ϕ_0 is the geodetic latitude of a launch point, λ_0 is the east longitude of the launch point, and h_0 is the height of the launch point above the reference ellipsoid. ϕ_0 and λ_0 are expressed in degrees-decimal-degrees.

[Doc. No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Amdt. 420-3, 72 FR 17019, Apr. 6, 2007; Amdt. 420-6, 77 FR 55113, Sept. 7, 2012; Doc. No. FAA-2019-0229, Amdt. 420-9, 85 FR 79716, Dec. 10, 2020]

§§ 420.6–420.14 [Reserved]

Subpart B—Criteria and Information Requirements for Obtaining a License

§ 420.15 Information requirements.

(a) *General*—(1) *Launch site operator*. An applicant shall identify the name and address of the applicant, and the name, address, and telephone number of any person to whom inquiries and correspondence should be directed.

(2) *Launch site*. An applicant shall provide the name and location of the proposed launch site and include the following information:

- (i) A list of downrange equipment;
- (ii) A description of the layout of the launch site, including launch points;
- (iii) The types of launch vehicles to be supported at each launch point;
- (iv) The range of launch azimuths planned from each launch point; and
- (v) The scheduled operational date.

(3) *Foreign ownership*. Identify foreign ownership of the applicant, as follows:

- (i) For a sole proprietorship or partnership, all foreign owners or partners;
- (ii) For a corporation, any foreign ownership interest of 10 percent or more; and
- (iii) For a joint venture, association, or other entity, any foreign entities participating in the entity.

(b) *Environmental*. The FAA is responsible for complying with the procedures and policies of the National Environmental Policy Act (NEPA) and other applicable environmental laws, regulations, and Executive Orders prior to issuing a launch site license. An applicant must provide the FAA with information needed to comply with such requirements. The FAA will consider and document the potential environmental

effects associated with issuing a launch site license.

(1) *Environmental impact statement or environmental assessment.* When directed by the FAA, an applicant must—

(i) Prepare an Environmental Assessment with FAA oversight;

(ii) Assume financial responsibility for preparation of an Environmental Impact Statement by an FAA-selected and -managed consultant contractor; or

(iii) Submit information to support a written re-evaluation of a previously submitted Environmental Assessment or Environmental Impact Statement when requested by the FAA.

(2) *Categorical exclusion.* The FAA may determine that a categorical exclusion is appropriate upon receipt of supporting information from an applicant.

(3) *Environmental information.* An application must include an approved FAA Environmental Assessment, Environmental Impact Statement, categorical exclusion determination, or written re-evaluation covering all planned licensed activities in compliance with NEPA and the Council on Environmental Quality Regulations for Implementing the Procedural Provisions of NEPA.

(c) *Launch site location.* (1) Except as provided by paragraph (c)(2) of this section, an applicant shall provide the information necessary to demonstrate compliance with §§ 420.19–420.29.

(2) An applicant who is proposing to locate a launch site at an existing launch point at a federal launch range is not required to comply with paragraph (c)(1) of this section if a launch vehicle of the same type and class as proposed for the launch point has been safely launched from the launch point.

(d) *Explosive site plan.* (1) Except as provided by paragraph (d)(2) of this section, an applicant shall submit an explosive site plan that complies with §§ 420.63, 420.65, 420.67, and 420.69.

(2) If an applicant plans to operate a launch site located on a federal launch range, and if the applicant is required by the federal launch range to comply with the federal launch range's explosive safety requirements, the applicant shall submit the explosive site plan submitted to the federal launch range.

(e) *Launch site operations.* An applicant shall provide the information necessary to demonstrate compliance with the requirements of §§ 420.53, 420.55, 420.57, 420.59, 420.61, and 420.71.

[Docket No. FAA–1999–5833, 65 FR 62861, Oct. 19, 2000, as amended by Doc. No. FAA–2019–0229, Amdt. 420–9, 85 FR 79716, Dec. 10, 2020]

§ 420.17 Bases for issuance of a license.

(a) The FAA will issue a license under this part when the FAA determines that:

(1) The application provides the information required by § 420.15;

(2) The FAA has completed an analysis of the environmental impacts associated with the proposed operation of the launch site, in accordance with NEPA, 40 CFR parts 1500–1508, and FAA Order 1050.1D;

(3) The launch site location meets the requirements of §§ 420.19, 420.21, 420.23, 420.25, 420.27, and 420.29;

(4) The applicant has completed the agreements required by § 420.31;

(5) The application demonstrates that the applicant shall satisfy the requirements of §§ 420.53, 420.55, 420.57, 420.59, 420.61 and 420.71;

(6) The explosive site plan meets the criteria of §§ 420.63, 420.65, 420.67 and 420.69; and

(7) Issuing a license would not jeopardize foreign policy or national security interests of the United States.

(b) The FAA advises an applicant, in writing, of any issue arising during an application review that would lead to denial. The applicant may respond in writing, submit additional information, or amend its license application.

§ 420.19 Launch site location review—general.

(a) To gain approval for a launch site location, an applicant shall demonstrate that for each launch point proposed for the launch site, at least one type of expendable or reusable launch vehicle can be flown from the launch point safely. For purposes of the launch site location review:

(1) A safe launch must possess a risk level estimated, in accordance with the requirements of this part, not to exceed an expected number of 1×10^{-4}

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casualties (E_c) to the collective members of the public exposed to hazards from the flight.

(2) Types of launch vehicles include orbital expendable launch vehicles, guided sub-orbital expendable launch vehicles, unguided sub-orbital expendable launch vehicles, and reusable launch vehicles. Orbital expendable launch vehicles are further classified by weight class, based on the weight of payload the launch vehicle can place in a 100-nm orbit, as defined in table 1.

(b) If an applicant proposes to have more than one type of launch vehicle

flown from a launch point, the applicant shall demonstrate that each type of expendable or reusable launch vehicle planned to be flown from the launch point can be flown from the launch point safely.

(c) If an applicant proposes to have more than one weight class of orbital expendable launch vehicles flown from a launch point, the applicant shall demonstrate that the heaviest weight class planned to be flown from the launch point can be flown from the launch point safely.

TABLE 1 OF § 420.19—ORBITAL EXPENDABLE LAUNCH VEHICLE CLASSES BY PAYLOAD WEIGHT (LBS)

100 nm orbit	Weight class			
	Small	Medium	Medium large	Large
28 degrees inclination *	≤4400	>4400 to ≤11100	>11100 to ≤18500	>18500
90 degrees inclination	≤3300	>3300 to ≤8400	>8400 to ≤15000	>15000

*28 degrees inclination orbit from a launch point at 28 degrees latitude.

[Docket No. FAA–1999–5833, 65 FR 62861, Oct. 19, 2000, as amended by Docket No. FAA–2014–0418, Amdt. No. 420–7, 81 FR 47026, July 20, 2016]

§ 420.21 Launch site location review—launch site boundary.

(a) The distance from any proposed launch point to the closest launch site boundary must be at least as great as the debris dispersion radius of the largest launch vehicle type and weight class proposed for the launch point.

(b) For a launch site supporting any expendable launch vehicle, an appli-

cant shall use the largest distance provided by table 2 for the type and weight class of any launch vehicle proposed for the launch point.

(c) For a launch site supporting any reusable launch vehicle, an applicant shall determine the debris dispersion radius that represents the maximum distance from a launch point that debris travels given a worst-case launch vehicle failure in the launch area. An applicant must clearly and convincingly demonstrate the validity of its proposed debris dispersion radius.

TABLE 2 OF § 420.21—MINIMUM DISTANCE FROM LAUNCH POINT TO LAUNCH SITE BOUNDARY (FEET)

Orbital expendable launch vehicle class			Type of suborbital launch vehicle		
Small	Medium	Medium large	Large	Guided	Unguided
7300	9300	10600	13000	8000	1600

§ 420.23 Launch site location review—flight corridor.

(a) *Guided orbital expendable launch vehicle.* For a guided orbital expendable launch vehicle, an applicant shall define a flight corridor that:

(1) Encompasses an area that the applicant estimates, in accordance with the requirements of this part, to contain debris with a ballistic coefficient

of ≥3 pounds per square foot, from any non-nominal flight of a guided orbital expendable launch vehicle from the launch point to a point 5000 nm downrange, or where the IIP leaves the surface of the Earth, whichever is shorter;

(2) Includes an overflight exclusion zone where the public risk criteria of 1

$\times 10^{-4}$ would be exceeded if one person were present in the open; and

(3) Uses one of the methodologies provided in appendix A or B of this part.

(b) *Guided sub-orbital expendable launch vehicle.* For a guided sub-orbital expendable launch vehicle, an applicant shall define a flight corridor that:

(1) Encompasses an area that the applicant estimates, in accordance with the requirements of this part, to contain debris with a ballistic coefficient of ≥ 3 pounds per square foot, from any non-nominal flight of a guided sub-orbital expendable launch vehicle from the launch point to impact with the earth's surface;

(2) Includes an impact dispersion area for the launch vehicle's last stage;

(3) Includes an overflight exclusion zone where the public risk criteria of 1×10^{-4} would be exceeded if one person were present in the open; and

(4) Uses one of the methodologies provided in appendix A or B to this part.

(c) *Unguided sub-orbital expendable launch vehicle.* (1) For an unguided sub-orbital expendable launch vehicle, an applicant shall define the following using the methodology provided by appendix D of this part:

(i) Impact dispersion areas that the applicant estimates, in accordance with the requirements of this part, to contain the impact of launch vehicle stages from nominal flight of an unguided sub-orbital expendable launch vehicle from the launch point to impact with the earth's surface; and

(ii) An overflight exclusion zone where the public risk criteria of 1×10^{-4} would be exceeded if one person were present in the open.

(2) An applicant shall base its analysis on an unguided suborbital launch vehicle whose final launch vehicle stage apogee represents the intended use of the launch point.

(d) *Reusable launch vehicle.* For a reusable launch vehicle, an applicant shall define a flight corridor that contains the hazardous debris from nominal and non-nominal flight of a reusable launch vehicle. The applicant must provide a clear and convincing

demonstration of the validity of its flight corridor.

[Docket No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Docket No. FAA-2014-0418, Amdt. No. 420-7, 81 FR 47026, July 20, 2016; Doc. No. FAA-2016-6761, Amdt. No. 420-8, 83 FR 28535, June 20, 2018]

§ 420.25 Launch site location review—risk analysis.

(a) If a flight corridor or impact dispersion area defined by § 420.23 contains a populated area, the applicant shall estimate the casualty expectation associated with the flight corridor or impact dispersion area. An applicant shall use the methodology provided in appendix C to this part for guided orbital or suborbital expendable launch vehicles and appendix D for unguided sub-orbital launch vehicles.

(b) For licensed launches, the FAA will not approve the location of the proposed launch point if the estimated expected casualty exceeds 1×10^{-4} .

[Doc. No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Amdt. 420-3, 72 FR 17019, Apr. 6, 2007; Docket No. FAA-2014-0418, Amdt. No. 420-7, 81 FR 47027, July 20, 2016; Doc. No. FAA-2016-6761, Amdt. No. 420-8, 83 FR 28535, June 20, 2018]

§ 420.27 Launch site location review—information requirements.

An applicant shall provide the following launch site location review information in its application:

(a) A map or maps showing the location of each launch point proposed, and the flight azimuth, IIP, flight corridor, and each impact range and impact dispersion area for each launch point;

(b) Each launch vehicle type and any launch vehicle class proposed for each launch point;

(c) Trajectory data;

(d) Wind data, including each month and any percent wind data used in the analysis;

(e) Any launch vehicle apogee used in the analysis;

(f) Each populated area located within a flight corridor or impact dispersion area;

(g) The estimated casualty expectancy calculated for each populated area within a flight corridor or impact dispersion area;

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(h) The effective casualty areas used in the analysis;

(i) The estimated casualty expectancy for each flight corridor or set of impact dispersion areas; and

(j) If populated areas are located within an overflight exclusion zone, a demonstration that there are times when the public is not present or that the applicant has an agreement in place to evacuate the public from the overflight exclusion zone during a launch.

§ 420.29 Launch site location review for unproven launch vehicles.

An applicant for a license to operate a launch site for an unproven launch vehicle shall provide a clear and convincing demonstration that its proposed launch site location provides an equivalent level of safety to that required by this part.

§ 420.30 Launch site location review for permitted launch vehicles.

If an applicant plans to use its proposed launch site solely for launches conducted under an experimental permit, the FAA will approve a launch site location if the FAA has approved an operating area under part 437 for launches from that site.

[Doc. No. FAA-2006-24197, 72 FR 17019, Apr. 6, 2007]

§ 420.31 Agreements.

(a) Except as provided by paragraph (c) of this section, an applicant shall complete an agreement with the local U.S. Coast Guard district to establish procedures for the issuance of a Notice to Mariners prior to a launch and other such measures as the Coast Guard deems necessary to protect public health and safety.

(b) Except as provided by paragraph (c) of this section, an applicant shall complete an agreement with the FAA Air Traffic Control (ATC) office having jurisdiction over the airspace through which launches will take place, to establish procedures for the issuance of a Notice to Airmen prior to a launch and for closing of air routes during the launch window and other such measures as the FAA ATC office deems necessary to protect public health and safety.

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(c) An applicant that plans to operate a launch site located on a federal launch range does not have to comply with section 420.31 if the applicant is using existing federal launch range agreements with the U.S. Coast Guard and the FAA ATC office having jurisdiction over the airspace through which launches will take place.

§§ 420.32-420.40 [Reserved]

Subpart C—License Terms and Conditions

§ 420.41 License to operate a launch site—general.

(a) A license to operate a launch site authorizes a licensee to operate a launch site in accordance with the representations contained in the licensee's application, with terms and conditions contained in any license order accompanying the license, and subject to the licensee's compliance with 51 U.S.C. Subtitle V, chapter 509 and this chapter.

(b) A license to operate a launch site authorizes a licensee to offer its launch site to a launch operator for each launch point for the type and any weight class of launch vehicle identified in the license application and upon which the licensing determination is based.

(c) Issuance of a license to operate a launch site does not relieve a licensee of its obligation to comply with any other laws or regulations; nor does it confer any proprietary, property, or exclusive right in the use of airspace or outer space.

[Doc. No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Amdt. 420-5, 77 FR 20533, Apr. 5, 2012]

§ 420.43 Duration.

A license to operate a launch site remains in effect for five years from the date of issuance unless surrendered, suspended, or revoked before the expiration of the term and is renewable upon application by the licensee.

§ 420.45 Transfer of a license to operate a launch site.

(a) Only the FAA may transfer a license to operate a launch site.

(b) The FAA will transfer a license to an applicant who has submitted an application in accordance with 14 CFR part 413, satisfied the requirements of § 420.15, and obtained each approval required by § 420.17 for a license.

(c) The FAA may incorporate by reference any findings made part of the record that supported a prior related licensing determination.

§ 420.47 License modification.

(a) Upon application or upon its own initiative, the FAA may modify a license to operate a launch site at any time by issuing a license order that adds, removes, or modifies a license term or condition to ensure compliance with the Act and the requirements of this chapter.

(b) After a license to operate a launch site has been issued, a licensee shall apply to the FAA for modification of its license if:

(1) The licensee proposes to operate the launch site in a manner that is not authorized by the license; or

(2) The licensee proposes to operate the launch site in a manner that would make any representation contained in the license application that is material to public health and safety or safety of property no longer accurate and complete.

(c) An application to modify a license shall be prepared and submitted in accordance with part 413 of this chapter. The licensee shall indicate any part of its license or license application that would be changed or affected by a proposed modification.

(d) The FAA approves a modification request that satisfies the requirements of this part.

(e) Upon approval of a license modification, the FAA issues either a written approval to the licensee or a license order modifying the license if a stated term or condition of the license is changed, added, or deleted. A written approval has the full force and effect of a license order and is part of the licensing record.

§ 420.49 Compliance monitoring.

A licensee shall allow access by and cooperate with federal officers or employees or other individuals authorized by the FAA to observe any activities of

the licensee, its customers, its contractors, or subcontractors, associated with licensed operation of the licensee's launch site.

Subpart D—Responsibilities of a Licensee

§ 420.51 Responsibilities—general.

A licensee must operate its launch site in accordance with the representations in its application.

[Docket No. FAA-2019-0229, Amdt. 420-9, 85 FR 79716, Dec. 10, 2020]

§ 420.53 Control of public access.

(a) A licensee shall prevent unauthorized access to the launch site, and unauthorized, unescorted access to explosive hazard facilities or other hazard areas not otherwise controlled by a launch operator, through the use of security personnel, surveillance systems, physical barriers, or other means approved as part of the licensing process.

(b) A licensee shall notify anyone entering the launch site of safety rules and emergency and evacuation procedures prior to that person's entry unless that person has received a briefing on those rules and procedures within the previous year.

(c) A licensee shall employ warning signals or alarms to notify any persons at the launch site of any emergency.

§ 420.55 Scheduling of launch site operations.

(a) A licensee shall develop and implement procedures to schedule operations to ensure that each operation carried out by a customer at the launch site does not create the potential for a mishap that could result in harm to the public because of the proximity of the operations, in time or place, to operations of any other customer. A customer includes any launch operator, and any contractor, subcontractor or customer of the launch site operator's customer at the launch site.

(b) A licensee shall provide its launch site scheduling requirements to each customer before the customer begins operations at the launch site.

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§ 420.57 Notifications.

(a) A licensee shall notify each launch operator and any other customer of any limitations on the use of the launch site. A licensee shall also communicate limitations on the use of facilities provided to customers by the launch site operator.

(b) A licensee shall maintain its agreement, made in accordance with § 420.31(a), with the local U.S. Coast Guard district.

(c) A licensee shall maintain its agreement, made in accordance with § 420.31(b), with the FAA ATC office having jurisdiction over the airspace through which launches will take place.

(d) At least 2 days prior to flight of a launch vehicle, unless the Administrator agrees to a different time frame in accordance with § 404.15, the licensee must notify local officials and all owners of land adjacent to the launch site of the flight schedule.

[Docket No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Doc. No. FAA-2019-0229, Amdt. 420-9, 85 FR 79716, Dec. 10, 2020]

§ 420.59 Mishap plan.

(a) *General.* A licensee must report, respond to, and investigate any event that meets either paragraph (1) or (5) of the definition of “mishap” in § 401.7 of this chapter. A licensee must submit a mishap plan that meets the requirements of § 450.173(b) through (f).

(b) *Launch mishaps.* A launch site operator’s mishap plan must also contain procedures for participating in an investigation of a launch mishap for launches launched from the launch site.

(c) *Other agency procedures.* Emergency response and investigation procedures developed in accordance with 29 CFR 1910.119 and 40 CFR part 68 will satisfy the requirements of § 450.173(d) and (e) to the extent that they include the elements required by § 450.173(d) and (e).

[Doc. No. FAA-2019-0229, Amdt. 420-9, 85 FR 79716, Dec. 10, 2020]

§ 420.61 Records.

(a) A licensee shall maintain all records, data, and other material needed to verify that its operations are con-

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ducted in accordance with representations contained in the licensee’s application. A licensee shall retain records for three years.

(b) For any event that meets any of paragraph (1), (5), or (8) of the definition of “mishap” in § 401.7 of this chapter, a licensee must preserve all records related to the event. Records must be retained until completion of any Federal investigation and the FAA advises the licensee that the records need not be retained.

(c) A licensee shall make available to federal officials for inspection and copying all records required to be maintained under the regulations.

[Docket No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Doc. No. FAA-2019-0229, Amdt. 420-9, 85 FR 79717, Dec. 10, 2020]

§ 420.63 Explosive siting.

(a) Except as otherwise provided by paragraph (b) of this section, a licensee must ensure the configuration of the launch site follows its explosive site plan, and the licensee’s explosive site plan complies with the requirements of §§ 420.65 through 420.70. The explosive site plan must include:

(1) A scaled map that shows the location of all explosive hazard facilities at the launch site and that shows actual and minimal allowable distances between each explosive hazard facility and all other explosive hazard facilities, each public traffic route, and each public area, including the launch site boundary;

(2) A list of the maximum quantity of energetic liquids, solid propellants and other explosives to be located at each explosive hazard facility, including explosive class and division;

(3) A description of each activity to be conducted at each explosive hazard facility; and

(4) An explosive site map using a scale sufficient to show whether distances and structural relationships satisfy the requirements of this part.

