APPENDIX F TO PART 417 [RESERVED]

APPENDIX G TO PART 417—NATURAL AND TRIGGERED LIGHTNING FLIGHT COMMIT CRITERIA

G417.1 GENERAL

This appendix provides flight commit criteria for mitigating against natural lightning strikes and lightning triggered by the flight of a launch vehicle through or near an electrified environment. A launch operator may not initiate flight unless the weather conditions at the time of launch satisfy all lightning flight commit criteria of this appendix.

(a) In order to meet the lightning flight commit criteria, a launch operator must employ any:

(1) Weather monitoring and measuring equipment needed, and

(2) Procedures needed to verify compliance.

(b) When equipment or procedures, such as a field mill or calculation of the volume-averaged, height-integrated radar reflectivity (VAHIRR) of clouds, are used with the lightning flight commit criteria to increase launch opportunities, a launch operator must evaluate all applicable measurements to determine whether the measurements satisfy the criteria. A launch operator may not turn off available instrumentation to create the appearance of meeting a requirement and must use all radar reflectivity measurements within a specified volume for a VAHIRR calculation.

(c) If a launch operator proposes any alternative lightning flight commit criteria, the launch operator must clearly and convincingly demonstrate that the alternative provides an equivalent level of safety to that required by this appendix.

G417.3 DEFINITIONS

For the purpose of this appendix:

Anvil cloud means a stratiform or fibrous cloud formed by the upper-level outflow or blow-off from a thunderstorm or convective cloud.

Associated means two or more clouds are caused by the same disturbed weather or are physically connected.

Bright band means an enhancement of radar reflectivity caused by frozen hydrometeors falling and beginning to melt at any altitude where the temperature is 0 degrees Celsius or warmer.

Cloud means a visible mass of suspended water droplets or ice crystals, or a combination of water droplets and ice crystals. The cloud is the entire volume containing such particles.

Cloud layer means a vertically continuous array of clouds, not necessarily of the same type, whose bases are approximately at the same altitude.

Cone of silence means the volume within which a radar cannot detect any object, and is an inverted circular cone centered on the radar antenna. A cone of silence consists of all elevation angles greater than the maximum elevation angle reached by the radar.

Debris cloud means any cloud, except an anvil cloud, that has become detached from a parent cumulonimbus cloud or thunderstorm, or that results from the decay of a parent cumulonimbus cloud or thunderstorm.

Disturbed weather means a weather system where a dynamical process destabilizes the air on a scale larger than the individual clouds or cells. Examples of disturbed weather include fronts, troughs, and squall lines.

Electric field means a vertical electric field (Ez) at the surface of the Earth.

Field mill means an electric-field sensor that uses a moving, grounded conductor to induce a time-varying electric charge on one or more sensing elements in proportion to the ambient electrostatic field.

Flight path means a launch vehicle's planned flight trajectory, and includes the trajectory's vertical and horizontal uncertainties resulting from all three-sigma guidance and performance deviations.

Horizontal distance means a distance that is measured horizontally between a field mill or electric field measurement point and the nearest part of the vertical projection of an object or flight path onto the surface of the Earth.

Moderate precipitation means a precipitation rate of 0.1 inches/hr or a radar reflectivity of 30 dBZ.

Non-transparent means that one or more of the following conditions apply:

(1) Objects above, including higher clouds, blue sky, and stars, are blurred, indistinct, or obscured when viewed from below when looking through a cloud at visible wavelengths; or objects below, including terrain, buildings, and lights on the ground, are blurred, indistinct, or obscured when viewed from above when looking through a cloud at visible wavelengths;

(2) Objects above an observer are seen distinctly only through breaks in a cloud; or

(3) The cloud has a radar reflectivity of 0 dBZ or greater.

Precipitation means detectable rain, snow, hail, graupel, or sleet at the ground; virga; or a radar reflectivity greater than 18 dBZ.

Radar reflectivity means the radar reflectivity factor due to hydrometeors, in dBZ.

Slant distance means the shortest distance between two ports, whether horizontal, vertical, or inclined, in three dimensional space.

Thick cloud layer means one or more cloud layers whose combined vertical extent from the base of the bottom cloud layer to the top of the uppermost cloud layer exceeds 4,500

feet. Cloud layers are combined with neighboring layers for determining total thickness only when they are physically connected by vertically continuous clouds.

Thunderstorm means any convective cloud that produces lightning.

