§ 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.
(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 “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. An applicant may use geographical information system software with global mapping data scaleable in accordance with paragraph (b)(1).

(ii) 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 1.0,000,000 inches per inch (in/in); or straight lines representing 100 nm or less on map scales less than 1.0,000,000 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 1.0,000,000 inches per inch (in/in); or straight lines representing 100 nm or less on map scales less than 1.0,000,000 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.

$\phi_1 = \text{Geodetic latitude of launch point (radians)}$

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

$\lambda_1 = \text{Longitude of launch point (DDD)}$

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

$S = \text{Range from launch point (nm)}$

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

$\alpha_{12} = \text{Azimuth bearing from launch point (deg)}$

$= \alpha_{12} \cdot (\text{DDD}) \cdot \frac{\pi}{180} \text{ (radians per degree)}$
(B) Computations. An applicant shall use the following equations to determine the latitude ($\varphi_2$) and longitude ($\lambda_2$) of a target point situated “$S$” nm from the launch point on an azimuth bearing ($\alpha_{12}$) degrees.

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

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

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

$$\beta_1 = \tan^{-1}\left[\frac{b \cdot \sin\varphi_1}{a \cdot \cos\varphi_1}\right] \quad \text{(Equation A4)}$$

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

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

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

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

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

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

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

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

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

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

$$A_4 = \left(\frac{M^2}{16}\right) \left[11 \cdot \theta - 13 \cdot \sin\theta \cdot \cos\theta - 8 \cdot \theta \cdot \cos^2\theta + 10 \cdot \sin\theta \cdot \cos^3\theta\right] \quad \text{(Equation A15)}$$
\[ A_5 = \frac{M \cdot N}{2} \left(3 \cdot \sin \theta + 2 \cdot \theta \cdot \cos \theta - 5 \cdot \sin \theta \cdot \cos^2 \theta \right) \]  (Equation A16)

\[ \delta = \theta - A_1 + A_2 + A_3 + A_4 + XA_5 \text{ (radians)} \]  (Equation A17)

\[ \sin \beta_2 = \sin \beta_1 \cdot \cos \delta + g \cdot \sin \delta \]  (Equation A18)

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

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

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

\[ \lambda_2 = (\lambda_1 + \Lambda + L) \cdot \left(\frac{180}{\pi}\right) \text{ (longitude of target point, DDD)} \]  (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 \( (P_1 \text{ and } P_2) \), the forward azimuth \( \alpha_{12} \) of the geodesic at \( P_1 \), and the back azimuth \( \alpha_{12} \) of the geodesic at \( P_2 \), given the geodetic latitude \( (+N) \), longitude \( (+E) \) of \( P_1 \) and \( P_2 \). Azimuth is measured positively clockwise from North.

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

\[ \phi_1 = \text{Geodetic latitude of launch point (radians)} = \phi_1 \cdot \left(\frac{\pi}{180}\right) \text{ (radians per degree)} \]

\[ \lambda_1 = \text{Longitude of launch point (DDD)} = \lambda_1 \cdot \left(\frac{\pi}{180}\right) \text{ (radians per degree)} \]

\[ S = \text{Range from launch point (nm)} = S \cdot \left(\frac{\pi}{180}\right) \text{ (radians per degree)} \]

\[ \alpha_{12} = \text{Azimuth bearing from launch point (deg)} = \alpha_{12} \cdot \left(\frac{\pi}{180}\right) \text{ (radians per degree)} \]

(B) Computations. An applicant shall use the following equations to determine the distance \( S \), the forward azimuth \( \alpha_{12} \) of the geodesic at \( P_1 \), and the back azimuth \( \alpha_{12} \) of the geodesic at \( P_2 \).
\[ f = 1 - \frac{b}{a} \quad \text{(Equation A23)} \]

where:
\[ a = \text{WGS}-84 \text{ semi-major axis (} 3443.91846652 \text{ nmi)} \]
\[ b = \text{WGS}-84 \text{ semi-minor axis (} 3432.37165994 \text{ nmi)} \]

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

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

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

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

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

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

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

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

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

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

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

\[ m = 1 - c^2 \quad \text{(Equation A35)} \]
(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 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) Select a debris dispersion radius (D_{max}) from Table A-1 and a downrange distance (D_{ozz}) 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 defined by two lines 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).