(b) A licensee operating a launch site located on a federal launch range does not have to comply with the requirements in §§ 420.65 through 420.70 if the licensee complies with the federal launch range’s explosive safety requirements.

(c) For explosive siting issues not addressed by the requirements of §§ 420.65 through 420.70, a launch site operator must clearly and convincingly demonstrate a level of safety equivalent to that otherwise required by this part.

(d) A launch site operator may separate an explosive hazard facility from another explosive hazard facility, public area, or public traffic route by a distance different from one required by this part only if the launch site operator clearly and convincingly demonstrates a level of safety equivalent to that required by this part.

[Doc. No. FAA-2011-0105, 77 FR 55113, Sept. 7, 2012]

§ 420.65 Separation distance requirements for handling division 1.1 and 1.3 explosives.

(a) *Quantity.* For each explosive hazard facility, a launch site operator must determine the total quantity of division 1.1 and 1.3 explosives as follows:

(1) A launch site operator must determine the maximum total quantity of division 1.1 and 1.3 explosives by class and division, in accordance with 49 CFR part 173, Subpart C, to be located in each explosive hazard facility where division 1.1 and 1.3 explosives will be handled.

(2) When division 1.1 and 1.3 explosives are located in the same explosive hazard facility, the total quantity of explosive must be treated as division 1.1 for determining separation distances; or, a launch site operator may add the net explosive weight of the division 1.3 items to the net explosive weight of division 1.1 items to determine the total quantity of explosives.

(b) *Separation of division 1.1 and 1.3 explosives and determination of distances.* A launch site operator must separate each explosive hazard facility where division 1.1 and 1.3 explosives are handled from all other explosive hazard facilities, all public traffic routes, and each public area, including the launch site boundary, by a distance no less than that provided for each quantity and explosive division in appendix E of this part as follows:

(1) For division 1.1 explosives, the launch site operator must use tables E-1, E-2, and E-3 of appendix E of this

part to determine the distance to each public area and public traffic route, and to determine each intraline distance.

(2) For division 1.3 explosives, the launch site operator must use table E-4 of appendix E of this part to determine the distance to each public area and public traffic route, and to determine each intraline distance.

(c) *Separation distance by weight and table.* A launch site operator must:

(1) Employ no less than the public area distance, calculated under paragraph (b) of this section, to separate an explosive hazard facility from each public area, including the launch site boundary.

(2) Employ no less than an intraline distance to separate an explosive hazard facility from all other explosive hazard facilities used by a single customer. For explosive hazard facilities used by different customers a launch site operator must use the greater public area distance to separate the facilities from each other.

(3) Separate each public area containing any member of the public in the open by a distance equal to $-1133.9 + [389 \cdot \ln(\text{NEW})]$, where the NEW is greater than 450 pounds and less than 501,500 pounds.

(d) *NEW Quantities that Fall between Table Entries.* A launch site operator must, when determining a separation distance for NEW quantities that fall between table entries, use the equation provided by tables E-1, E-3, or E-4 of appendix E of this part.

(e) *Calculating Maximum Permissible NEW Given a Distance.* A launch site operator must, when determining a permissible quantity of explosives, calculate maximum permissible NEW using the equation of tables E-1, E-3, or E-4 of appendix E of this part.

[Doc. No. FAA-2011-0105, 77 FR 55114, Sept. 7, 2012]

§ 420.66 Separation distance requirements for storage of hydrogen peroxide, hydrazine, and liquid hydrogen and any incompatible energetic liquids stored within an intraline distance.

(a) *Separation of energetic liquids and determination of distances.* A launch site operator must separate each explosive

hazard facility from each other explosive hazard facility, each public area, and each public traffic route in accordance with the minimum separation distance determined under this section for each explosive hazard facility storing:

(1) Hydrogen peroxide in concentrations of greater than 91 percent;

(2) Hydrazine;

(3) Liquid hydrogen; or

(4) Any energetic liquid that is:

(i) Incompatible with any of the energetic liquids of paragraph (a)(1) through (3) of this section; and

(ii) Stored within an intraline distance of any of them.

(b) *Quantity.* For each explosive hazard facility, a launch site operator must determine the total quantity of all energetic liquids in paragraph (a)(1) through (4) of this section as follows:

(1) The quantity of energetic liquid in a tank, drum, cylinder, or other container is the net weight in pounds of the energetic liquid in the container. The determination of quantity must include any energetic liquid in associated piping to any point where positive means exist for:

(i) Interrupting the flow through the pipe, or

(ii) Interrupting a reaction in the pipe in the event of a mishap.

(2) A launch site operator must convert the quantity of each energetic liquid from gallons to pounds using the conversion factors provided in table E-6 of appendix E of this part and the following equation:

Pounds of energetic liquid = gallons × density of energetic liquid (pounds per gallon).

(3) Where two or more containers of compatible energetic liquids are stored in the same explosive hazard facility, the total quantity of energetic liquids is the total quantity of energetic liquids in all containers, unless:

(i) The containers are each separated from each other by the distance required by paragraph (c) of this section; or

(ii) The containers are subdivided by intervening barriers that prevent mixing, such as diking.

(4) Where two or more containers of incompatible energetic liquids are stored within an intraline distance of

each other, paragraph (d) of this section applies.

(c) *Determination of separation distances for compatible energetic liquids.* A launch site operator must determine separation distances for compatible energetic liquids as follows:

(1) To determine each intraline, public area, and public traffic route distance, a launch site operator must use the following tables in appendix E of this part:

(i) Table E-7 for hydrogen peroxide in concentrations of greater than 91 percent; and

(ii) Table E-8 for hydrazine and liquid hydrogen.

(2) For liquid hydrogen and hydrazine, a launch site operator must use the “intra-line distance to compatible energetic liquids” for the energetic liquid that requires the greater distance under table E-8 of appendix E of this part as the minimum separation distance between compatible energetic liquids.

(d) *Determination of separation distances for incompatible energetic liquids.* If incompatible energetic liquids are stored within an intraline distance of each other, a launch site operator must determine the explosive equivalent in pounds of the combined liquids as provided by paragraph (d)(2) of this section unless intervening barriers prevent mixing.

(1) If intervening barriers prevent mixing, a launch site operator must separate the incompatible energetic liquids by no less than the intraline distance that tables E-7 and E-8 of appendix E of this part apply to compatible energetic liquids using the quantity or energetic liquid requiring the greater separation distance.

(2) A launch site operator must use the formulas provided in table E-5 of appendix E of this part, to determine the explosive equivalent in pounds of the combined incompatible energetic liquids. A launch site operator must then use the explosive equivalent in pounds requiring the greatest separation distance to determine the minimum separation distance between each explosive hazard facility and all other explosive hazard facilities and each public area and public traffic

route as required by tables E-1, E-2 and E-3 of appendix E of this part.

[Doc. No. FAA-2011-0105, 77 FR 55114, Sept. 7, 2012]

§ 420.67 Separation distance requirements for handling incompatible energetic liquids that are co-located.

(a) *Separation of energetic liquids and determination of distances.* Where incompatible energetic liquids are co-located in a launch or reentry vehicle tank or other vessel, a launch site operator must separate each explosive hazard facility from each other explosive hazard facility, each public area, and each public traffic route in accordance with the minimum separation distance determined under this section for each explosive hazard facility.

(b) *Quantity.* For each explosive hazard facility, a launch site operator must determine the total quantity of all energetic liquids as follows:

(1) The quantity of energetic liquid in a launch or reentry vehicle tank is the net weight in pounds of the energetic liquid. The determination of quantity must include any energetic liquid in associated piping to any point where positive means exist for:

- (i) Interrupting the flow through the pipe; or
- (ii) Interrupting a reaction in the pipe in the event of a mishap.

(2) A launch site operator must convert each energetic liquid's quantity from gallons to pounds using the conversion factors provided by table E-6 of appendix E of this part and the following equation:

Pounds of energetic liquid = gallons × density of energetic liquid (pounds per gallon).

(c) *Determination of separation distances for incompatible energetic liquids.* A launch site operator must determine separation distances for incompatible energetic liquids as follows:

(1) A launch site operator must use the formulas provided in table E-5 of appendix E of this part, to determine the explosive equivalent in pounds of the combined incompatible energetic liquids; and

(2) A launch site operator must then use the explosive equivalent in pounds to determine the minimum separation

distance between each explosive hazard facility and all other explosive hazard facilities and each public area and public traffic route as required by tables E-1, E-2 and E-3 of appendix E of this part. Where two explosive hazard facilities contain different quantities, the launch site operator must use the quantity of liquid propellant requiring the greatest separation distance to determine the minimum separation distance between the two explosive hazard facilities.

(d) *Separation distance by weight and table.* For each explosive hazard facility, a launch site operator must:

(1) For an explosive equivalent weight from one pound through and including 450 pounds, determine the distance to any public area and public traffic route following table E-1 of appendix E of this part;

(2) For explosive equivalent weight greater than 450 pounds, determine the distance to any public area and public traffic route following table E-2 of appendix E of this part;

(3) Separate each public area containing any member of the public in the open by a distance equal to $-1133.9 + [389 * \ln(\text{NEW})]$, where the NEW is greater than 450 pounds and less than 501,500 pounds;

(4) Separate each explosive hazard facility from all other explosive hazard facilities of a single customer using the intraline distance provided by table E-3 of appendix E of this part; and

(5) For explosive hazard facilities used by different customers, use the greater public area distance to separate the facilities from each other.

[Doc. No. FAA-2011-0105, 77 FR 55115, Sept. 7, 2012]

§ 420.69 Separation distance requirements for co-location of division 1.1 and 1.3 explosives with liquid propellants.

(a) *Separation of energetic liquids and explosives and determination of distances.* A launch site operator must separate each explosive hazard facility from each other explosive hazard facility, each public traffic route, and each public area in accordance with the minimum separation distance determined under this section for each explosive hazard facility where division 1.1 and

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1.3 explosives are co-located with liquid propellants. A launch site operator must determine each minimum separation distance from an explosive hazard facility where division 1.1 and 1.3 explosives and liquid propellants are to be located together, to each other explosive hazard facility, public traffic route, and public area as described in paragraphs (b) through (e) of this section.

(b) *Liquid propellants and division 1.1 explosives located together.* For liquid propellants and division 1.1 explosives located together, a launch site operator must:

(1) Determine the explosive equivalent weight of the liquid propellants by following § 420.67(c);

(2) Add the explosive equivalent weight of the liquid propellants and the net explosive weight of division 1.1 explosives to determine the combined net explosive weight;

(3) Use the combined net explosive weight to determine the distance to each public area, public traffic route, and each other explosive hazard facility by following tables E-1, E-2, and E-3 of appendix E of this part; and

(4) Separate each public area containing any member of the public in the open by a distance equal to $-1133.9 + [389 \cdot \ln(\text{NEW})]$, where the net explosive weight is greater than 450 pounds and less than 501,500 pounds.

(c) *Liquid propellants and division 1.3 explosives located together.* For liquid propellants and division 1.3 explosives located together, a launch site operator must separate each explosive hazard facility from each other explosive hazard facility, public area, and public traffic route using either of the following two methods:

(1) *Method 1.* (i) Determine the explosive equivalent weight of the liquid propellants by following § 420.67(c);

(ii) Add to the explosive equivalent weight of the liquid propellants, the net explosive weight of each division 1.3 explosive, treating division 1.3 explosives as division 1.1 explosives;

(iii) Use the combined net explosive weight to determine the minimum separation distance to each public area, public traffic route, and each other explosive hazard facility by following ta-

bles E-1, E-2, and E-3 of appendix E of this part; and

(iv) Separate each public area containing any member of the public in the open by a distance equal to $-1133.9 + [389 \cdot \ln(\text{NEW})]$, where the net explosive weight is greater than 450 pounds and less than 501,500 pounds.

(2) *Method 2.* (i) Determine the explosive equivalent weight of each liquid propellant by following § 420.67(c);

(ii) Add to the explosive equivalent weight of the liquid propellants, the net explosive weight of each division 1.3 explosive to determine the combined net explosive weight;

(iii) Use the combined net explosive weight to determine the minimum separation distance to each public area, public traffic route, and each other explosive hazard facility by following tables E-1, E-2, and E-3 of appendix E of this part; and

(iv) Separate each public area containing any member of the public in the open by a distance equal to $-1133.9 + [389 \cdot \ln(\text{NEW})]$, where the net explosive weight is greater than 450 pounds and less than 501,500 pounds.

(d) *Liquid propellants and division 1.1 and 1.3 explosives located together.* For liquid propellants and division 1.1 and 1.3 explosives located together, a launch site operator must:

(1) Determine the explosive equivalent weight of the liquid propellants by following § 420.67(c);

(2) Determine the total explosive quantity of each division 1.1 and 1.3 explosive by following § 420.65(a)(2);

(3) Add the explosive equivalent weight of the liquid propellants to the total explosive quantity of division 1.1 and 1.3 explosives together to determine the combined net explosive weight;

(4) Use the combined net explosive weight to determine the distance to each public area, public traffic route, and each other explosive hazard facility by following tables E-1, E-2, and E-3 of appendix E of this part; and

(5) Separate each public area containing any member of the public in the open by a distance equal to $-1133.9 + [389 \cdot \ln(\text{NEW})]$, where the net explosive weight is greater than 450 pounds and less than 501,500 pounds

(e) *Use of maximum credible event analysis.* If a launch site operator does not want to employ paragraphs (b), (c), or (d) of this section, the launch site operator must analyze the maximum credible event (MCE) or the worst case explosion expected to occur. If the MCE shows there will be no simultaneous explosion reaction of the liquid propellant tanks and the solid propellant motors, the minimum distance between the explosive hazard facility and all other explosive hazard facilities and public areas must be based on the MCE.

[Doc. No. FAA-2011-0105, 77 FR 55115, Sept. 7, 2012]

§ 420.70 Separation distance measurement requirements.

(a) This section applies to all measurements of distances performed under §§ 420.63 through 420.69.

(b) A launch site operator must measure each separation distance along straight lines. For large intervening topographical features such as hills, the launch site operator must measure over or around the feature, whichever is the shorter.

(c) A launch site operator must measure each minimum separation distance from the closest hazard source, such as a container, building, segment, or positive cut-off point in piping, in an explosive hazard facility. When measuring, a launch site operator must:

(1) For a public traffic route distance, measure from the nearest side of the public traffic route to the closest point of the hazard source; and

(2) For an intraline distance, measure from the nearest point of one hazard source to the nearest point of the next hazard source. The minimum separation distance must be the distance for the quantity of energetic liquids or net explosive weight that requires the greater distance.

[Doc. No. FAA-2011-0105, 77 FR 55116, Sept. 7, 2012]

§ 420.71 Lightning protection.

(a) *Lightning protection.* A licensee shall ensure that the public is not exposed to hazards due to the initiation of explosives by lightning.

(1) *Elements of a lightning protection system.* Unless an explosive hazard facility

meets the conditions of paragraph (a)(3) of this section, all explosive hazard facilities shall have a lightning protection system to ensure explosives are not initiated by lightning. A lightning protection system shall meet the requirements of this paragraph and include the following:

(i) *Air terminal.* An air terminal to intentionally attract a lightning strike.

(ii) *Down conductor.* A low impedance path connecting an air terminal to an earth electrode system.

(iii) *Earth electrode system.* An earth electrode system to dissipate the current from a lightning strike to ground.

(2) *Bonding and surge protection.* A lightning protection system must meet the requirements of this paragraph and include the following:

(i) *Bonding.* All metallic bodies shall be bonded to ensure that voltage potentials due to lightning are equal everywhere in the explosive hazard facility. Any fence within six feet of a lightning protection system shall have a bond across each gate and other discontinuations and shall be bonded to the lightning protection system. Railroad tracks that run within six feet of the lightning protection system shall be bonded to the lightning protection system.

(ii) *Surge protection.* A lightning protection system shall include surge protection to reduce transient voltages due to lightning to a harmless level for all metallic power, communication, and instrumentation lines entering an explosive hazard facility.

(3) *Circumstances where no lightning protection system is required.* No lightning protection system is required for an explosive hazard facility when a lightning warning system is available to permit termination of operations and withdrawal of the public to public area distance prior to an electrical storm, or for an explosive hazard facility containing explosives that cannot be initiated by lightning. If no lightning protection system is required, a licensee must ensure the withdrawal of the public to a public area distance prior to an electrical storm.

(4) *Testing and inspection.* Lightning protection systems shall be visually inspected semiannually and shall be tested once each year for electrical continuity and adequacy of grounding. A licensee shall maintain at the explosive hazard facility a record of results obtained from the tests, including any action taken to correct deficiencies noted.

(b) *Electrical power lines.* A licensee shall ensure that electric power lines at its launch site meet the following requirements:

(1) Electric power lines shall be no closer to an explosive hazard facility than the length of the lines between the poles or towers that support the lines unless an effective means is provided to ensure that energized lines cannot, on breaking, come in contact with the explosive hazard facility.

(2) Towers or poles supporting electrical distribution lines that carry between 15 and 69 KV, and unmanned electrical substations shall be no closer to an explosive hazard facility than the public area distance for that explosive hazard facility.

(3) Towers or poles supporting electrical transmission lines that carry 69 KV or more, shall be no closer to an explosive hazard facility than the public area distance for that explosive hazard facility.

APPENDIX A TO PART 420—METHOD FOR DEFINING A FLIGHT CORRIDOR

(a) *Introduction*

(1) This appendix provides a method for constructing a flight corridor from a launch point for a guided suborbital launch vehicle or any one of the four classes of guided orbital launch vehicles from table 1, §420.19, without the use of local meteorological data or a launch vehicle trajectory.

(2) A flight corridor includes an overflight exclusion zone in a launch area and, for a guided suborbital launch vehicle, an impact dispersion area in a downrange area. A flight corridor for a guided suborbital launch vehicle ends with the impact dispersion area, and, for the four classes of guided orbital launch vehicles, 5000 nautical miles (nm) from the launch point.

(b) *Data requirements*

(1) *Maps.* An applicant shall use any map for the launch site region with a scale not less than 1:250,000 inches per inch in the launch area and 1:20,000,000 inches per inch in the downrange area. As described in paragraph (b)(2), an applicant shall use a mechanical method, a semi-automated method, or a fully-automated method to plot a flight corridor on maps. A source for paper maps acceptable to the FAA is the U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

(i) Projections for mechanical plotting method. An applicant shall use a conic projection. The FAA will accept a “Lambert-Conformal” conic projection. A polar aspect of a plane-azimuthal projection may also be used for far northern launch sites.

(ii) Projections for semi-automated plotting method. An applicant shall use cylindrical, conic, or plane projections for semi-automated plotting. The FAA will accept “Mercator” and “Oblique Mercator” cylindrical projections. The FAA will accept “Lambert-Conformal” and “Albers Equal-Area” conic projections. The FAA will accept “Lambert Azimuthal Equal-Area” and “Azimuthal Equidistant” plane projections.

(iii) Projections for fully-automated plotting method. The FAA will accept map projections used by geographical information system software scaleable pursuant to the requirements of paragraph (b)(1).

(2) *Plotting Methods.*

(i) *Mechanical method.* An applicant may use mechanical drafting equipment such as pencil, straight edge, ruler, protractor, and compass to plot the location of a flight corridor on a map. The FAA will accept straight lines for distances less than or equal to 7.5 times the map scale on map scales greater than or equal to 1:1,000,000 inches per inch (in/in); or straight lines representing 100 nm or less on map scales less than 1:1,000,000 in/in.

(ii) *Semi-automated method.* An applicant may employ the range and bearing techniques in paragraph (b)(3) to create latitude and longitude points on a map. The FAA will accept straight lines for distances less than or equal to 7.5 times the map scale on map scales greater than or equal to 1:1,000,000 inches per inch (in/in); or straight lines representing 100 nm or less on map scales less than 1:1,000,000 in/in.