Transparent means that any of the following conditions apply:

(1) Objects above, including higher clouds, blue sky, and stars, are not blurred, are distinct and are not obscured when viewed at visible wavelengths; or objects below, including terrain, buildings, and lights on the ground, are clear, distinct, and not obscured when viewed at visible wavelengths; (2) Objects identified in paragraph (1) of this definition are seen distinctly not only through breaks in a cloud; and (3) The cloud has a radar reflectivity of less than 0 dBZ.

Triboelectrification means the transfer of electrical charge between ice particles and a launch vehicle when the ice particles collide with the vehicle during flight.

Volume-averaged, height integrated radar reflectivity (VAHIRR) means the product, expressed in units of dBZ-km or dBZ-kft, of a volume-averaged radar reflectivity and an average cloud thickness in a specified volume corresponding to a point.

G417.5 LIGHTNING

(a) A launch operator must wait 30 minutes to initiate flight after any type of lightning occurs in a thunderstorm if the flight path will carry the launch vehicle at a slant distance of less than or equal to 10 nautical miles from that thunderstorm. This paragraph does not apply to an anvil cloud that is attached to a parent thunderstorm.

(b) A launch operator must wait 30 minutes to initiate flight after any type of lightning occurs at a slant distance of less than or equal to 10 nautical miles from the flight path, unless:

(1) The non-transparent part of the cloud that produced the lightning is at a slant distance of greater than 10 nautical miles from the flight path;

(2) There is at least one working field mill at a horizontal distance of less than or equal to 5 nautical miles from each such lightning discharge; and

(3) The absolute values of all electric field measurements at a horizontal distance of less than or equal to 5 nautical miles from the flight path and at each field mill specified in paragraph (b)(2) of this section have been less than 1000 volts/meter for at least 15 minutes.

G417.7 CUMULUS CLOUDS

(a) This section applies to non-transparent cumulus clouds, except for cirrocumulus, altocumulus, or stratocumulus clouds. This section does not apply to an anvil cloud that is attached to a parent cumulus cloud.

(b) A launch operator may not initiate flight if the slant distance to the flight path is less than or equal to 10 nautical miles from any cumulus cloud that has a top at an altitude where the temperature is colder than or equal to −20 degrees Celsius.

(c) A launch operator may not initiate flight if the slant distance to the flight path is less than or equal to 5 nautical miles from any cumulus cloud that has a top at an altitude where the temperature is colder than or equal to −10 degrees Celsius.

(d) A launch operator may not initiate flight if the flight path will carry the launch vehicle through any cumulus cloud with its top at an altitude where the temperature is colder than or equal to −5 degrees Celsius.

(e) A launch operator may not initiate flight if the flight path will carry the launch vehicle through any cumulus cloud that has a top at an altitude where the temperature is colder than or equal to +5, and warmer than −5 degrees Celsius unless:

(1) The cloud is not producing precipitation;

(2) The horizontal distance from the center of the cloud top to at least one working field mill is less than 2 nautical miles; and

(3) All electric field measurements at a horizontal distance of less than or equal to 5 nautical miles of the flight path and at each field mill specified in paragraph (e)(2) of this section have been between −100 volts/meter and +500 volts/meter for at least 15 minutes.

G417.9 ATTACHED ANVIL CLOUDS

(a) This section applies to any non-transparent anvil cloud formed from a parent cloud that has a top at an altitude where the temperature is colder than or equal to −10 degrees Celsius.

(b) Flight path through cloud: If a flight path will carry a launch vehicle through any attached anvil cloud, the launch operator may not initiate flight unless:

(1) The portion of the attached anvil cloud at a slant distance of less than or equal to 5 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(2) The volume-averaged, height-integrated radar reflectivity is less than +10 dBZ-km (+33 dBZ-kft) at every point at a slant distance of less than or equal to 1 nautical mile from the flight path.

(c) Flight path between 0 and 3 nautical miles from cloud: If a flight path will carry a launch vehicle at a slant distance of greater than 0, but less than or equal to 3, nautical miles from any attached anvil cloud, a launch operator must wait 3 hours to initiate flight after a lightning discharge in or from the parent cloud or anvil cloud, unless:

(1) The portion of the attached anvil cloud at a slant distance of less than or equal to 5 nautical miles from the flight path is located

entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(2) The volume-averaged, height-integrated radar reflectivity is less than +10 dBZ-km (+33 dBZ-kft) at every point at a slant distance of less than or equal to 1 nautical mile from the flight path.

(d) Flight path between 3 and 5 nautical miles from cloud: If a flight path will carry a launch vehicle at a slant distance of greater than 3 and less than or equal to 5 nautical miles from any attached anvil cloud, a launch operator must wait 3 hours to initiate flight after every lightning discharge in or from the parent cloud or anvil cloud, unless the portion of the attached anvil cloud at a slant distance of less than or equal to 5 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius.