(iv) 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 $D_{\text{max}}$.
   (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 [$\text{DISP}(H_{ap})$] 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:
      \[
      R = H_{ap} \cdot \text{DISP}(H_{ap}) \quad \text{(Equation A41)}
      \]
      where: $\text{DISP}(H_{ap}) = 0.05$
      (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.
**Commercial Space Transportation, FAA, DOT**

### TABLE A–1—Debris Dispersion Radius (D<sub>max</sub>) (IN)

<table>
<thead>
<tr>
<th>Orbital launch vehicles</th>
<th>Suborbital launch vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>Medium</td>
</tr>
<tr>
<td>87,600</td>
<td>111,600</td>
</tr>
<tr>
<td>(1.20 nm)</td>
<td>(1.53 nm)</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium large</td>
</tr>
<tr>
<td>127,200</td>
<td>156,000</td>
</tr>
<tr>
<td>(1.74 nm)</td>
<td>(2.14 nm)</td>
</tr>
<tr>
<td>Large</td>
<td>Guided</td>
</tr>
<tr>
<td>156,000</td>
<td></td>
</tr>
<tr>
<td>(2.14 nm)</td>
<td>(1.32 nm)</td>
</tr>
</tbody>
</table>

### TABLE A–2—Overflight Exclusion Zone Downrange Distance (D<sub>oez</sub>) (IN)

<table>
<thead>
<tr>
<th>Orbital launch vehicles</th>
<th>Suborbital launch vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small</td>
<td>Medium</td>
</tr>
<tr>
<td>240,500</td>
<td>253,000</td>
</tr>
<tr>
<td>(3.30 nm)</td>
<td>(3.47 nm)</td>
</tr>
<tr>
<td>Medium</td>
<td>Medium large</td>
</tr>
<tr>
<td>253,000</td>
<td>310,300</td>
</tr>
<tr>
<td>(3.47 nm)</td>
<td>(4.26 nm)</td>
</tr>
<tr>
<td>Large</td>
<td>Guided</td>
</tr>
<tr>
<td>937,700</td>
<td>232,100</td>
</tr>
<tr>
<td>(12.86 nm)</td>
<td>(3.18 nm)</td>
</tr>
</tbody>
</table>

### Table A-3: Flight Corridor Line Segment Lengths

<table>
<thead>
<tr>
<th>D&lt;sub&gt;max&lt;/sub&gt; (in)</th>
<th>Line Segment Lengths (x 10&lt;sup&gt;5&lt;/sup&gt; inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orbital Launch Vehicles</td>
<td>CF</td>
</tr>
<tr>
<td>Small</td>
<td>87600</td>
</tr>
<tr>
<td>(1.20 nm)</td>
<td>(39.45 nm)</td>
</tr>
<tr>
<td>Medium</td>
<td>111,600</td>
</tr>
<tr>
<td>(1.53 nm)</td>
<td>(40.76 nm)</td>
</tr>
<tr>
<td>Med-Large</td>
<td>127,200</td>
</tr>
<tr>
<td>(1.74 nm)</td>
<td>(41.62 nm)</td>
</tr>
<tr>
<td>Large</td>
<td>156,000</td>
</tr>
<tr>
<td>(2.14 nm)</td>
<td>(43.20 nm)</td>
</tr>
<tr>
<td>Suborbital Launch Vehicles</td>
<td>CF</td>
</tr>
<tr>
<td>Guided</td>
<td>96,000</td>
</tr>
<tr>
<td>(1.32 nm)</td>
<td>(39.91 nm)</td>
</tr>
</tbody>
</table>
Figure A-1
Overflight Exclusion Zone

FLIGHT AZIMUTH

D_{max}

D_{GEZ}

LAUNCH POINT

NOT TO SCALE
NOT TO SCALE

Figure A.2
Flight Corridor

LAUNCH
POINT

UPRANGE
BOUNDARY

DOWN RANGE
5000 nmi

RIGHT
BOUNDARY

DOWN RANGE
AREA

100 NM

40 NM

LAUNCH
AREA