(iii) *Fully-automated method.* An applicant may use geographical information system software with global mapping data scaleable in accordance with paragraph (b)(1).

(3) *Range and bearing computations on an ellipsoidal Earth model.*

(i) To create latitude and longitude pairs on an ellipsoidal Earth model, an applicant

shall use the following equations to calculate geodetic latitude (+N) and longitude (+E) given the launch point geodetic latitude (+N), longitude (+E), range (nm), and bearing (degrees, positive clockwise from North).

(A) Input. An applicant shall use the following input in making range and bearing computations. Angle units must be in radians.

ϕ_1 = Geodetic latitude of launch point (radians)

$$= \phi_1 \text{ (DDD)} \cdot \frac{\pi}{180} \text{ (radians per degree)}$$

λ_1 = Longitude of launch point (DDD)

$$= \lambda \text{ (DDD)} \cdot \frac{\pi}{180} \text{ (radians per degree)}$$

S = Range from launch point (nm)

$$= S \text{ (DDD)} \cdot \frac{\pi}{180} \text{ (radians per degree)}$$

α_{12} = Azimuth bearing from launch point (deg)

$$= \alpha_{12} \text{ (DDD)} \cdot \frac{\pi}{180} \text{ (radians per degree)}$$

(B) Computations. An applicant shall use the following equations to determine the latitude (ϕ_2) and longitude (λ_2) of a target point situated "S" nm from the launch point on an azimuth bearing (α_{12}) degrees.

where:

a = WGS-84 semi-major axis (3443.91846652 nmi)

b = WGS-84 semi-minor axis (3432.37165994 nmi)

$$f = 1 - \frac{b}{a} \quad \text{(Equation A1)}$$

$$e^2 = \frac{(a^2 - b^2)}{b^2} \quad \text{(Equation A2)}$$

$$\theta = \frac{S}{b} \text{ (radians)} \quad \text{(Equation A3)}$$

$$\beta_1 = \tan^{-1} \left[\frac{(b \cdot \sin \phi_1)}{(a \cdot \cos \phi_1)} \right] \quad \text{(Equation A4)}$$

$$g = (\cos \beta_1)(\cos \alpha_{12}) \quad \text{(Equation A5)}$$

$$h = (\cos \beta_1)(\sin \alpha_{12}) \quad \text{(Equation A6)}$$

$$m = \frac{\left[1 + \left(\frac{\epsilon^2}{2}\right) \sin^2 \beta_1\right] [1 - h^2]}{2} \quad (\text{Equation A7})$$

$$n = \frac{\left[1 + \left(\frac{\epsilon^2}{2}\right) \sin^2 \beta_1\right] \left[(\sin^2 \beta_1)(\cos \theta) + g \cdot (\sin \beta_1)(\sin \theta)\right]}{2} \quad (\text{Equation A8})$$

$$L = h \cdot \left[-f \cdot \theta + 3 \cdot f^2 \cdot n \cdot \sin \theta + \frac{3 \cdot f^2 \cdot m \cdot (\theta - \sin \theta \cdot \cos \theta)}{2} \right] (\text{radians}) \quad (\text{Equation A9})$$

$$M = m \cdot \epsilon^2 \quad (\text{Equation A10})$$

$$N = n \cdot \epsilon^2 \quad (\text{Equation A11})$$

$$A_1 = N \cdot \sin \theta \quad (\text{Equation A12})$$

$$A_2 = \left(\frac{M}{2}\right) (\sin \theta \cdot \cos \theta - \theta) \quad (\text{Equation A13})$$

$$A_3 = \left(\frac{5}{2}\right) (N^2 \cdot \sin \theta \cdot \cos \theta) \quad (\text{Equation A14})$$

$$A_4 = \left(\frac{M^2}{16}\right) (11 \cdot \theta - 13 \cdot \sin \theta \cdot \cos \theta - 8 \cdot \theta \cdot \cos^2 \theta + 10 \cdot \sin \theta \cdot \cos^3 \theta) \quad (\text{Equation A15})$$

$$A_5 = \left(\frac{M \cdot N}{2}\right) (3 \cdot \sin \theta + 2 \cdot \theta \cdot \cos \theta - 5 \cdot \sin \theta \cdot \cos^2 \theta) \quad (\text{Equation A16})$$

$$\delta = \theta - A_1 + A_2 + A_3 + A_4 + 5A_5 (\text{radians}) \quad (\text{Equation A17})$$

$$\sin \beta_2 = \sin \beta_1 \cdot \cos \delta + g \cdot \sin \delta \quad (\text{Equation A18})$$

$$\cos \beta_2 = \left[h^2 + (g \cdot \cos \delta - \sin \beta_1 \cdot \sin \delta)^2 \right]^{\frac{1}{2}} \quad (\text{Equation A19})$$

$$\phi_2 = \left\{ \tan^{-1} \left[\frac{(a \cdot \sin \beta_2)}{(b \cdot \cos \beta_2)} \right] \right\} \cdot \left(\frac{180}{\pi} \right) (\text{geodetic latitude of target point, DDD}) \quad (\text{Equation A20})$$

$$\Lambda = \tan^{-1} \left[\frac{(\sin \delta \cdot \sin \alpha_{12})}{(\cos \beta_1 \cdot \cos \delta - \sin \beta_1 \cdot \sin \delta \cdot \cos \alpha_{12})} \right] \quad (\text{Equation A21})$$

$$\lambda_2 = (\lambda_1 + \Lambda + L) \left(\frac{180}{\pi} \right) (\text{longitude of target point, DDD}) \quad (\text{Equation A22})$$

(ii) To create latitude and longitude pairs on an ellipsoidal Earth model, an applicant shall use the following equations to calculate the distance (S) of the geodesic between two points (P₁ and P₂), the forward azimuth (α₁₂) of the geodesic at P₁, and the

back azimuth (α₂₁) of the geodesic at P₂, given the geodetic latitude (+N), longitude (+E) of P₁ and P₂. Azimuth is measured positively clockwise from North.

(A) Input. An applicant shall use the following input. Units must be in radians.

φ₁ = Geodetic latitude of launch point (radians)

$$= \phi_1(\text{DDD}) \cdot \frac{\pi}{180} (\text{radians per degree})$$

λ₁ = Longitude of launch point (DDD)

$$= \lambda_1(\text{DDD}) \cdot \frac{\pi}{180} (\text{radians per degree})$$

S = Range from launch point (nm)

$$= S(\text{DDD}) \cdot \frac{\pi}{180} (\text{radians per degree})$$

α₁₂ = Azimuth bearing from launch point (deg)

$$= \alpha_{12}(\text{DDD}) \cdot \frac{\pi}{180} (\text{radians per degree})$$

(B) Computations. An applicant shall use the following equations to determine the distance (S), the forward azimuth (α₁₂) of the

geodesic at P₁, and the back azimuth (α₁₂) of the geodesic at P₂.

$$f = 1 - \frac{b}{a} \quad (\text{Equation A23})$$

where:

a = WGS-84 semi-major axis (3443.91846652 nmi)

b = WGS-84 semi-minor axis (3432.37165994 nmi)

$$L = \lambda_2 - \lambda_1 \quad (\text{Equation A24})$$

$$\beta_1 = \tan^{-1} \left[\frac{(b \cdot \sin \phi_1)}{\alpha \cdot \cos \phi_1} \right] \quad (\text{Equation A25})$$

$$\beta_2 = \tan^{-1} \left[\frac{(b \cdot \sin \phi_2)}{\alpha \cdot \cos \phi_2} \right] \quad (\text{Equation A26})$$

$$A = \sin \beta_1 \cdot \sin \beta_2 \quad (\text{Equation A27})$$

$$B = \cos \beta_1 \cdot \cos \beta_2 \quad (\text{Equation A28})$$

$$\cos \delta = A + B \cdot \cos L \quad (\text{Equation A29})$$

$$n = \frac{(a - b)}{(a + b)} \quad (\text{Equation A30})$$

$$(\beta_2 - \beta_1) = (\phi_2 - \phi_1) + 2 \cdot [A \cdot (n + n^2 + n^3) - B \cdot (n - n^2 + n^3)] \cdot \sin(\phi_2 - \phi_1) \text{ radians} \quad (\text{Equation A31})$$

$$\sin \delta = \left\{ (\sin L \cdot \cos \beta_2)^2 + [\sin(\beta_2 - \beta_1) + 2 \cdot \cos \beta_2 \cdot \sin \beta_1 \cdot \sin^2(L/2)]^2 \right\}^{\frac{1}{2}} \quad (\text{Equation A32})$$

$$\delta = \tan^{-1} \left(\frac{\sin \delta}{\cos \delta} \right) \text{ evaluated in positive radians } \leq \pi \quad (\text{Equation A33})$$

$$c = \frac{B \cdot \sin L}{\sin \delta} \quad (\text{Equation A34})$$

$$m = 1 - c^2 \quad (\text{Equation A35})$$

$$S = b \cdot \left\{ \begin{array}{l} \delta \cdot [1 + f + f^2] + A \cdot [(f + f^2) \cdot \sin \delta - (f^2 \cdot \delta^2) / (2 \cdot \sin \delta)] \\ -(m/2) [(f + f^2)(\delta + \sin \delta \cdot \cos \delta) - (f^2 \cdot \delta^2) / (\tan \delta)] \\ -(A^2 \cdot f^2 / 2) \cdot \sin \delta \cdot \cos \delta \\ +(f^2 \cdot m^2 / 16) [\delta + \sin \delta \cdot \cos \delta - 2 \cdot \sin \delta \cdot \cos^3 \delta - 8\delta^2 / (\tan \delta)] \\ +(A^2 \cdot m \cdot f^2 / 2) [\sin \delta \cdot \cos^2 \delta + \delta + \delta^2 / (\sin \delta)] \text{ in the same units as "a" and "b"} \end{array} \right\} \quad (\text{Equation A36})$$

$$\Lambda = L + c \cdot \left\{ \begin{array}{l} \delta \cdot (f + f^2) - (A \cdot f^2 / 2) [\sin \delta + 2\delta^2 / (\sin \delta)] \\ +(m \cdot f^2 / 4) [\sin \delta \cos \delta - 5\delta + 4\delta^2 / (\tan \delta)] \end{array} \right\} \text{ radians} \quad (\text{Equation A37})$$

$$\alpha_{12} = \tan^{-1} \left\{ \frac{(\cos \beta_2 \cdot \sin \Lambda)}{[\sin(\beta_2 - \beta_1) + 2 \cdot \cos \beta_2 \cdot \sin \beta_1 \cdot \sin^2(\Lambda/2)]} \right\} \cdot \left(\frac{180}{\pi} \right) \text{ degrees} \quad (\text{Equation A38})$$

$$\alpha_{21} = \tan^{-1} \left\{ \frac{(-\cos \beta_1 \cdot \sin \Lambda)}{[2 \cdot \cos \beta_1 \cdot \sin \beta_2 \cdot \sin^2(\Lambda/2) - \sin(\beta_2 - \beta_1)]} \right\} \cdot \left(\frac{180}{\pi} \right) \text{ degrees} \quad (\text{Equation A39})$$

(c) *Creation of a Flight Corridor*

(1) To define a flight corridor, an applicant shall:

(i) Select a guided suborbital or orbital launch vehicle, and, for an orbital launch vehicle, select from table 1 of § 420.19 a launch vehicle weight class that best represents the launch vehicle the applicant plans to support at its launch point;

(ii) Select a debris dispersion radius (D_{max}) from table A-1 corresponding to the guided suborbital launch vehicle or orbital launch vehicle class selected in paragraph (c)(1)(i);

(iii) Select a launch point geodetic latitude and longitude; and

(iv) Select a flight azimuth.

(2) An applicant shall define and map an overflight exclusion zone using the following method:

(i) Select a debris dispersion radius (D_{max}) from table A-1 and a downrange distance (D_{OEZ}) from table A-2 to define an overflight exclusion zone for the guided suborbital launch vehicle or orbital launch vehicle class selected in paragraph (c)(1)(i).

(ii) An overflight exclusion zone is described by the intersection of the following boundaries, which are depicted in figure A-1:

(A) An applicant shall define an uprange boundary with a half-circle arc of radius D_{max} and a chord of length twice D_{max} connecting the half-circle arc endpoints. The uprange boundary placement on a map has the chord midpoint positioned on the launch point with the chord oriented along an azimuth $\pm 90^\circ$ from the launch azimuth and the half-circle arc located uprange from the launch point.

(B) An applicant shall define the downrange boundary with a half-circle arc of radius D_{max} and a chord of length twice D_{max} connecting the half-circle arc endpoints. The downrange boundary placement on a map has the chord midpoint intersecting the nominal flight azimuth line at a distance D_{OEZ} inches downrange with the chord oriented along an azimuth $\pm 90^\circ$ from the launch azimuth and the half-circle arc located downrange from the intersection of the chord and the flight azimuth line.

(C) Crossrange boundaries of an overflight exclusion zone are defined by two line segments. Each is parallel to the flight azimuth with one to the left side and one to the right side of the flight azimuth line. Each line connects an uprange half-circle arc endpoint to a downrange half-circle arc endpoint as shown in figure A-1.

(iii) An applicant shall identify the overflight exclusion zone on a map that meets the requirements of paragraph (b).

(3) An applicant shall define and map a flight corridor using the following method:

(i) In accordance with paragraph (b), an applicant shall draw a flight corridor on one or more maps with the D_{max} origin centered on the intended launch point and the flight corridor centerline (in the downrange direction) aligned with the initial flight azimuth. The flight corridor is depicted in figure A-2 and its line segment lengths are tabulated in table A-3.

(ii) An applicant shall define the flight corridor using the following boundary definitions:

(A) An applicant shall draw an uprange boundary, which is defined by an arc-line GB (figure A-2), directly uprange from and centered on the intended launch point with radius D_{max} .

(B) An applicant shall draw line CF perpendicular to and centered on the flight azimuth line, and positioned 10 nm downrange from the launch point. The applicant shall use the length of line CF provided in table A-3 corresponding to the guided suborbital launch

vehicle or orbital launch vehicle class selected in paragraph (c)(1)(i).

(C) An applicant shall draw line DE perpendicular to and centered on the flight azimuth line, and positioned 100 nm downrange from the launch point. The applicant shall use the length of line DE provided in table A-3 corresponding to the guided suborbital launch vehicle or orbital launch vehicle class selected in paragraph (c)(1)(i).

(D) Except for a guided suborbital launch vehicle, an applicant shall draw a downrange boundary, which is defined by line HI and is drawn perpendicular to and centered on the flight azimuth line, and positioned 5,000 nm downrange from the launch point. The applicant shall use the length of line HI provided in table A-3 corresponding to the orbital launch vehicle class selected in paragraph (c)(1)(i).

(E) An applicant shall draw crossrange boundaries, which are defined by three lines on the left side and three lines on the right side of the flight azimuth. An applicant shall construct the left flight corridor boundary according to the following, and as depicted in figure A-3 :

(1) The first line (line BC in figure A-3) is tangent to the uprange boundary arc, and ends at endpoint C of line CF, as depicted in figure A-3;

(2) The second line (line CD in figure A-3) begins at endpoint C of line BC and ends at endpoint D of line DH, as depicted in figure A-3;

(3) For all orbital launch vehicles, the third line (line DH in figure A-3) begins at endpoint D of line CD and ends at endpoint H of line HI, as depicted in figure A-3; and

(4) For a guided suborbital launch vehicle, the line DH begins at endpoint D of line CD and ends at a point tangent to the impact dispersion area drawn in accordance with paragraph (c)(4) and as depicted in figure A-4.

(F) An applicant shall repeat the procedure in paragraph (c)(3)(ii)(E) for the right side boundary.

(iii) An applicant shall identify the flight corridor on a map that meets the requirements of paragraph (b).

(4) For a guided suborbital launch vehicle, an applicant shall define a final stage impact dispersion area as part of the flight corridor and show the impact dispersion area on a map, as depicted in figure A-4, in accordance with the following:

(i) An applicant shall select an apogee altitude (H_{ap}) for the launch vehicle final stage. The apogee altitude should equal the highest altitude intended to be reached by a guided suborbital launch vehicle launched from the launch point.

(ii) An applicant shall define the impact dispersion area by using an impact range factor $[IP(H_{ap})]$ and a dispersion factor $[DISP(H_{ap})]$ as shown below:

(A) An applicant shall calculate the impact range (D) for the final launch vehicle stage. An applicant shall set D equal to the maximum apogee altitude (H_{ap}) multiplied by the impact range factor as shown below:

$$D = H_{ap} \cdot IP(H_{ap}) \quad (\text{Equation A40})$$

where: $IP(H_{ap}) = 0.4$ for an apogee less than 100 km; and $IP(H_{ap}) = 0.7$ for an apogee 100 km or greater.

(B) An applicant shall calculate the impact dispersion radius (R) for the final launch vehicle stage. An applicant shall set R equal to the maximum apogee altitude (H_{ap}) multiplied by the dispersion factor as shown below:

$$R = H_{ap} \cdot DISP(H_{ap}) \quad (\text{Equation A41})$$

where: $DISP(H_{ap}) = 0.05$

(iii) An applicant shall draw the impact dispersion area on a map with its center on

the predicted impact point. An applicant shall then draw line DH in accordance with paragraph (c)(3)(ii)(E)(4).

(d) Evaluate the Flight Corridor

(1) An applicant shall evaluate the flight corridor for the presence of any populated areas. If an applicant determines that no populated area is located within the flight corridor, then no additional steps are necessary.

(2) If a populated area is located in an overflight exclusion zone, an applicant may modify its proposal or demonstrate that there are times when no people are present or that the applicant has an agreement in place to evacuate the public from the overflight exclusion zone during a launch.

(3) If a populated area is located within the flight corridor, an applicant may modify its proposal and create another flight corridor pursuant to appendix A, use appendix B to narrow the flight corridor, or complete a risk analysis in accordance with appendix C.