(e) Flight path between 5 and 10 nautical miles from cloud: If the flight path will carry the launch vehicle at a slant distance of greater than 5 and less than or equal to 10 nautical miles from any attached anvil cloud, the launch operator must wait to initiate flight for 30 minutes after every lightning discharge in or from the parent cloud or anvil cloud, unless the portion of the attached anvil cloud at a slant distance of less than or equal to 10 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius.

G417.11 Detached Anvil Clouds

(a) This section applies to any non-transparent anvil cloud formed from a parent cloud that had a top at an altitude where the temperature was colder than or equal to −10 degrees Celsius.

(b) Flight path through cloud: If the flight path will carry the launch vehicle through a detached anvil cloud, the launch operator may not initiate flight unless:

(1) The launch operator waits 4 hours after every lightning discharge in or from the detached anvil cloud; and observation shows that 3 hours have passed since the anvil cloud detached from the parent cloud; or

(2) Each of the following conditions exists:

(i) Any portion of the detached anvil cloud at a slant distance of less than or equal to 5 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(ii) The VAHIRR is less than +10 dBZ-km (+33 dBZ-kft) everywhere in the flight path.

(c) Flight path between 0 and 3 nautical miles from cloud: If a flight path will carry a launch vehicle at a slant distance of greater than 0 and less than or equal to 3 nautical miles from a detached anvil cloud, the launch operator must accomplish both of the following:

(1) Wait 30 minutes to initiate flight after every lightning discharge in or from the parent cloud or anvil cloud before detachment of the anvil cloud, and after every lightning discharge in or from the detached anvil cloud after detachment, unless:

(i) The portion of the detached anvil cloud less than or equal to 5 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(ii) The VAHIRR is less than +10 dBZ-km (+33 dBZ-kft) at every point at a slant distance of less than or equal to 1 nautical mile from the flight path; and

(2) If a launch operator is unable to initiate flight in the first 30 minutes under paragraph (c)(1) of this section, the launch operator must wait to initiate flight for 3 hours after every lightning discharge in or from the parent cloud or anvil cloud before detachment of the anvil cloud, and after every lightning discharge in or from the detached anvil cloud after detachment, unless:

(i) All of the following are true:

(A) There is at least one working field mill at a horizontal distance of less than or equal to 5 nautical miles from the detached anvil cloud;

(B) The absolute values of all electric field measurements at a horizontal distance of less than or equal to 5 nautical miles from the flight path and at each field mill specified in paragraph (c)(2)(i)(A) of this section have been less than 1000 V/m for at least 15 minutes; and

(C) The maximum radar reflectivity from any part of the detached anvil cloud at a slant distance of less than or equal to 5 nautical miles from the flight path has been less than +10 dBZ for at least 15 minutes; or

(ii) Both of the following are true:

(A) The portion of the detached anvil cloud at a slant distance of less than or equal to 5 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(B) The volume-averaged, height-integrated radar reflectivity is less than +10 dBZ-km (+33 dBZ-kft) at every point at a slant distance of less than or equal to 1 nautical mile from the flight path.

(d) Flight path between 3 and 10 nautical miles from cloud: If a flight path will carry a launch vehicle at a slant distance of greater than 3 and less than or equal to 10 nautical miles from a detached anvil cloud, the launch operator must wait 30 minutes to initiate flight after every lightning discharge in or from the parent cloud or anvil cloud before detachment, and after every lightning discharge in or from the detached anvil cloud after detachment, unless the portion of the detached anvil cloud at a slant distance of less than or equal to 10 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius.

G417.13 DEBRIS CLOUDS

(a) This section applies to any non-transparent debris cloud whose parent cumuliform cloud has had any part at an altitude where the temperature was colder than −20 degrees Celsius or to any debris cloud formed by a thunderstorm. This section does not apply to a detached anvil cloud.

(b) A launch operator must calculate a ''3-hour period'' as starting at the latest of the following times:

(1) The debris cloud is observed to be detached from the parent cloud;

(2) The debris cloud is observed to have formed by the collapse of the parent cloud top to an altitude where the temperature is warmer than −10 degrees Celsius; or

(3) Any lightning discharge occurs in or from the debris cloud.

(c) Flight path through cloud: If a flight path will carry a launch vehicle through a debris cloud, the launch operator may not initiate flight during the ''3-hour period,'' of paragraph (b) of this section, unless:

(1) The portion of the debris cloud at a slant distance of less than or equal to 5 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(2) The VAHIRR is less than +10 dBZ-km (+33 dBZ-kft) everywhere in the flight path.