TABLE A–1—DEBRIS DISPERSION RADIUS (D_{max}) (IN)

Orbital launch vehicles				Suborbital launch vehicles
Small	Medium	Medium large	Large	Guided
87,600 (1.20 nm)	111,600 (1.53 nm)	127,200 (1.74 nm)	156,000 (2.14 nm)	96,000 (1.32 nm)

TABLE A–2—OVERFLIGHT EXCLUSION ZONE DOWNRANGE DISTANCE (D_{ocz}) (IN)

Orbital launch vehicles				Suborbital launch vehicles
Small	Medium	Medium large	Large	Guided
240,500 (3.30 nm)	253,000 (3.47 nm)	310,300 (4.26 nm)	937,700 (12.86 nm)	232,100 (3.18 nm)

Table A-3: Flight Corridor Line Segment Lengths

D_{max} (in)		Line Segment Lengths (x 10^6 inches)		
Orbital Launch Vehicles		\overline{CF}	\overline{DE}	\overline{HI}
Small	87600 (1.20 nm)	2.87620 (39.45 nm)	8.59452 (117.87 nm)	128.566 (1763.27 nm)
Medium	111,600 (1.53 nm)	2.97220 (40.76 nm)	8.64252 (118.53 nm)	128.566 (1763.27 nm)
Med-Large	127,200 (1.74 nm)	3.03460 (41.62 nm)	8.67372 (118.96 nm)	128.566 (1763.27 nm)
Large	156,000 (2.14 nm)	3.14979 (43.20 nm)	8.73131 (119.75 nm)	128.566 (1763.27 nm)
Suborbital Launch Vehicles		\overline{CF}	\overline{DE}	\overline{HI}
Guided	96,000 (1.32 nm)	2.90980 (39.91 nm)	8.61132 (118.10 nm)	N/A

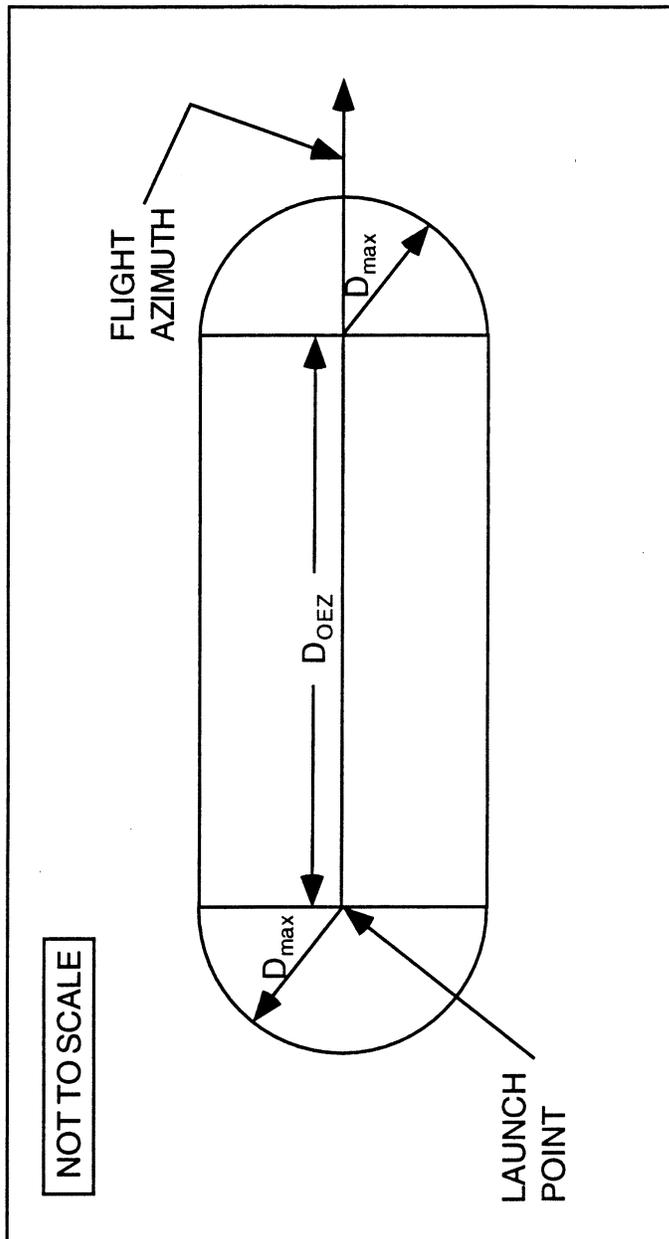


Figure A-1
Overflight Exclusion Zone

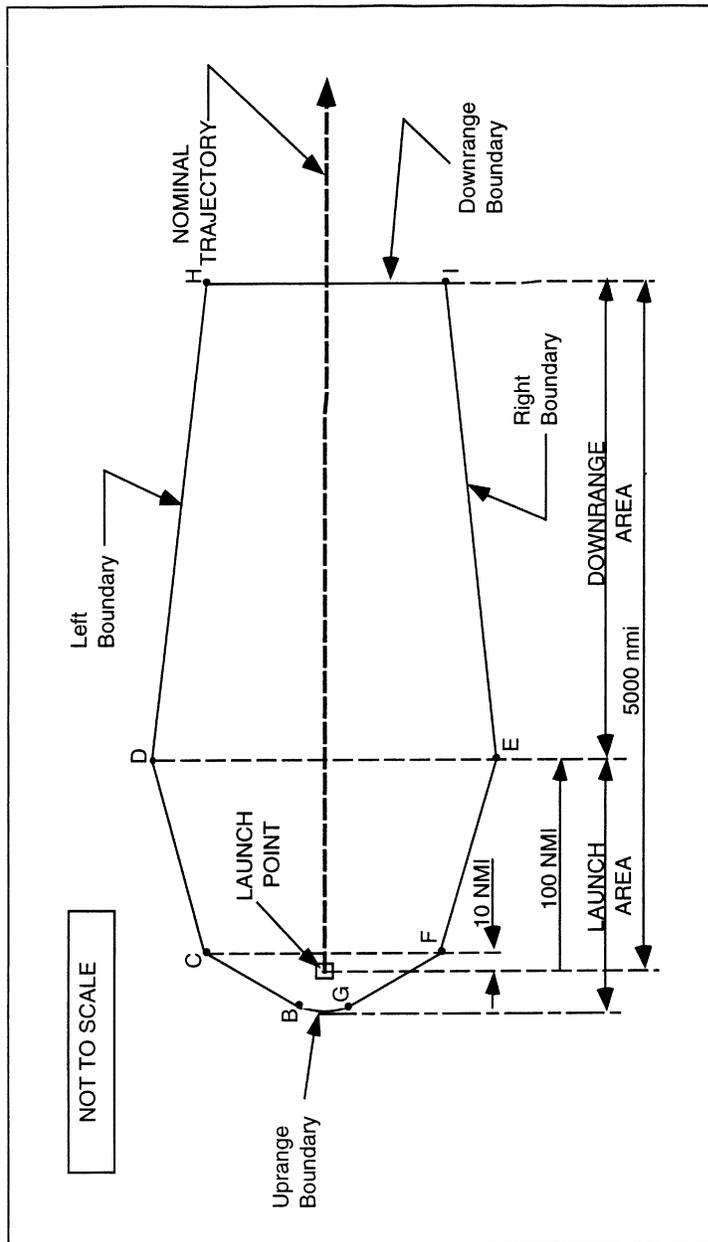


Figure A-2
Flight Corridor

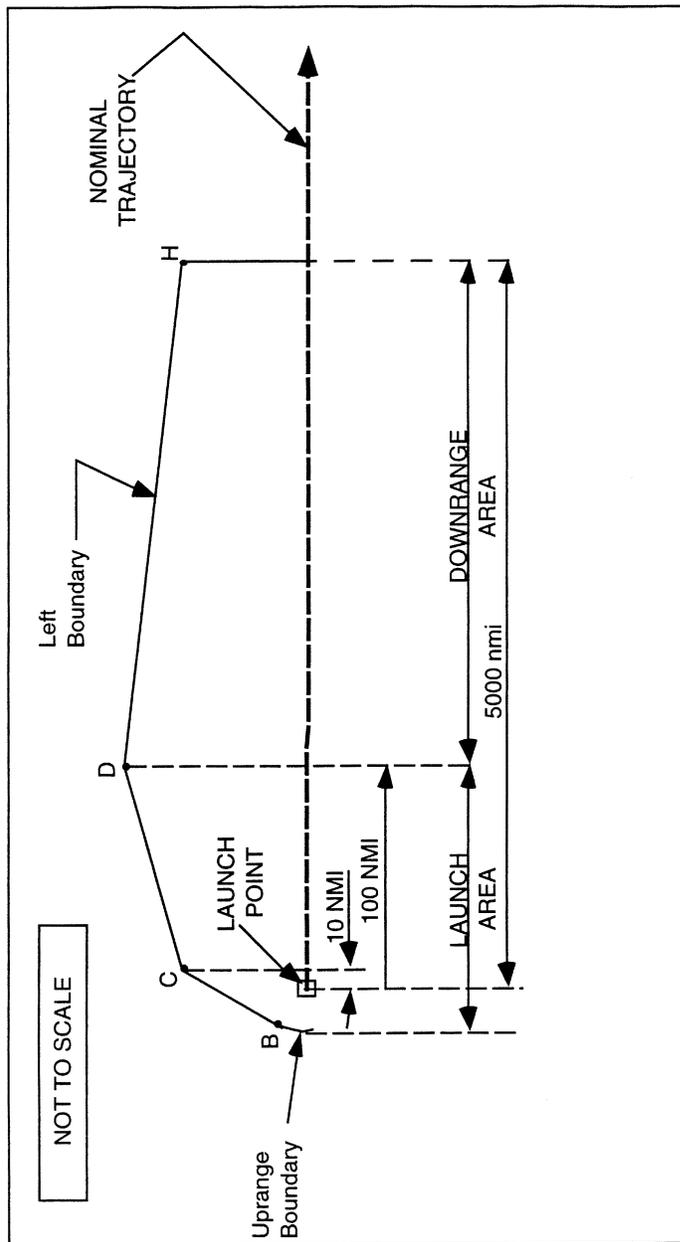


Figure A-3
Construction of Left Boundary of Flight Corridor

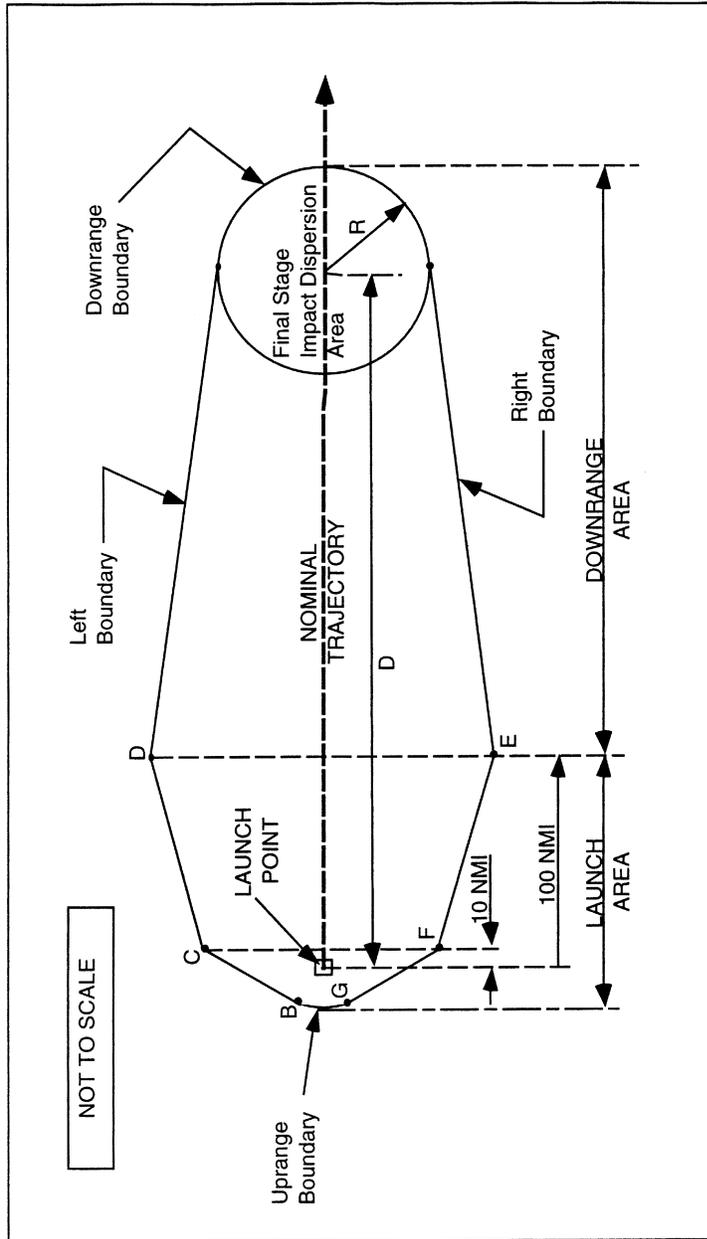


Figure A-4
Flight Corridor for Guided Sub-Orbital Launch Vehicles

APPENDIX B TO PART 420—METHOD FOR DEFINING A FLIGHT CORRIDOR

(a) Introduction

(1) This appendix provides a method to construct a flight corridor from a launch point for a guided suborbital launch vehicle or any one of the four weight classes of guided orbital launch vehicles from table 1, §420.19, using local meteorological data and a launch vehicle trajectory.

(2) A flight corridor is constructed in two sections—one section comprising a launch area and one section comprising a downrange area. The launch area of a flight corridor reflects the extent of launch vehicle debris impacts in the event of a launch vehicle failure and applying local meteorological conditions. The downrange area reflects the extent of launch vehicle debris impacts in the event of a launch vehicle failure and applying vehicle imparted velocity, malfunctions turns, and vehicle guidance and performance dispersions.

(3) A flight corridor includes an overflight exclusion zone in the launch area and, for a guided suborbital launch vehicle, an impact dispersion area in the downrange area. A flight corridor for a guided suborbital launch vehicle ends with an impact dispersion area and, for the four classes of guided orbital launch vehicles, 5,000 nautical miles (nm) from the launch point, or where the IIP leaves the surface of the Earth, whichever is shorter.

(b) Data Requirements

(1) Launch area data requirements. An applicant shall satisfy the following data requirements to perform the launch area analysis of this appendix. The data requirements are identified in table B-1 along with sources where data acceptable to the FAA may be obtained.

(i) An applicant must select meteorological data that meet the specifications in table B-1 for the proposed launch site.

TABLE B-1—LAUNCH AREA DATA REQUIREMENTS

Data category	Data item	Data source
Meteorological Data	Local statistical wind data as a function of altitude up to 50,000 feet. Required data include: altitude (ft), atmospheric density (slugs/ft ³), mean East/West meridional (u) and North/South zonal (v) wind (ft/sec), standard deviation of u and v wind (ft/sec), correlation coefficient, number of observations and wind percentile (%).	These data may be obtained from: Global Gridded Upper Air Statistics, Climate Applications Branch National Climatic Data Center.
Nominal Trajectory Data	State vector data as function of time after liftoff in topocentric launch point centered X,Y,Z,X,Y,Z coordinates with the X-axis aligned with the flight azimuth. Trajectory time intervals shall not be greater than one second. XYZ units are in feet and X,Y,Z units are in ft/sec.	Actual launch vehicle trajectory data; or trajectory generation software that meets the requirements of paragraph (b)(1)(ii).
Debris Data	A fixed ballistic coefficient equal to 3 lbs/ft ² is used for the launch area.	N/A.
Geographical Data	Launch point geodetic latitude on a WGS-84 ellipsoidal Earth model. Launch point longitude on an ellipsoidal Earth model. Maps using scales of not less than 1:250,000 inches per inch within 100 nm of a launch point and 1:20,000,000 inches per inch for distances greater than 100 nm from a launch point.	Geographical surveys or Global Positioning System. Map types with scale and projection information are listed in the Defense Mapping Agency, Public Sale, Aeronautical Charts and Publications Catalog. The catalog and maps may be ordered through the U.S. Dept. of Commerce, National Oceanic and Atmospheric Administration, National Ocean Service.

(ii) For a guided orbital launch vehicle, an applicant shall obtain or create a launch vehicle nominal trajectory. An applicant may use trajectory data from a launch vehicle manufacturer or generate a trajectory using trajectory simulation software. Trajectory time intervals shall be no greater than one

second. If an applicant uses a trajectory computed with commercially available software, the software must calculate the trajectory using the following parameters, or clearly and convincingly demonstrated equivalents:

(A) Launch location:

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(1) Launch point, using geodetic latitude and longitude to four decimal places; and

(2) Launch point height above sea level.

(B) Ellipsoidal Earth:

(1) Mass of Earth;

(2) Radius of Earth;

(3) Earth flattening factor; and

(4) Gravitational harmonic constants (J2, J3, J4).

(C) Vehicle characteristics:

(1) Mass as a function of time;

(2) Thrust as a function of time;

(3) Specific impulse (I_{sp}) as a function of time; and

(4) Stage dimensions.

(D) Launch events:

(1) Stage burn times; and

(2) Stage drop-off times.

(E) Atmosphere:

(1) Density as a function of altitude;

(2) Pressure as a function of altitude;

(3) Speed of sound as a function of altitude; and

(4) Temperature as a function of altitude.

(F) Winds:

(1) Wind direction as a function of altitude; and

(2) Wind magnitude as a function of altitude.

(I) Aerodynamics: drag coefficient as a function of mach number for each stage of flight showing subsonic, transonic and supersonic mach regions for each stage.

(iii) An applicant shall use a ballistic coefficient (β) of 3 lbs/ft² for debris impact computations.

(iv) An applicant shall satisfy the map and plotting requirements for a launch area of appendix A, paragraph (b).

(2) Downrange area data requirements. An applicant shall satisfy the following data requirements to perform the downrange area analysis of this appendix.

(i) The launch vehicle weight class and method of generating a trajectory used in the launch area shall be used by an applicant in the downrange area as well. Trajectory time intervals must not be greater than one second.

(ii) An applicant shall satisfy the map and plotting data requirements for a downrange area of appendix A, paragraph (b).

(c) Construction of a Launch Area of a Flight Corridor

(1) An applicant shall construct a launch area of a flight corridor using the processes and equations of this paragraph for each trajectory position. An applicant shall repeat these processes at time points on the launch vehicle trajectory for time intervals of no greater than one second. When choosing wind data, an applicant shall use a time period of between one and 12 months.

(2) A launch area analysis must include all trajectory positions whose Z-values are less than or equal to 50,000 ft.

(3) Each trajectory time is denoted by the subscript “i”. Height intervals for a given atmospheric pressure level are denoted by the subscript “j”.

(4) Using data from the GGUAS CD-ROM, an applicant shall estimate the mean atmospheric density, maximum wind speed, height interval fall times and height interval debris dispersions for 15 mean geometric height intervals.

(i) The height intervals in the GGUAS source data vary as a function of the following 15 atmospheric pressure levels expressed in millibars: surface, 1000, 850, 700, 500, 400, 300, 250, 200, 150, 100, 70, 50, 30, 10. The actual geometric height associated with each pressure level varies depending on the time of year. An applicant shall estimate the mean geometric height over the period of months selected in subparagraph (1) of this paragraph for each of the 15 pressure levels as shown in equation B1.

$$\bar{H}_j = \frac{\sum_{m=1}^k h_m \cdot n_m}{\sum_{m=1}^k n_m} \quad \text{(Equation B1)}$$

where:

\bar{H}_j = mean geometric height h_m = geometric height for a given month n_m = number of observations for a given month

k = number of wind months of interest

(ii) The atmospheric densities in the source data also vary as a function of the 15 atmospheric pressure levels. The actual atmospheric density associated with each pressure level varies depending on the time of year. An applicant shall estimate the mean atmospheric density over the period of months selected in accordance with subparagraph (1) of this paragraph for each of the 15 pressure levels as shown in equation B2.

$$\bar{\rho}_j = \frac{\sum_{m=1}^k \rho_m \cdot n_m}{\sum_{m=1}^k n_m} \quad \text{(Equation B2)}$$

where:

ρ_j = mean atmospheric density

$\bar{\rho}_m$ = atmospheric density for a given month n_m = number of observations for a given month

k = number of wind months of interest

(iii) An applicant shall estimate the algebraic maximum wind speed at a given pressure level as follows and shall repeat the process for each pressure level.

(A) For each month, an applicant shall calculate the monthly mean wind speed (\bar{W}_{az}) for 360 azimuths using equation B3;

(B) An applicant shall select the maximum monthly mean wind speed from the 360 azimuths;

(C) An applicant shall repeat subparagraphs (c)(4)(iii)(A) and (B) for each month of interest; and

(D) An applicant shall select the maximum mean wind speed from the range of months. The absolute value of this wind is designated W_{max} for the current pressure level.

(iv) An applicant shall calculate wind speed using the means for winds from the West (u) and winds from the North (v). An applicant shall use equation B3 to resolve the winds to a specific azimuth bearing.

$$\bar{W}_{az} = u \cdot \cos(90 - az) + v \cdot \sin(90 - az) \quad (\text{Equation B3})$$

where:

az = wind azimuth
 u = West zonal wind component
 v = North zonal wind component
 \bar{W}_{az} = mean wind speed at azimuth for each month

(v) An applicant shall estimate the interval fall time over a height interval assuming the initial descent velocity is equal to the terminal velocity (V_{Tj}). An applicant shall use equations B4 through B6 to estimate the fall time over a given height interval.

$$\Delta H_j = \bar{H}_{j+1} - \bar{H}_j \quad (\text{Equation B4})$$

$$V_{Tj} = \left[\frac{2 \cdot \beta}{\frac{(\bar{\rho}_{j+1} + \bar{\rho}_j)}{2}} \right]^{0.5} \quad (\text{Equation B5})$$

$$t_j = \frac{\Delta H_j}{V_{Tj}} \quad (\text{Equation B6})$$

where:

ΔH_{Tj} = height difference between two mean geometric heights
 β = ballistic coefficient
 $\bar{\rho}_x$ = mean atmospheric density for the corresponding mean geometric heights
 V_{Tj} = terminal velocity

(vi) An applicant shall estimate the interval debris dispersion (D_j) by multiplying the interval fall time by the algebraic maximum mean wind speed (W_{max}) as shown in equation B7.

$$D_j = t_j \cdot W_{max} \quad (\text{Equation B7})$$

(5) Once the D_j are estimated for each height interval, an applicant shall determine the total debris dispersion (D_i) for each Z_i using a linear interpolation and summation exercise, as shown below in equation B8. An applicant shall use a launch point height of zero equal to the surface level of the nearest GGUAS grid location.

$$D_i = D_j \cdot \left(\frac{Z_i - \bar{H}_i}{\bar{H}_{j+1} - \bar{H}_i} \right) + \sum_{n=1}^{j-1} D_n \quad (\text{Equation B8})$$

where:

n = number of height intervals below jth height interval

(6) Once all the D_i radii have been calculated, an applicant shall produce a launch area flight corridor in accordance with the requirements of subparagraphs (c)(6)(i)–(iv).

(i) On a map meeting the requirements of appendix A, paragraph (b), an applicant shall plot the X_i position location on the flight azimuth for the corresponding Z_i position;

(ii) An applicant shall draw a circle of radius D_i centered on the corresponding X_i position; and

(iii) An applicant shall repeat the instructions in subparagraphs (c)(6)(i)–(ii) for each D_i radius.

(iv) The launch area of a flight corridor is the enveloping line that encloses the outer boundary of the D_i circles as shown in Fig. B-1. The uprange portion of a flight corridor is described by a semi-circle arc that is a

portion of either the most uprange D_i dispersion circle, or the overflight exclusion zone (defined by subparagraph (c)(7)), whichever is further uprange.

(7) An applicant shall define an overflight exclusion zone in the launch area in accord-

ance with the requirements of appendix A, subparagraph (c)(2).

(8) An applicant shall draw the launch area flight corridor and overflight exclusion zone on a map or maps that meet the requirements of table B-1.

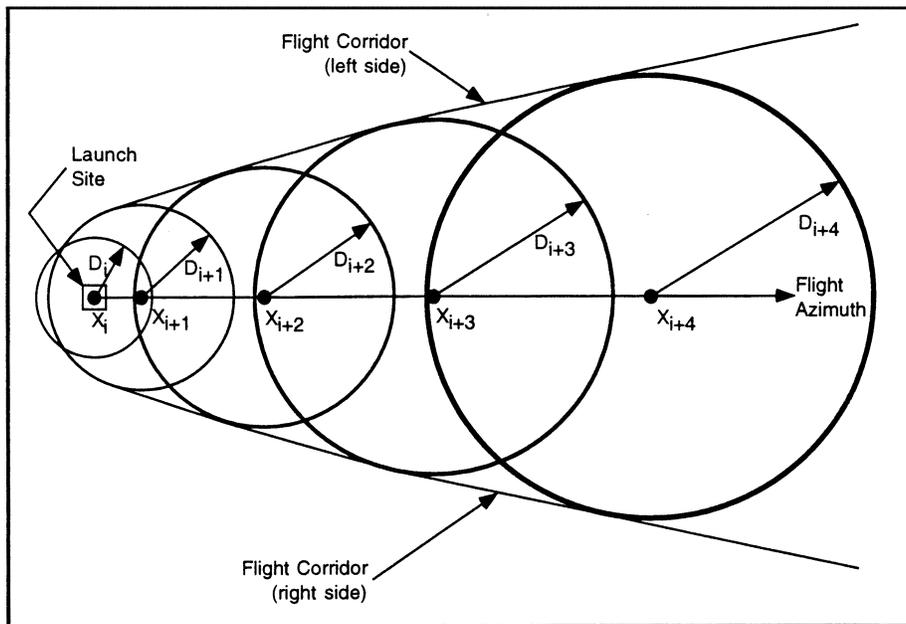


Figure B - 1: Launch Area of a Flight Corridor

(d) Construction of a Downrange Area of a Flight Corridor

(1) The downrange area analysis estimates the debris dispersion for the downrange time points on a launch vehicle trajectory. An applicant shall perform the downrange area analysis using the processes and equations of this paragraph.

(2) The downrange area analysis shall include trajectory positions at a height (the Z_i -values) greater than 50,000 feet and nominal trajectory IIP values less than or equal to 5,000 nm. For a guided suborbital launch vehicle, the final IIP value for which an applicant must account is the launch vehicle final stage impact point. Each trajectory time shall be one second or less and is denoted by the subscript 'i'.

(3) An applicant shall compute the downrange area of a flight corridor boundary in four steps, from each trajectory time increment: determine a reduction ratio factor; calculate the launch vehicle position after

simulating a malfunction turn; rotate the state vector after the malfunction turn in the range of three degrees to one degree as a function of X_i distance downrange; and compute the IIP of the resulting trajectory. The locus of IIPs describes the boundary of the downrange area of a flight corridor. An applicant shall use the following subparagraphs, (d)(3)(i)-(v), to compute the downrange area of the flight corridor boundary:

(i) Compute the downrange Distance to the final IIP position for a nominal trajectory as follows:

(A) Using equations B30 through B69, determine the IIP coordinates $(\phi_{max}, \lambda_{max})$ for the nominal state vector before the launch vehicle enters orbit where α in equation B30 is the nominal flight azimuth angle measured from True North.

(B) Using the range and bearing equations of appendix A, paragraph (b)(3), determine

the distance (S_{max}) from the launch point coordinates (ϕ_{lp}, λ_{lp}) to the IIP coordinates ($\phi_{max}, \lambda_{max}$) computed in accordance with (3)(i)(A) of this paragraph.

(C) The distance for S_{max} may not exceed 5000 nm. In cases when the actual value exceeds 5000 nm the applicant shall use 5000 nm for S_{max} .

(ii) Compute the reduction ratio factor (F_{ri}) for each trajectory time increment as follows:

(A) Using equations B30 through B69, determine the IIP coordinates (ϕ_i, λ_i) for the nominal state vector where α in equation B30 is the nominal flight azimuth angle measured from True North.

(B) Using the range and bearing equations of appendix A, paragraph (b)(3), determine the distance (S_i) from the launch point co-

ordinates (ϕ_{lp}, λ_{lp}) to the IIP coordinates (ϕ_i, λ_i) computed in (3)(ii)(A) of this paragraph.

(C) The reduction ratio factor is:

$$F_{ri} = \left(1 - \frac{S_i}{S_{max}} \right) \quad \text{(Equation B9)}$$

(iii) An applicant shall compute the launch vehicle position and velocity components after a simulated malfunction turn for each X_i using the following method.

(A) Turn duration (Δt) = 4 sec.

(B) Turn angle (θ)

$$\theta = (F_{ri}) * 45 \text{ degrees.} \quad \text{(Equation B10)}$$

The turn angle equations perform a turn in the launch vehicle's yaw plane, as depicted in figure B-2.

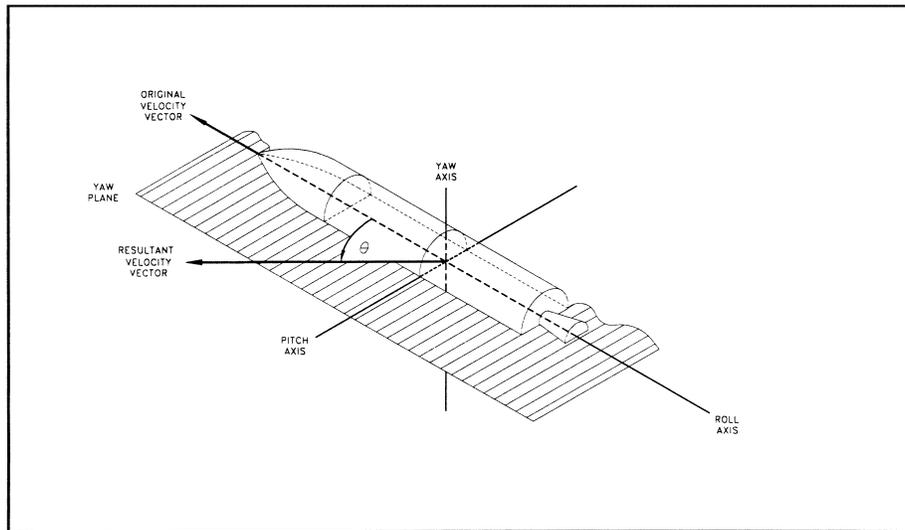


Figure B-2: Velocity Vector Turn Angle in Yaw Plane

(C) Launch vehicle velocity magnitude at the beginning of the turn (V_b) and velocity magnitude at the end of the turn (V_e)

$$V_b = \left(\dot{X}_1^2 + \dot{Y}_1^2 + \dot{Z}_1^2 \right)^{0.5} \text{ ft/sec} \quad \text{(Equation B11)}$$

$$V_e = \left(\dot{X}_{i+5}^2 + \dot{Y}_{i+5}^2 + \dot{Z}_{i+5}^2 \right)^{0.5} \text{ ft/sec} \quad \text{(Equation B12)}$$

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(D) Average velocity magnitude over the turn duration (\bar{V})

(E) Velocity vector path angle (γ_i) at turn epoch

$$\bar{V}_i = \frac{(V_b + V_e)}{2} \text{ ft/sec} \quad (\text{Equation B13})$$

$$\gamma_i = \tan^{-1} \left[\frac{\dot{Z}_i}{\left(\begin{matrix} \cdot & \cdot \\ \cdot & \cdot \\ \cdot & \cdot \end{matrix} \right)^{0.5}} \right] \quad (\text{Equation B14})$$

(F) Launch vehicle position components at the end of turn duration

$$X_{90L} = X_i + \bar{V}_i \cdot \Delta t \cdot \cos\left(\frac{-\theta}{2}\right) \cdot \cos(\gamma_i)$$

$$X_{90R} = X_i + \bar{V}_i \cdot \Delta t \cdot \cos\left(\frac{\theta}{2}\right) \cdot \cos(\gamma_i)$$

$$Y_{90L} = Y_i + \bar{V}_i \cdot \Delta t \cdot \sin\left(\frac{-\theta}{2}\right)$$

$$Y_{90R} = Y_i + \bar{V}_i \cdot \Delta t \cdot \sin\left(\frac{\theta}{2}\right)$$

$$Z_{90L} = Z_i + \bar{V}_i \cdot \Delta t \cdot \cos\left(\frac{-\theta}{2}\right) \cdot \sin(\gamma_i) - \left(\frac{1}{2}\right) \cdot g_1 \cdot \Delta t^2 \quad (\text{Equations B15 - B20})$$

$$Z_{90R} = Z_i + \bar{V}_i \cdot \Delta t \cdot \cos\left(\frac{\theta}{2}\right) \cdot \sin(\gamma_i) - \left(\frac{1}{2}\right) \cdot g_1 \cdot \Delta t^2$$

where: $g_1 = 32.17405 \text{ ft/sec}^2$

(G) Launch vehicle velocity components at the end of turn duration

$$\begin{aligned} \dot{X}_{90L} &= (X_{90L} - X_i) / \Delta t \\ \dot{X}_{90R} &= (X_{90R} - X_i) / \Delta t \\ \dot{Y}_{90L} &= |(Y_{90L} - Y_i) / \Delta t| \\ \dot{Y}_{90R} &= (-1) \cdot |(Y_{90R} - Y_i) / \Delta t| \quad (\text{Equations B21 - B26}) \\ \dot{Z}_{90L} &= (Z_{90L} - Z_i) / \Delta t \\ \dot{Z}_{90R} &= (Z_{90R} - Z_i) / \Delta t \end{aligned}$$

(iv) An applicant shall rotate the trajectory state vector at the end of the turn duration to the right and left to define the right-lateral flight corridor boundary and the left-lateral flight corridor boundary, respectively. An applicant shall perform the trajectory rotation in conjunction with a trajectory transformation from the X_{90} , Y_{90} , Z_{90} , \dot{X}_{90} , \dot{Y}_{90} , \dot{Z}_{90} , components to E, N, U, E, N, U. The trajectory subscripts "R" and "L" from

equations B15 through B26 have been discarded to reduce the number of equations. An applicant shall transform from to E,N,U,E,N,U to E,F,G,E,F,G. An applicant shall use the equations of paragraph (d)(3)(iv)(A)-(F) to produce the EFG components necessary to estimate each instantaneous impact point.

(A) An applicant must calculate the flight angle (α)

$$\Delta\alpha_i = 3 - 2 \cdot f_1 \cdot (1 - F_{ri}) \quad (\text{Equation B27})$$

$$\alpha_{Li} = (\text{Flight Azimuth} - \Delta\alpha_i)$$

for left lateral boundary computations (Equation B28)

-OR

$$\alpha_{Ri} = (\text{Flight Azimuth} - \Delta\alpha_i)$$

for right lateral boundary computations (Equation B29)

where: $f_1 = \begin{cases} 0.0: F_{ri} \geq 0.8 \\ 1.0: F_{ri} < 0.8 \end{cases}$

(B) An applicant shall transform X_{90}, Y_{90}, Z_{90} to E,N,U

$$\begin{aligned} E &= X_{90} \sin(\alpha) - Y_{90} \cos(\alpha) \\ N &= X_{90} \cos(\alpha) + Y_{90} \sin(\alpha) \quad (\text{Equations B30 - B32}) \\ U &= Z_{90} \end{aligned}$$

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(C) An applicant shall transform to \dot{X}_{90} , \dot{Y}_{90} , \dot{Z}_{90} to \dot{E} , \dot{N} , \dot{U} .

$$\begin{aligned}\dot{E} &= \dot{X}_{90} \sin(\alpha) - \dot{Y}_{90} \cos(\alpha) \\ \dot{N} &= \dot{X}_{90} \cos(\alpha) + \dot{Y}_{90} \sin(\alpha) \quad (\text{Equations B33 - B35}) \\ \dot{U} &= \dot{Z}_{90}\end{aligned}$$

(D) An applicant shall transform the launch point coordinates (ϕ_0, λ_0, h_0) to E_0, F_0, G_0

$$\begin{aligned}\text{where: } R &= a_E \left\{ 1 - e^2 \left[\sin^2(\phi_0) \right] \right\}^{-0.5} \\ a_E &= 20925646.3255 \text{ ft} \\ e^2 &= 0.00669437999013 \\ E_0 &= (R + h_0) \cos(\phi_0) \cos(\lambda_0) \quad (\text{Equations B36 - B39}) \\ F_0 &= (R + h_0) \cos(\phi_0) \sin(\lambda_0) \\ G_0 &= \left[R(1 - e^2) + h_0 \right] \sin(\phi_0)\end{aligned}$$

(E) An applicant shall transform E, N, U to E_{90}, F_{90}, G_{90}

$$\begin{aligned}E_{90} &= E \cos(270 - \lambda_0) + N \cos(90 - \phi_0) \sin(270 - \lambda_0) - U \sin(90 - \phi_0) \sin(270 - \lambda_0) \quad (\text{Equations B40 - B42}) \\ F_{90} &= E \sin(270 - \lambda_0) + N \cos(90 - \phi_0) \cos(270 - \lambda_0) - U \sin(90 - \phi_0) \cos(270 - \lambda_0) \\ G_{90} &= N \sin(90 - \phi_0) + U \cos(90 - \phi_0) + G_0\end{aligned}$$

(F) An applicant shall transform to $\dot{E}, \dot{N}, \dot{U}$
TO E, F, G

$$\begin{aligned}\dot{E}_{90} &= \dot{E} \cos(270 - \lambda_0) + \dot{N} \cos(90 - \phi_0) \sin(270 - \lambda_0) - \dot{U} \sin(90 - \phi_0) \sin(270 - \lambda_0) \quad (\text{Equations B43 - B45}) \\ \dot{F}_{90} &= \dot{E} \sin(270 - \lambda_0) + \dot{N} \cos(90 - \phi_0) \cos(270 - \lambda_0) - \dot{U} \sin(90 - \phi_0) \cos(270 - \lambda_0) \\ \dot{G}_{90} &= \dot{N} \sin(90 - \phi_0) + \dot{U} \cos(90 - \phi_0)\end{aligned}$$

(v) The IIP computation implements an iterative solution to the impact point problem. An applicant shall solve equations B46

through B69, with the appropriate substitutions, up to a maximum of five times. Each repetition of the equations provides a more accurate prediction of the IIP. An applicant shall use the required IIP computations of paragraphs (d)(3)(v)(A)-(W) below. An applicant shall use this IIP computation for both the left-and right-lateral offsets. The IIP computations will result in latitude and longitude pairs for the left-lateral flight corridor boundary and the right-lateral flight corridor boundary. An applicant shall

use the lines connecting the latitude and longitude pairs to describe the entire downrange area boundary of the flight corridor up to 5000 nm or a final stage impact dispersion area.

(A) An applicant shall approximate the radial distance ($r_{k,l}$) from the geocenter to the IIP. The distance from the center of the Earth ellipsoid to the launch point shall be used for the initial approximation of $r_{k,l}$ as shown in equation B46.

$$r_{k,l} = \left(E_0^2 + F_0^2 + G_0^2 \right)^{0.5} \quad \text{(Equation B46)}$$

(B) An applicant shall compute the radial distance (r) from the geocenter to the launch vehicle position.

$$r = \left(E_{90}^2 + F_{90}^2 + G_{90}^2 \right)^{0.5} \quad \text{(Equation B47)}$$

If $r < r_{k,l}$ then the launch vehicle position is below the Earth's surface and an impact point cannot be computed. An applicant

must restart the calculations with the next trajectory state vector.

(C) An applicant shall compute the inertial velocity components.

$$\begin{aligned} \dot{E}I_{90} &= \dot{E}_{90} - \omega \cdot F_{90} \\ \dot{F}I_{90} &= \dot{F}_{90} + \omega \cdot E_{90} \end{aligned} \quad \text{(Equations B48-B49)}$$

where: $\omega = 4.178074 \times 10^{-3}$ deg/sec

(D) An applicant shall compute the magnitude of the inertial velocity vector.

$$v_0 \left(\dot{E}I_{90}^2 + \dot{F}I_{90}^2 + \dot{G}_{90}^2 \right)^{0.5} \quad \text{(Equation B50)}$$

(E) An applicant shall compute the eccentricity of the trajectory ellipse multiplied by the cosine of the eccentric anomaly at epoch (ϵ_c).

$$\epsilon_c = \left(\frac{r \cdot v_0^2}{K} \right) - 1 \quad \text{(Equation B51)}$$

where: $K = 1.407644 \times 10^{16}$ ft³/sec²

(F) An applicant shall compute the semi-major axis of the trajectory ellipse (a_t).

$$a_t = \frac{r}{1 - \epsilon_c} \quad \text{(Equation B52)}$$

If $a_t > 0$ or a_t , then the trajectory orbit is not elliptical, but is hyperbolic or parabolic, and an impact point cannot be computed. The launch vehicle has achieved escape velocity and the applicant may terminate computations.

(G) An applicant shall compute the eccentricity of the trajectory ellipse multiplied by the sine of the eccentric anomaly at epoch (ϵ_s).

$$\epsilon_s = \frac{(E_{90}\dot{E}I_{90} + F_{90}\dot{F}I_{90} + G_{90}\dot{G}_{90})}{(K \cdot a_t)^{0.5}} \quad (\text{Equation B53})$$

(H) An applicant shall compute the eccentricity of the trajectory ellipse squared (ϵ^2).

$$\epsilon^2 = (\epsilon_c^2 + \epsilon_s^2) \quad (\text{Equation B54})$$

If $a_t(1-\epsilon) - a_E] > 0$ and $\epsilon \geq 0$ then the trajectory perigee height is positive and an impact point cannot be computed. The launch vehicle has achieved Earth orbit and the applicant may terminate computations.

(I) An applicant shall compute the eccentricity of the trajectory ellipse multiplied by the cosine of the eccentric anomaly at impact (ϵ_{c_k}).

$$\epsilon_{c_k} = \frac{(a_t - r_{k,1})}{a_t} \quad (\text{Equation B55})$$

(J) An applicant shall compute the eccentricity of the trajectory ellipse multiplied by the sine of the eccentric anomaly at impact (ϵ_{s_k}).

$$\epsilon_{s_k} = -(\epsilon^2 - \epsilon_{c_k}^2)^{0.5} \quad (\text{Equation B56})$$

If $\epsilon_{s_k} < 0$ then the trajectory orbit does not intersect the Earth's surface and an impact point cannot be computed. The launch vehicle has achieved Earth orbit and the applicant may terminate computations.

(K) An applicant shall compute the cosine of the difference between the eccentric anomaly at impact and the eccentric anomaly at epoch ($\Delta\epsilon_{c_k}$).

$$\Delta\epsilon_{c_k} = \frac{(\epsilon_{c_k} \cdot \epsilon_c) + (\epsilon_{s_k} \cdot \epsilon_s)}{\epsilon^2} \quad (\text{Equation B57})$$

(L) An applicant shall compute the sine of the difference between the eccentric anomaly at impact and the eccentric anomaly at epoch ($\Delta\epsilon_{s_k}$).

$$\Delta\epsilon_{s_k} = \frac{(\epsilon_{s_k} \cdot \epsilon_c) - (\epsilon_{c_k} \cdot \epsilon_s)}{\epsilon^2} \quad (\text{Equation B58})$$

(M) An applicant shall compute the f-series expansion of Kepler's equations.

$$f_2 = \frac{(\Delta\epsilon_{c_k} - \epsilon_c)}{(1 - \epsilon_c)} \quad (\text{Equation B59})$$

(N) An applicant shall compute the g-series expansion of Kepler's equations.

$$g_2 = (\Delta\epsilon_{s_k} + \epsilon_s - \epsilon_{s_k}) \left(\frac{a_t^3}{K} \right)^{0.5} \quad (\text{Equation B60})$$

(O) An applicant shall compute the E,F,G coordinates at impact (E_i, F_i, G_i).

$$\begin{aligned} E_k &= f_2 \cdot E_{90} + g_2 \cdot \dot{E}l_{90} \\ F_k &= f_2 \cdot F_{90} + g_2 \cdot \dot{F}l_{90} \\ G_k &= f_2 \cdot G_{90} + g_2 \cdot \dot{G}l_{90} \end{aligned} \quad \text{(Equations B61-B63)}$$

(P) An applicant shall approximate the distance from the geocenter to the launch vehicle position at impact ($r_{k,2}$).

$$r_{k,2} = \frac{a_E}{\left[\left(\frac{e^2}{1-e^2} \right) \left(\frac{G_k}{r_{k,1}} \right)^2 + 1 \right]^{0.5}} \quad \text{(Equation B64)}$$

where:

$$\begin{aligned} a_E &= 20925646.3255 \text{ ft} \\ e^2 &= 0.00669437999013 \end{aligned}$$

(Q) An applicant shall let $r_{k+1,1} = r_{k,2}$, substitute $r_{k+1,1}$ for $r_{k,1}$ in equation B55 and repeat equations B55–B64 up to four more times increasing ‘‘k’’ by an increment of one on each loop (e.g. $k \in \{1, 2, 3, 4, 5\}$). If $|r_{s,1} - r_{s,2}| > 1$ then the iterative solution does not converge and an impact point does not meet the accuracy tolerance of plus or minus one foot. An applicant must try more iterations, or re-

start the calculations with the next trajectory state vector.

(R) An applicant shall compute the difference between the eccentric anomaly at impact and the eccentric anomaly at epoch ($\Delta\varepsilon$).

$$\Delta\varepsilon = \tan^{-1} \left(\frac{\Delta\varepsilon_{s_5}}{\Delta\varepsilon_{c_5}} \right) \quad \text{(Equation B65)}$$

(S) An applicant shall compute the time of flight from epoch to impact (t).

$$t = (\Delta\varepsilon + \varepsilon_s - \varepsilon_{s_5}) \left(\frac{a_t^3}{K} \right)^{0.5} \quad \text{(Equation B66)}$$

(T) An applicant shall compute the geocentric latitude at impact (ϕ').

$$\phi'_i = \sin^{-1} \left(\frac{G_5}{r_{5,2}} \right) \quad \text{(Equation B67)}$$

Where: $+90^\circ > \phi'_i > -90^\circ$

(U) An applicant shall compute the geodetic latitude at impact (ϕ).

$$\phi_i = \tan^{-1} \left[\frac{\tan(\phi'_i)}{(1-e^2)} \right] \quad \text{(Equation B68)}$$

Where: $+90^\circ > \phi_i > -90^\circ$

(V) An applicant shall compute the East longitude at impact (λ).

$$\lambda_i = \tan^{-1} \left(\frac{F_5}{E_5} \right) - \omega t \quad \text{(Equation B69)}$$

(W) If the range from the launch point to the impact point is equal to or greater than 5000 nm, an applicant shall terminate IIP computations.

(4) For a guided suborbital launch vehicle, an applicant shall define a final stage impact dispersion area as part of the flight corridor and show the area on a map using the following procedure:

(i) For equation B70 below, an applicant shall use an apogee altitude (H_{ap}) corresponding to the highest altitude reached

by the launch vehicle final stage in the applicant's launch vehicle trajectory analysis done in accordance with paragraph (b)(1)(ii).

(ii) An applicant shall define the final stage impact dispersion area by using a dispersion factor [DISP(H_{ap})] as shown below. An applicant shall calculate the impact dispersion radius (R) for the final launch vehicle stage. An applicant shall set R equal to the maximum apogee altitude (H_{ap}) multiplied by the dispersion factor as shown below:

$$R = H_{ap} \cdot \text{DISP}(H_{ap}) \quad (\text{Equation B70})$$

where: $\text{DISP}(H_{ap}) = 0.05$

(5) An applicant shall combine the launch area and downrange area flight corridor and any final stage impact dispersion area for a guided suborbital launch vehicle.

(i) On the same map with the launch area flight corridor, an applicant shall plot the latitude and longitude positions of the left and right sides of the downrange area of the flight corridor calculated in accordance with subparagraph (d)(3).

(ii) An applicant shall connect the latitude and longitude positions of the left side of the downrange area of the flight corridor sequentially starting with the last IIP calculated on the left side and ending with the first IIP calculated on the left side. An applicant shall repeat this procedure for the right side.

(iii) An applicant shall connect the left sides of the launch area and downrange portions of the flight corridor. An applicant shall repeat this procedure for the right side.

(iv) An applicant shall plot the overflight exclusion zone defined in subparagraph (c)(7).

(v) An applicant shall draw any impact dispersion area on the downrange map with the center of the impact dispersion area on the launch vehicle final stage impact point obtained from the applicant's launch vehicle trajectory analysis done in accordance with subparagraph (b)(1)(ii).

(e) Evaluate the Launch Site

(1) An applicant shall evaluate the flight corridor for the presence of populated areas. If no populated area is located within the flight corridor, then no additional steps are necessary.

(2) If a populated area is located in an overflight exclusion zone, an applicant may modify its proposal or demonstrate that there are times when no people are present or that the applicant has an agreement in place to evacuate the public from the overflight exclusion zone during a launch.

(3) If a populated area is located within the flight corridor, an applicant may modify its proposal or complete an overflight risk analysis in accordance with appendix C.

APPENDIX C TO PART 420—RISK ANALYSIS

(a) Introduction

(1) This appendix provides a method for an applicant to estimate the expected casualty (E_c) for a launch of a guided expendable launch vehicle using a flight corridor generated either by appendix A or appendix B. This appendix also provides an applicant options to simplify the method where population at risk is minimal.

(2) An applicant shall perform a risk analysis when a populated area is located within a flight corridor defined by either appendix A or appendix B. If the estimated expected casualty exceeds 1×10^{-4} , an applicant may either modify its proposal, or if the flight corridor used was generated by the appendix A method, use the appendix B method to narrow the flight corridor and then redo the overflight risk analysis pursuant to this appendix. If the estimated expected casualty still exceeds 1×10^{-4} , the FAA will not approve the location of the proposed launch point.

(b) Data Requirements

(1) An applicant shall obtain the data specified by subparagraphs (b)(2) and (3) and summarized in table C-1. Table C-1 provides sources where an applicant may obtain data acceptable to the FAA. An applicant must also employ the flight corridor information from appendix A or B, including flight azimuth and, for an appendix B flight corridor, trajectory information.

(2) Population data. Total population (N) and the total landmass area within a populated area (A) are required. Population data up to and including 100 nm from the launch point are required at the U.S. census block group level. Population data downrange from 100 nm are required at no greater than $1^\circ \times 1^\circ$ latitude/longitude grid coordinates.

(3) Launch vehicle data. Launch vehicle data consist of the launch vehicle failure probability (P_f), the launch vehicle effective casualty area (A_e), trajectory position data, and the overflight dwell time (t_d). The failure probability is a constant ($P_f = 0.10$) for a guided orbital or suborbital expendable launch vehicle. Table C-3 provides effective casualty area data based on IIP range. Trajectory position information is provided from distance computations provided by this appendix for an appendix A flight corridor, or trajectory data used in appendix B for an appendix B flight corridor. The dwell time (t_d) may be determined from trajectory data produced when creating an appendix B flight corridor.

TABLE C-1—OVERFLIGHT ANALYSIS DATA REQUIREMENTS

Data category	Data item	Data source
Population Data	Total population within a populated area (N)	Within 100 nm of the launch point: U.S. census data at the census block-group level. Downrange from 100 nm beyond the launch point, world population data are available from:
	Total landmass area within the populated area (A)	Carbon Dioxide Information Analysis Center (CDIAC) Oak Ridge National Laboratory Database—Global Population Distribution (1990), Terrestrial Area and Country Name Information on a One by One Degree Grid Cell Basis (DB1016 (8-1996))
Launch Vehicle Data	Failure probability— $P_f = 0.10$	N/A.
	Effective casualty area (A_c)	See table C-3.
	Overflight dwell time	Determined by range from the launch point or trajectory used by applicant.
	Nominal trajectory data (for an appendix B flight corridor only).	See appendix B, table B-1.

(c) Estimating Corridor Casualty Expectation

(1) A corridor casualty expectation [$E_C(\text{Corridor})$] estimate is the sum of the expected casualty measurement of each populated area inside a flight corridor.

(2) An applicant shall identify and locate each populated area in the proposed flight corridor.

(3) An applicant shall determine the probability of impact in each populated area using the procedures in subparagraphs (5) or (6) of this paragraph. Figures C-1 and C-2 illustrate an area considered for probability of impact (P_i) computations by the dashed-lined box around the populated area within a flight corridor, and figure C-3 illustrates a populated area in a final stage impact dispersion area. An applicant shall then estimate the E_C for each populated area in accordance with subparagraphs (7) and (8) of this paragraph.

(4) The P_i computations do not directly account for populated areas whose areas are bisected by an appendix A flight corridor centerline or an appendix B nominal trajectory ground trace. Accordingly, an applicant must evaluate P_i for each of the bi-sections as two separate populated areas, as shown in figure C-4, which shows one bi-section to the left of an appendix A flight corridor's centerline and one to its right.

(5) Probability of impact (P_i) computations for a populated area in an appendix A flight corridor. An applicant shall compute P_i for each populated area using the following method:

(i) For the launch and downrange areas, but not for a final stage impact dispersion area for a guided suborbital launch vehicle, an applicant shall compute P_i for each populated area using the following equation:

$$P_i = \frac{\left(\frac{|y_2 - y_1|}{\sigma_y}\right)}{6\sqrt{2\pi}} \cdot \left(\exp\left(\frac{-\left(\frac{y_1}{\sigma_y}\right)^2}{2}\right) + 4 \cdot \exp\left[\frac{-\left(\frac{y_1 + y_2}{2\sigma_y}\right)^2}{2}\right] + \exp\left(\frac{-\left(\frac{y_2}{\sigma_y}\right)^2}{2}\right) \right) \cdot \left[\frac{P_f \cdot (x_2 - x_1)}{C \cdot R} \right] \quad (\text{Equation C1})$$

where:

x_1, x_2 = closest and farthest downrange distance (nm) along the flight corridor centerline to the populated area (see figure C-1)

y_1, y_2 = closest and farthest cross range distance (nm) to the populated area measured from the flight corridor centerline (see figure C-1)

σ_y = one-third of the cross range distance from the centerline to the flight corridor boundary (see figure C-1)

exp = exponential function (e^x)
 P_f = probability of failure = 0.10
 R = IIP range rate (nm/sec) (see table C-2)
 C = 643 seconds (constant)

TABLE C-2—IIP RANGE RATE VS. IIP RANGE

IIP range (nm)	IIP range rate (nm/s)
0-75	0.75
76-300	1.73
301-900	4.25

TABLE C-2—IIP RANGE RATE VS. IIP RANGE—Continued

IIP range (nm)	IIP range rate (nm/s)
901-1700	8.85
1701-2600	19.75
2601-3500	42.45
3501-4500	84.85
4501-5250	154.95

(ii) For each populated area within a final stage impact dispersion area, an applicant shall compute P_i using the following method:

(A) An applicant shall estimate the probability of final stage impact in the x and y sectors of each populated area within the final stage impact dispersion area using equations C2 and C3:

$$P_x = \left(\frac{|x_2 - x_1|}{\sigma_x} \right) \cdot \left(\exp \left(\frac{-(x_1/\sigma_x)^2}{2} \right) + 4 \cdot \exp \left[\frac{-(x_1 + x_2)^2}{2\sigma_x^2} \right] + \exp \left(\frac{-(x_2/\sigma_x)^2}{2} \right) \right) \quad \text{(Equation C2)}$$

where:

X₁, X₂ = closest and farthest downrange distance, measured along the flight corridor centerline, measured from the nominal

impact point to the populated area (see figure C-3)

σ_x = one-third of the impact dispersion radius (see figure C-3)

exp = exponential function (e^x)

$$P_y = \left(\frac{|y_2 - y_1|}{\sigma_y} \right) \cdot \left(\exp \left(\frac{-(y_1/\sigma_y)^2}{2} \right) + 4 \cdot \exp \left[\frac{-(y_1 + y_2)^2}{2\sigma_y^2} \right] + \exp \left(\frac{-(y_2/\sigma_y)^2}{2} \right) \right) \quad \text{(Equation C3)}$$

where:

y₁, y₂ = closest and farthest cross range distance to the populated area measured from the flight corridor centerline (see figure C-3)

σ_y = one-third of the impact dispersion radius (see figure C-3)

exp = exponential function (e^x)

(B) If a populated area intersects the impact dispersion area boundary so that the x₂ or y₂ distance would otherwise extend outside the impact dispersion area, the x₂ or y₂ distance should be set equal to the impact dispersion area radius. The x₂ distance for populated area A in figure C-3 is an example. If a populated area intersects the flight azimuth, an applicant shall solve equation C3 by obtaining the solution in two parts. An

applicant shall determine, first, the probability between y₁ = 0 and y₂ = a and, second, the probability between y₁ = 0 and y₂ = b, as depicted in figure C-4. The probability P_y is then equal to the sum of the probabilities of the two parts. If a populated area intersects the line that is normal to the flight azimuth on the impact point, an applicant shall solve equation C2 by obtaining the solution in two parts in the same manner as with the values of x.

(C) An applicant shall calculate the probability of impact for each populated area using equation C4 below:

$$P_i = P_s \cdot P_x \cdot P_y \quad \text{(Equation C4)}$$

where: P_s = 1 - P_f = 0.90

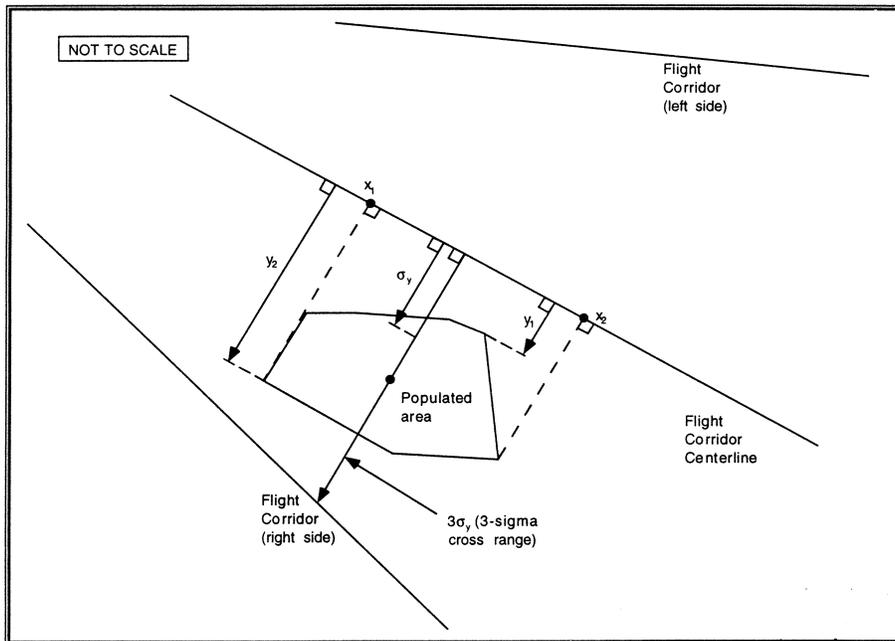


Figure C-1: Analysis of an Appendix A Flight Corridor

(6) Probability of impact computations for a populated area in an appendix B flight corridor. An applicant shall compute P_i using the following method:

(i) For the launch and downrange areas, but not for a final stage impact dispersion area for a guided suborbital launch vehicle, an applicant shall compute P_i for each populated area using the following equation:

$$P_i = \frac{\left(\frac{|y_2 - y_1|}{\sigma_y}\right)}{6\sqrt{2\pi}} \cdot \left(\exp\left(\frac{-\left(\frac{y_1}{\sigma_y}\right)^2}{2}\right) + 4 \cdot \exp\left(\frac{-\left(\frac{y_1 + y_2}{2\sigma_y}\right)^2}{2}\right) + \exp\left(\frac{-\left(\frac{y_2}{\sigma_y}\right)^2}{2}\right) \right) \cdot \left(\frac{P_f}{t} \cdot t_d\right) \quad \text{(Equation C5)}$$

where:

y_1, y_2 = closest and farthest cross range distance (nm) to a populated area measured from the nominal trajectory IIP ground trace (see figure C-2)

σ_y = one-third of the cross range distance (nm) from nominal trajectory to the flight corridor boundary (see figure C-2)

exp = exponential function (e^x)

P_f = probability of failure = 0.10

t = flight time from lift-off to orbital insertion (seconds)

t_d = overflight dwell time (seconds)

(ii) For each populated area within a final stage impact dispersion area, an applicant shall compute P_i using the following method:

(A) An applicant shall estimate the probability of final stage impact in the x and y sectors of each populated area within the final stage impact dispersion area using equations C6 and C7:

$$P_x = \frac{\left(\frac{|x_2 - x_1|}{\sigma_x}\right)}{6\sqrt{2\pi}} \cdot \left(\exp\left(\frac{-(x_1/\sigma_x)^2}{2}\right) + 4 \cdot \exp\left[\frac{-(\frac{x_1 + x_2}{2\sigma_x})^2}{2}\right] + \exp\left(\frac{-(x_2/\sigma_x)^2}{2}\right) \right) \quad \text{(Equation C6)}$$

where:

x_1, x_2 = closest and farthest downrange distance, measured along nominal trajectory IIP ground trace, measured from the

nominal impact point to the populated area (see figure C-3)
 σ_x = one-third of the impact dispersion radius (see figure C-3)
 exp = exponential function (e^x)

$$P_y = \frac{\left(\frac{|y_2 - y_1|}{\sigma_y}\right)}{6\sqrt{2\pi}} \cdot \left(\exp\left(\frac{-(y_1/\sigma_y)^2}{2}\right) + 4 \cdot \exp\left[\frac{-(\frac{y_1 + y_2}{2\sigma_y})^2}{2}\right] + \exp\left(\frac{-(y_2/\sigma_y)^2}{2}\right) \right) \quad \text{(Equation C7)}$$

where:

y_1, y_2 = closest and farthest cross range distance to the populated area measured from the nominal trajectory IIP ground trace (see figure C-3)
 σ_y = one-third of the impact dispersion radius (see figure C-3)
 exp = exponential function (e^x)

(B) If a populated area intersects the impact dispersion area boundary so that the x_2 or y_2 distance would otherwise extend outside the impact dispersion area, the x_2 or y_2 distance should be set equal to the impact dispersion area radius. The x_2 distance for populated area A in figure C-3 is an example. If a populated area intersects the flight azi-

muth, an applicant shall solve equation C7 by obtaining the solution in two parts. An applicant shall determine, first, the probability between $y_1 = 0$ and $y_2 = a$ and, second, the probability between $y_1 = 0$ and $y_2 = b$, as depicted in figure C-4. The probability P_y is then equal to the sum of the probabilities of the two parts. If a populated area intersects the line that is normal to the flight azimuth on the impact point, an applicant shall solve equation C6 by obtaining the solution in two parts in a similar manner with the values of x .

(C) An applicant shall calculate the probability of impact for each populated area using equation C8 below:

$$P_i = P_s \cdot P_x \cdot P_y \quad \text{(Equation C8)}$$

where: $P_s = 1 - P_f = 0.90$

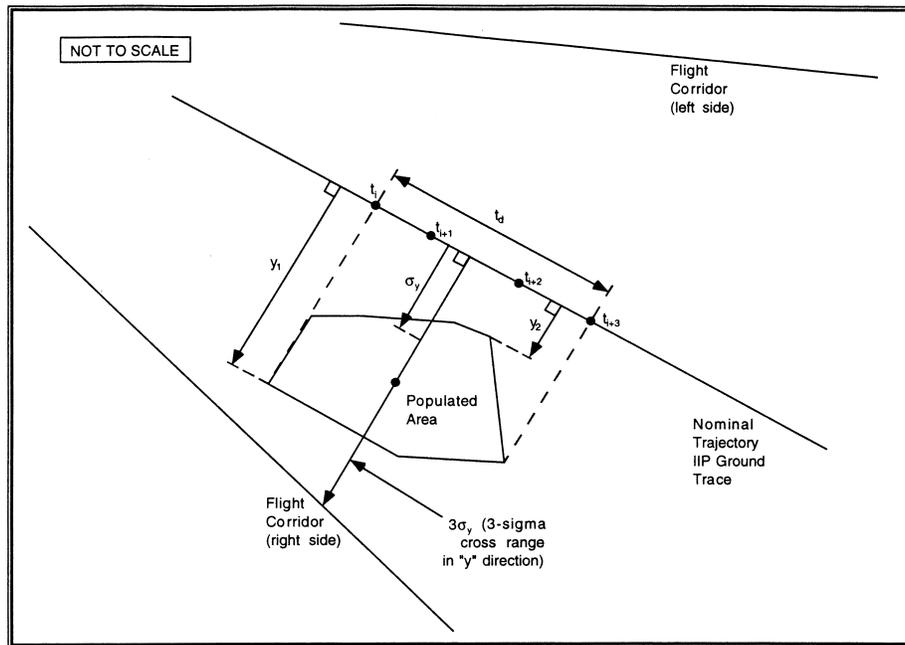


Figure C-2: Analysis of an Appendix B Flight Corridor

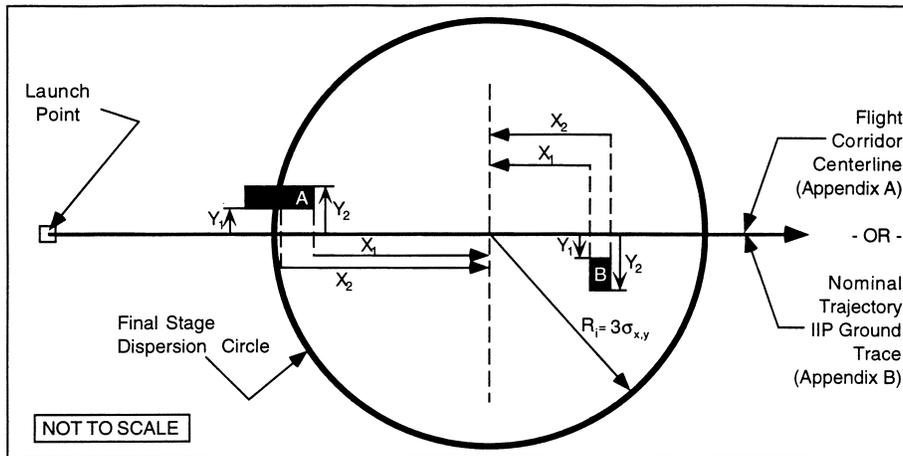


Figure C-3: Appendix A and B Final Stage Impact Risk Analysis

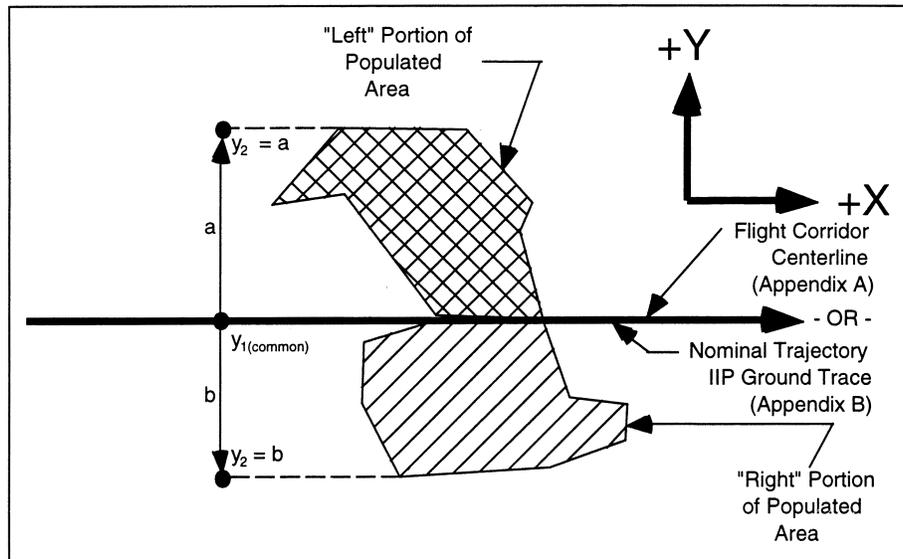


Figure C-4: Flight Azimuth Intersecting a Populated Area

(7) Using the P_i calculated in either subparagraph (c)(5) or (6) of this paragraph, an applicant shall calculate the casualty expectancy for each populated area within the flight corridor in accordance with equation C9. E_{ck} is the casualty expectancy for a given populated area as shown in equation C9,

where individual populated areas are designated with the subscript “k”.

$$E_{ck} = P_i \cdot \left(\frac{A_c}{A_k} \right) \cdot N_k \quad \text{(Equation C9)}$$

where:

A_c = casualty area (from table C-3)
 A_k = populated area

N_k = population in A_k

TABLE C-3—EFFECTIVE CASUALTY AREA (MILES²) AS A FUNCTION OF IIP RANGE (NM)

Instantaneous impact point range (nautical miles)	Orbital launch vehicles				Suborbital launch vehicles
	Small	Medium	Medium large	Large	Guided
0-49	3.14×10^{-2}	1.28×10^{-1}	4.71×10^{-2}	8.59×10^{-2}	4.3×10^{-1}
50-1749	2.47×10^{-2}	2.98×10^{-2}	9.82×10^{-3}	2.45×10^{-2}	1.3×10^{-1}
1750-5000	3.01×10^{-4}	5.52×10^{-3}	7.82×10^{-3}	1.14×10^{-2}	3.59×10^{-6}

(8) An applicant shall estimate the total corridor risk using the following summation of risk:

$$E_c(\text{Corridor}) = \left(\sum_{k=1}^n E_{c_k} \right) \quad (\text{Equation C10})$$

(9) Alternative casualty expectancy (E_c) analyses. An applicant may employ specified variations to the analysis defined by subparagraphs (c)(1)-(8). Those variations are identified in subparagraphs (9)(i) through (vi) of this paragraph. Subparagraphs (i) through (iv) permit an applicant to make conservative assumptions that would lead to an overestimation of the corridor E_c compared with the analysis defined by subparagraphs (c)(1)-(8). In subparagraphs (v) and (vi), an applicant that would otherwise fail the analysis prescribed by subparagraphs (c)(1)-(8) may avoid (c)(1)-(8)'s overestimation of the probability of impact in each populated area. An applicant employing a variation shall identify the variation used, show and discuss the specific assumptions made to modify the analysis defined by subparagraphs (c)(1)-(8), and demonstrate how each assumption leads to overestimation of the corridor E_c compared with the analysis defined by subparagraphs (c)(1)-(c)(8).

(i) Assume that P_x and P_y have a value of 1.0 for all populated areas.

(ii) Combine populated areas into one or more larger populated areas, and use a population density for the combined area or areas equal to the most densely populated area.

(iii) For any given populated area, assume P_y has a value of one.

(iv) For any given P_x sector (an area spanning the width of a flight corridor and bounded by two time points on the trajectory IIP ground trace) assume P_y has a value of one and use a population density for the sector equal to the most densely populated area.

(v) For a given populated area, divide the populated area into smaller rectangles, de-

termine P_i for each individual rectangle, and sum the individual impact probabilities to determine P_i for the entire populated area.

(vi) For a given populated area, use the ratio of the populated area to the area of the P_i rectangle from the subparagraph (c)(1)-(8) analysis.

(d) Evaluation of Results

(1) If the estimated expected casualty does not exceed 1×10^{-4} , the FAA will approve the launch site location.

(2) If the estimated expected casualty exceeds 1×10^{-4} , then an applicant may either modify its proposal, or, if the flight corridor used was generated by the appendix A method, use the appendix B method to narrow the flight corridor and then perform another appendix C risk analysis.

[Doc. No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Amdt. 420-2, 71 FR 51972, Aug. 31, 2006; Docket No. FAA-2014-0418, Amdt. No. 420-7, 81 FR 47027, July 20, 2016]

APPENDIX D TO PART 420—IMPACT DISPERSION AREAS AND CASUALTY EXPECTANCY ESTIMATE FOR AN UNGUIDED SUBORBITAL LAUNCH VEHICLE

(a) Introduction

(1) This appendix provides a method for determining the acceptability of the location of a launch point from which an unguided suborbital launch vehicle would be launched. The appendix describes how to define an overflight exclusion zone and impact dispersion areas, and how to evaluate whether the

public risk presented by the launch of an unguided suborbital launch vehicle remains at acceptable levels.

(2) An applicant shall base its analysis on an unguided suborbital launch vehicle whose final launch vehicle stage apogee represents the intended use of the launch point.

(3) An applicant shall use the apogee of each stage of an existing unguided suborbital launch vehicle with a final launch vehicle stage apogee equal to the one proposed, and calculate each impact range and dispersion area using the equations provided.

(4) This appendix also provides a method for performing an impact risk analysis that estimates the expected casualty (E_c) within each impact dispersion area. This appendix provides an applicant options to simplify the method where population at risk is minimal.

(5) If the estimated E_c is less than or equal to 1×10^{-4} , the FAA will approve the launch point for unguided suborbital launch vehicles. If the estimated E_c exceeds 1×10^{-4} , the proposed launch point will fail the launch site location review.

(b) Data Requirements

(1) An applicant shall employ the apogee of each stage of an existing unguided suborbital launch vehicle whose final stage apogee represents the maximum altitude to be reached by unguided suborbital launch vehicles launched from the launch point. The apogee shall be obtained from one or more actual flights of an unguided suborbital launch vehicle launched at an 84 degree elevation.

(2) An applicant shall satisfy the map and plotting data requirements of appendix A, paragraph (b).

(3) Population data. An applicant shall use total population (N) and the total landmass area within a populated area (A) for all populated areas within an impact dispersion area. Population data up to and including 100 nm from the launch point are required at the U.S. census block group level. Population data downrange from 100 nm are required at no greater than $1^\circ \times 1^\circ$ latitude/longitude grid coordinates.

(c) Overflight Exclusion Zone and Impact Dispersion Areas

(1) An applicant shall choose a flight azimuth from a launch point.

(2) An applicant shall define an overflight exclusion zone as a circle with a radius of 1600 feet centered on the launch point.

(3) An applicant shall define an impact dispersion area for each stage of the suborbital

launch vehicle chosen in accordance with subparagraph (b)(1) in accordance with the following:

(i) An applicant shall calculate the impact range for the final launch vehicle stage (D_n). An applicant shall set D_n equal to the last stage apogee altitude (H_n) multiplied by an impact range factor [$IP(H_n)$] in accordance with the following:

$$D_n = H_n \cdot IP(H_n) \quad (\text{Equation D1})$$

where:

$IP(H_n) = 0.4$ for an apogee less than 100 km,
and

$IP(H_n) = 0.7$ for an apogee of 100 km or greater.

(ii) An applicant shall calculate the impact range for each intermediate stage (D_i), where $i \in \{1, 2, 3, \dots, (n-1)\}$, and where n is the total number of launch vehicle stages. Using the apogee altitude (H_i) of each intermediate stage, an applicant shall use equation D1 to compute the impact range of each stage by substituting H_i for H_n . An applicant shall use the impact range factors provided by equation D1.

(iii) An applicant shall calculate the impact dispersion radius for the final launch vehicle stage (R_n). An applicant shall set R_n equal to the last stage apogee altitude (H_n) multiplied by an impact dispersion factor [$DISP(H_n)$] in accordance with the following:

$$R_n = H_n \cdot DISP(H_n) \quad (\text{Equation D2})$$

where:

$DISP(H_n) = 0.4$ for an apogee less than 100 km, and

$DISP(H_n) = 0.7$ for an apogee of 100 km or greater.

(iv) An applicant shall calculate the impact dispersion radius for each intermediate stage (R_i), where $i \in \{1, 2, 3, \dots, (n-1)\}$ and where n is the total number of launch vehicle stages. Using the apogee altitude (H_i) of each intermediate stage, an applicant shall use equation D2 to compute an impact dispersion radius of each stage by substituting H_i for H_n . An applicant shall use the dispersion factors provided by equation D2.

(4) An applicant shall display an overflight exclusion zone, each intermediate and final stage impact point (D_i through D_n), and each impact dispersion area for the intermediate and final launch vehicle stages on maps in accordance with paragraph (b)(2).

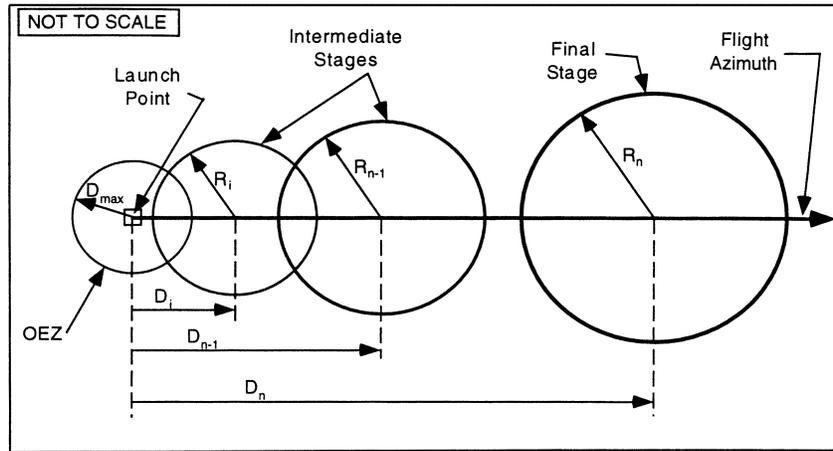


Figure D-1
Unguided Suborbital Launch Vehicle Overflight Exclusion Zone and Impact Dispersion Areas

(d) Evaluate the Overflight Exclusion Zone and Impact Dispersion Areas

(1) An applicant shall evaluate the overflight exclusion zone and each impact dispersion area for the presence of any populated areas. If an applicant determines that no populated area is located within the overflight exclusion zone or any impact dispersion area, then no additional steps are necessary.

(2) If a populated area is located in an overflight exclusion zone, an applicant may modify its proposal or demonstrate that there are times when no people are present or that the applicant has an agreement in place to evacuate the public from the overflight exclusion zone during a launch.

(3) If a populated area is located within any impact dispersion area, an applicant may modify its proposal and define a new overflight exclusion zone and new impact

dispersion areas, or perform an impact risk analysis in accordance with paragraph (e).

(e) Impact Risk Analysis

(1) An applicant shall estimate the expected average number of casualties, E_c , within the impact dispersion areas according to the following method:

(i) An applicant shall calculate the E_c by summing the impact risk for the impact dispersion areas of the final launch vehicle stage and all intermediate stages. An applicant shall estimate E_c for the impact dispersion area of each stage by using equations D3 through D7 for each of the populated areas located within the impact dispersion areas.

(ii) An applicant shall estimate the probability of impacting inside the X and Y sectors of each populated area within each impact dispersion area using equations D3 and D4:

$$P_x = \frac{\left(\frac{x_2 - x_1}{\sigma_x} \right)}{6\sqrt{2\pi}} \cdot \left(\exp \left(\frac{\left(\frac{x_1}{\sigma_x} \right)^2}{2} \right) + 4 \cdot \exp \left[\frac{\left(\frac{x_1 + x_2}{2\sigma_x} \right)^2}{2} \right] + \exp \left(\frac{\left(\frac{x_2}{\sigma_x} \right)^2}{2} \right) \right) \quad \text{(Equation D3)}$$

where:

x_1, x_2 = closest and farthest downrange distance to populated area (see figure D-2)

σ_x = one-third of the impact dispersion radius (see figure D-2)

exp = exponential function (e^x)

$$P_y = \frac{\left(\frac{|y_2|}{\sigma_y} - \frac{|y_1|}{\sigma_y} \right)}{6\sqrt{2\pi}} \cdot \left(\exp\left[\frac{-\left(\frac{y_1}{\sigma_y} \right)^2}{2} \right] + 4 \cdot \exp\left[\frac{-\left(\frac{y_1+y_2}{2\sigma_y} \right)^2}{2} \right] + \exp\left[\frac{-\left(\frac{y_2}{\sigma_y} \right)^2}{2} \right] \right) \quad \text{(Equation D4)}$$

where:

y_1, y_2 = closest and farthest cross range distance to the populated area (see figure D-2)

σ_y = one-third of the impact dispersion radius (see figure D-2)

exp = exponential function (e^x)

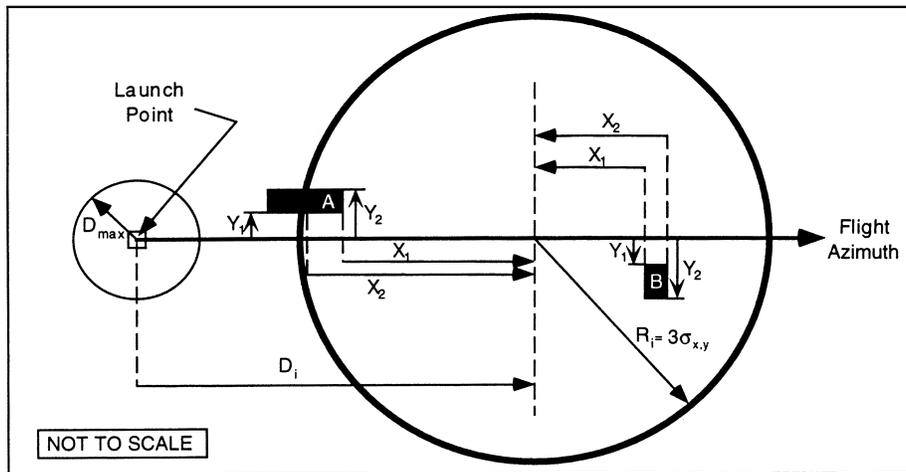


Figure D-2
Intermediate and Final Stage Impact Risk Analysis

(iii) If a populated area intersects the impact dispersion area boundary so that the x_2 or y_2 distance would otherwise extend outside the impact dispersion area, the x_2 or y_2 distance should be set equal to the impact dispersion area radius. The x_2 distance for populated area A in figure D-2 is an example.

(iv) If a populated area intersects the flight azimuth, an applicant shall solve equation D4 by obtaining the solution in two parts. An applicant shall determine, first, the prob-

ability between $y_1 = 0$ and $y_2 = a$ and, second, the probability between $y_1 = 0$ and $y_2 = b$, as depicted in figure D-3. The probability P_y is then equal to the sum of the probabilities of the two parts. If a populated area intersects the line that is normal to the flight azimuth on the impact point, an applicant shall solve equation D3 by obtaining the solution in two parts in the same manner as with the values of x .

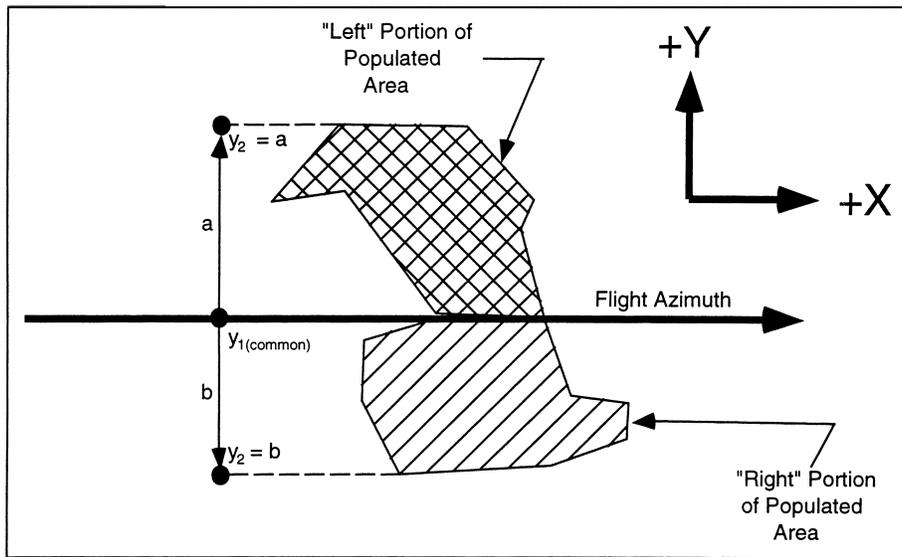


Figure D-3
Flight Azimuth Intersecting a Populated Area

(v) An applicant shall calculate the probability of impact (P_i) for each populated area using the following equation:

$$P_i = P_s \cdot P_x \cdot P_y \quad (\text{Equation D5})$$

where:

P_s = probability of success = 0.98

(vi) An applicant shall calculate the casualty expectancy for each populated area. E_{ck} is the casualty expectancy for a given populated area as shown in equation D6, where in-

dividual populated areas are designated with the subscript "k".

$$E_{ck} = P_i \cdot \left(\frac{A_c}{A_k} \right) \cdot N_k \quad (\text{Equation D6})$$

where:

$k \in \{1, 2, 3, \dots, n\}$

A_c = casualty area (from table D-1)

A_k = populated area

N_k = population in A_k

TABLE D-1—EFFECTIVE CASUALTY AREA (A_c) VS. IMPACT RANGE

Impact range (nm)	Effective casualty area (miles ²)
0-4	9×10^{-3}
5-49	9×10^{-3}
50-1,749	1.1×10^{-5}
1,750-4,999	3.6×10^{-6}
5,000-more	3.6×10^{-6}

(vii) An applicant shall estimate the total risk using the following summation of risk:

$$E_c(\text{Corridor}) = \left(\sum_{k=1}^n E_{c_k} \right) \quad (\text{Equation D7})$$

(viii) Alternative casualty expectancy (E_c) analysis. An applicant may employ specified variations to the analysis defined by subparagraphs (d)(1)(i)-(vii). Those variations are identified in subparagraphs (viii)(A) through (F) of this paragraph. Subparagraphs (A) through (D) permit an applicant to make conservative assumptions that would lead to an overestimation of E_c compared with the analysis defined by subparagraphs (d)(1)(i)-(vii). In subparagraphs (E) and (F), an applicant that would otherwise fail the analysis prescribed by subparagraphs (d)(1)(i)-(vii) may avoid (d)(1)(i)-(vii)'s overestimation of the probability of impact in each populated area. An applicant employing a variation shall identify the variation used, show and discuss the specific assumptions made to modify the analysis defined by subparagraphs (d)(1)(i)-(vii), and demonstrate how each assumption leads to overestimation of the corridor E_c compared with the analysis defined by subparagraphs (d)(1)(i)-(vii).

(A) Assume that P_x and P_y have a value of 1.0 for all populated areas.

(B) Combine populated areas into one or more larger populated areas, and use a population density for the combined area or areas equal to the most densely populated area.

(C) For any given populated area, assume P_x has a value of one.

(D) For any given populated area, assume P_y has a value of one.

(E) For a given populated area, divide the populated area into smaller rectangles, determine P_i for each individual rectangle, and sum the individual impact probabilities to determine P_i for the entire populated area.

(F) For a given populated area, use the ratio of the populated area to the area of the P_i rectangle used in the subparagraph (d)(1)(i)-(vii) analysis.

(2) If the estimated expected casualty does not exceed 1×10^{-4} , the FAA will approve the launch point.

(3) If the estimated expected casualty exceeds 1×10^{-4} , then an applicant may modify its proposal and then repeat the impact risk analysis in accordance with this appendix D.

If no set of impact dispersion areas exist which satisfy the FAA's risk threshold, the applicant's proposed launch site will fail the launch site location review.

[Docket No. FAA-1999-5833, 65 FR 62861, Oct. 19, 2000, as amended by Docket No. FAA-2014-0418, Amdt. No. 420-7, 81 FR 47027, July 20, 2016]

APPENDIX E TO PART 420—TABLES FOR EXPLOSIVE SITE PLAN

TABLE E-1—DIVISION 1.1 DISTANCES TO A PUBLIC AREA OR PUBLIC TRAFFIC ROUTE FOR NEW >450 LBS

NEW (lbs.)	Distance to public area (ft) ^{1,2}	Distance to public traffic route distance (ft) ²
≤0.5	236	142
0.7	263	158
1	291	175
2	346	208
3	378	227
5	419	251
7	445	267
10	474	284
15	506	304
20	529	317
30	561	337
31	563	338
50	601	361
70	628	377
100	658	395
150	815	489
200	927	556
300	1085	651
450	1243	746

¹ To calculate distance d to a public area from NEW:
 NEW ≤0.5 lbs: d = 236
 0.5 lbs <NEW <100 lbs: d = 291.3 + [79.2 *ln(NEW)]
 100 lbs ≤NEW ≤450 lbs: d = -1133.9 + [389 *ln(NEW)]
 NEW is in lbs; d is in ft; ln is natural logarithm.
 To calculate maximum NEW given distance d (noting that d can never be less than 236 ft):
 0 ≤d <236 ft: Not allowed (d cannot be less than 236 ft)
 236 ft ≤d <658 ft: NEW = exp [(d/79.2)-3.678]
 658 ft ≤d <1250 ft: NEW = exp [(d/389) + 2.914]
 NEW is in lbs; d is in ft; exp[x] is e^x.
² The public traffic route distance is 60 percent of the distance to a public area.

TABLE E-2—DIVISION 1.1 DISTANCE TO PUBLIC AREA AND PUBLIC TRAFFIC ROUTE FOR NEW >450 LBS

NEW (lbs)	Distance to public area (ft) ¹	Distance to public traffic route (ft)
450 lbs <NEW ≤30,000 lbs	1,250	750.
30,000 lbs <NEW ≤100,000 lbs	40*NEW ^{1/3}	0.60*(Distance to Public Area).
100,000 lbs <NEW ≤250,000 lbs	2.42*NEW ^{0.577}	0.60*(Distance to Public Area).

TABLE E-2—DIVISION 1.1 DISTANCE TO PUBLIC AREA AND PUBLIC TRAFFIC ROUTE FOR NEW >450 LBS—Continued

NEW (lbs)	Distance to public area (ft) ¹	Distance to public traffic route (ft)
250,000 lbs<NEW	50*NEW ^{1/3}	0.60*(Distance to Public Area).

¹ To calculate NEW from distance d to a public area:
 1, 243 ft<d ≤1,857 ft: NEW = d³/64,000
 1, 857 ft<d ≤3,150 ft: NEW = 0.2162 * d^{1.7931}
 3,150 ft<d: NEW = d³/125,000
 NEW is in lbs; d is in ft.

TABLE E-3—DIVISION 1.1 INTRALINE DISTANCES^{1 2 3}

NEW (lbs)	Intraline Distance (ft)
50	66
70	74
100	84
150	96
200	105
300	120
500	143
700	160
1,000	180
1,500	206
2,000	227
3,000	260
5,000	308
7,000	344
10,000	388
15,000	444
20,000	489
30,000	559
50,000	663
70,000	742
100,000	835
150,000	956
200,000	1,053
300,000	1,205
500,000 ³	1,429
700,000	1,598
1,000,000	1,800
1,500,000	2,060
2,000,000	2,268
3,000,000	2,596
5,000,000	3,078

¹ To calculate intraline distance d from NEW:
 $d = 18 \cdot \text{NEW}^{1/3}$
 NEW is in pounds; d is in feet
² To calculate maximum NEW from given intraline distance d:
 $\text{NEW} = d^3/5,832$
 NEW is in pounds; d is in feet.
³ NEW values of more than 500,000 lbs only apply to liquid propellants with TNT equivalents equal to those NEW values. The intraline distances for NEW greater than 500,000 pounds do not apply to division 1.1 explosives.

TABLE E-4—DIVISION 1.3 SEPARATION DISTANCES

NEW (lbs)	Distance to public area or public traffic route (ft) ¹	Intraline distance (ft) ²
≤1000	75	50
1,500	82	56
2,000	89	61
3,000	101	68
5,000	117	80
7,000	130	88

TABLE E-4—DIVISION 1.3 SEPARATION DISTANCES—Continued

NEW (lbs)	Distance to public area or public traffic route (ft) ¹	Intraline distance (ft) ²
10,000	145	98
15,000	164	112
20,000	180	122
30,000	204	138
50,000	240	163
70,000	268	181
100,000	300	204
150,000	346	234
200,000	385	260
300,000	454	303
500,000	569	372
700,000	668	428
1,000,000	800	500
1,500,000	936	577
2,000,000	1,008	630

¹ To calculate distance d to a public area or traffic route from NEW:
 NEW ≤1,000 lbs
 $d = 75 \text{ ft}$
 1,000 lbs<NEW ≤96,000 lbs
 $d = \exp[2.47 + 0.2368 \cdot (\ln(\text{NEW})) + 0.00384 \cdot (\ln(\text{NEW}))^2]$
 96,000 lbs<NEW ≤1,000,000 lbs
 $d = \exp[7.2297 - 0.5984 \cdot (\ln(\text{NEW})) + 0.04046 \cdot (\ln(\text{NEW}))^2]$
 NEW >1,000,000 lbs
 $d = 8 \cdot \text{NEW}^{1/3}$
 NEW is in pounds; d is in feet; exp[x] is e^x; ln is natural logarithm.

² To calculate intraline distance d from NEW:
 NEW ≤1,000 lbs
 $d = 50 \text{ ft}$
 1,000 lbs<NEW ≤84,000 lbs
 $d = \exp[2.0325 + 0.2488 \cdot (\ln(\text{NEW})) + 0.00313 \cdot (\ln(\text{NEW}))^2]$
 84,000 lbs<NEW ≤1,000,000 lbs
 $d = \exp[4.338 - 0.1695 \cdot (\ln(\text{NEW})) + 0.0221 \cdot (\ln(\text{NEW}))^2]$
 1,000,000 lbs<NEW
 $d = 5 \cdot \text{NEW}^{1/3}$
 NEW is in pounds; d is in feet; exp[x] is e^x; ln is natural logarithm
 To calculate NEW from an intraline distance d:
 0 ≤d <50 ft:
 Not allowed (d cannot be less than 50 ft) for NEW ≤1000 lbs
 50 ft ≤d <192 ft
 $\text{NEW} = \exp[-39.744 + (930.257 + 319.49 \cdot (\ln(d)))^{1/2}]$
 192 ft<d ≤500 ft
 $\text{NEW} = \exp[3.834 + (-181.58 + 45.249 \cdot (\ln(d)))^{1/2}]$

500 ft<d
NEW = d³/125

NEW is in pounds; d is in feet; exp[x] is e^x; ln is natural logarithm

TABLE E-5—ENERGETIC LIQUID EXPLOSIVE EQUIVALENTS^{1 2 3}

Energetic liquids	TNT Equivalence	TNT Equivalence
LO ₂ /LH ₂	Static Test Stands	Launch Pads.
LO ₂ /LH ₂ + LO ₂ /RP-1	See Note 3	See Note 3.
LO ₂ /RP-1	Sum of (see Note 3 for LO ₂ /LH ₂) + (10% for LO ₂ /RP1).	Sum of (see Note 3 for LO ₂ /LH ₂) + (20% for LO ₂ /RP1).
IRFNA/UDMH	10%	20% up to 500,000 lbs
N ₂ O ₄ /UDMH + N ₂ H ₄	5%	Plus 10% over 500,000 lbs
		10%.
		10%.

¹A launch site operator must use the percentage factors of table E-5 to determine TNT equivalencies of incompatible energetic liquids that are within an intraline distance of each other.

²A launch site operator may substitute the following energetic liquids to determine TNT equivalency under this table as follows:

- Alcohols or other hydrocarbon for RP-1
- H₂O₂ for LO₂ (only when H₂O₂ is in combination with RP-1 or equivalent hydrocarbon fuel)
- MMH for N₂H₄, UDMH, or combinations of the two.

³TNT equivalency for LO₂/LH₂ is the larger of:
(a) TNT equivalency of 8*W²%, where W is the weight of LO₂/LH₂ in lbs; or
(b) 14 percent of the LO₂/LH₂ weight.

TABLE E-6—FACTORS TO USE WHEN CONVERTING ENERGETIC LIQUID DENSITIES

Item	Density (lb/gal)	Temperature (°F)
Ethyl alcohol	6.6	68
Hydrazine	8.4	68
Hydrogen peroxide (90 percent)	11.6	68
Liquid hydrogen	0.59	-423
Liquid oxygen	9.5	-297
Red fuming nitric acid (IRFNA)	12.9	77
RP-1	6.8	68
UDMH	6.6	68
UDMH/Hydrazine	7.5	68

TABLE E-7—SEPARATION DISTANCE CRITERIA FOR STORAGE OF HYDROGEN PEROXIDE IN CONCENTRATIONS OF MORE THAN 91 PERCENT^{1 2}—Continued

Quantity (lbs)	Intraline distance or distance to public area or distance to public traffic route (ft)
50,000	884
70,000	989
100,000	1114
150,000	1275
200,000	1404
300,000	1607
500,000	1905

TABLE E-7—SEPARATION DISTANCE CRITERIA FOR STORAGE OF HYDROGEN PEROXIDE IN CONCENTRATIONS OF MORE THAN 91 PERCENT^{1 2}

Quantity (lbs)	Intraline distance or distance to public area or distance to public traffic route (ft)
10,000	510
15,000	592
20,000	651
30,000	746

¹ Multiple tanks containing hydrogen peroxide in concentrations of greater than 91 percent may be located at distances less than those required by table E-7; however, if the tanks are not separated from each other by 10 percent of the distance specified for the largest tank, then the launch site operator must use the total contents of all tanks to calculate each intraline distance and the distance to each public area and each public traffic route.

² A launch site operator may use the equations below to determine permissible distance or quantity between the entries of table E-7:

W > 10,000 lbs Distance = 24 * W^{1/3}
Where Distance is in ft and W is in lbs.
To calculate weight of hydrogen peroxide from a distance d:
d > 75 ft
W = exp[-134.286 + 71.998*(ln(d)) - 12.363*(ln(d))² + 0.7229*(ln(d))³]

TABLE E-8—SEPARATION DISTANCE CRITERIA FOR STORAGE OF LIQUID HYDROGEN AND BULK QUANTITIES OF HYDRAZINE

Pounds of energetic liquid	Pounds of energetic liquid	Public area and intraline distance to incompatible energetic liquids	Intraline distance to compatible energetic liquids	Pounds of energetic liquid	Pounds of energetic liquid	Public area and intraline distance to incompatible energetic liquids	Intraline distance to compatible energetic liquids
Over	Not Over	Distance in feet	Distance in feet	Over	Not Over	Distance in feet	Distance in feet
100	200	600	35	60,000	70,000	1,200	130
200	300	600	40	70,000	80,000	1,200	130
				80,000	90,000	1,200	135

TABLE E-8—SEPARATION DISTANCE CRITERIA FOR STORAGE OF LIQUID HYDROGEN AND BULK QUANTITIES OF HYDRAZINE—Continued

Pounds of energetic liquid	Pounds of energetic liquid	Public area and intraline distance to incompatible energetic liquids	Intraline distance to compatible energetic liquids	Pounds of energetic liquid	Pounds of energetic liquid	Public area and intraline distance to incompatible energetic liquids	Intraline distance to compatible energetic liquids
300	400	600	45	90,000	100,000	1,200	135
400	500	600	50	100,000	125,000	1,800	140
500	600	600	50	125,000	150,000	1,800	145
600	700	600	55	150,000	175,000	1,800	150
700	800	600	55	175,000	200,000	1,800	155
800	900	600	60	200,000	250,000	1,800	160
900	1,000	600	60	250,000	300,000	1,800	165
1,000	2,000	600	65	300,000	350,000	1,800	170
2,000	3,000	600	70	350,000	400,000	1,800	175
3,000	4,000	600	75	400,000	450,000	1,800	180
4,000	5,000	600	80	450,000	500,000	1,800	180
5,000	6,000	600	80	500,000	600,000	1,800	185
6,000	7,000	600	85	600,000	700,000	1,800	190
7,000	8,000	600	85	700,000	800,000	1,800	195
8,000	9,000	600	90	800,000	900,000	1,800	200
9,000	10,000	600	90	900,000	1,000,000	1,800	205
10,000	15,000	1,200	95	1,000,000	2,000,000	1,800	235
15,000	20,000	1,200	100	2,000,000	3,000,000	1,800	255
20,000	25,000	1,200	105	3,000,000	4,000,000	1,800	265
25,000	30,000	1,200	110	4,000,000	5,000,000	1,800	275
30,000	35,000	1,200	110	5,000,000	6,000,000	1,800	285
35,000	40,000	1,200	115	6,000,000	7,000,000	1,800	295
40,000	45,000	1,200	120	7,000,000	8,000,000	1,800	300
45,000	50,000	1,200	120	8,000,000	9,000,000	1,800	305
50,000	60,000	1,200	125	9,000,000	10,000,000	1,800	310

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431.16-431.20 [Reserved]

PARTS 421-430 [RESERVED]

Subpart B—Policy Review and Approval for Launch and Reentry of a Reusable Launch Vehicle

PART 431—LAUNCH AND REENTRY OF A REUSABLE LAUNCH VEHICLE (RLV)

- 431.21 General.
- 431.23 Policy review.
- 431.25 Application requirements for policy review.
- 431.27 Denial of policy approval.
- 431.28-431.30 [Reserved]

Subpart A—General

Subpart C—Safety Review and Approval for Launch and Reentry of a Reusable Launch Vehicle

- Sec.
- 431.1 General.
- 431.2 Licenses issued under this part.
- 431.3 Types of reusable launch vehicle mission licenses.
- 431.5 Policy and safety approvals.
- 431.7 Payload and payload reentry determinations.
- 431.8 Human space flight.
- 431.9 Issuance of a reusable launch vehicle mission license.
- 431.11 Additional license terms and conditions.
- 431.13 Transfer of a reusable launch vehicle mission license.
- 431.15 Rights not conferred by a reusable launch vehicle mission license.

- 431.31 General.
- 431.33 Safety organization.
- 431.35 Acceptable reusable launch vehicle mission risk.
- 431.37 Mission readiness.
- 431.39 Mission rules, procedures, contingency plans, and checklists.
- 431.41 Communications plan.
- 431.43 Reusable launch vehicle mission operational requirements and restrictions.
- 431.45 Mishap investigation plan and emergency response plan.
- 431.47 Denial of safety approval.
- 431.48-431.50 [Reserved]