(d) Flight path between 0 and 3 nautical miles from cloud: If the flight path will carry the launch vehicle at a slant distance of greater than or equal to 0 and less than or equal to 3 nautical miles from the debris cloud, the launch operator may not initiate flight during the ''3-hour period,'' unless one of the following applies:

(1) A launch operator may initiate flight during the ''3-hour period,'' of paragraph (b) of this section if:

(i) There is at least one working field mill at a horizontal distance of less than or equal to 5 nautical miles from the debris cloud;

(ii) The absolute values of all electric field measurements at a horizontal distance of less than or equal to 5 nautical miles from the flight path and at each field mill specified in paragraph (d)(1)(i) of this section have been less than 1000 volts/meter for at least 15 minutes; and

(ii) The maximum radar reflectivity from any part of the debris cloud less than or equal to a slant distance of 5 nautical miles from the flight path has been less than +10 dBZ for at least 15 minutes; or

(2) A launch operator may initiate flight during the ''3-hour period,'' of paragraph (b) of this section if:

(i) The portion of the debris cloud at a slant distance of less than or equal to 5 nautical miles from the flight path is located entirely at altitudes where the temperature is colder than 0 degrees Celsius; and

(ii) The VAHIRR is less than + 10 dBZ-km (+33 dBZ-kft) at every point at a slant distance of less than or equal to 1 nautical mile from the flight path.

G417.15 DISTURBED WEATHER

A launch operator may not initiate flight if the flight path will carry the launch vehicle through a non-transparent cloud associated with disturbed weather that has clouds with tops at altitudes where the temperature is colder than 0 degrees Celsius and that contains, at a slant distance of less than or equal to 5 nautical miles from the flight path, either:

(a) Moderate or greater precipitation; or

(b) Evidence of melting precipitation such as a radar bright band.

G417.17 THICK CLOUD LAYERS

(a) This section does not apply to either attached or detached anvil clouds.

(b) A launch operator may not initiate flight if the flight path will carry the launch vehicle through a non-transparent cloud layer that is:

(1) Greater than or equal to 4,500 feet thick and any part of the cloud layer in the flight path is located at an altitude where the temperature is between 0 degrees Celsius and −20 degrees Celsius, inclusive; or

(2) Connected to a thick cloud layer that, at a slant distance of less than or equal to 5 nautical miles from the flight path, is greater than or equal to 4,500 feet thick and has any part located at any altitude where the temperature is between 0 degrees Celsius and −20 degrees Celsius, inclusive.

(c) A launch operator may initiate flight despite paragraphs (a)(1) and (a)(2) of this section if the thick cloud layer:

(1) Is a cirriform cloud layer that has never been associated with convective clouds,

(2) Is located entirely at altitudes where the temperature is colder than or equal to −15 degrees Celsius, and

(3) Shows no evidence of containing liquid water.

G417.19 SMOKE PLUMES

(a) A launch operator may not initiate flight if the flight path will carry the launch vehicle through any non-transparent cumulus cloud that has developed from a smoke plume while the cloud is attached to the smoke plume, or for the first 60 minutes after the cumulus cloud is observed to be detached from the smoke plume.

(b) This section does not apply to non-transparent cumulus clouds that have formed above a fire but have been detached from the smoke plume for more than 60 minutes. Section G417.7 applies.

G417.21 SURFACE ELECTRIC FIELDS

(a) A launch operator must wait 15 minutes to initiate flight after the absolute value of any electric field measurement at a horizontal distance of less than or equal to 5 nautical miles from the flight path has been greater than or equal to 1500 volts/meter.

(b) A launch operator must wait 15 minutes to initiate flight after the absolute value of any electric field measurement at a horizontal distance of less than or equal to 5 nautical miles from the flight path has been greater than or equal to 1000 volts/meter, unless:

(1) All clouds at a slant distance of less than or equal to 10 nautical miles from the flight path are transparent; or

(2) All non-transparent clouds at a slant distance less than or equal to 10 nautical miles from the flight path:

(i) Have tops at altitudes where the temperature is warmer than or equal to +5 degrees Celsius, and

(ii) Have not been part of convective clouds with cloud tops at altitudes where the temperature was colder than or equal to −10 degrees Celsius for 3 hours.

G417.23 TRIBOELECTRIFICATION

(a) A launch operator may not initiate flight if the flight path will carry the launch vehicle through any part of a cloud at any altitude where:

(1) The temperature is colder than or equal to −10 degrees Celsius; and

(2) The launch vehicle's velocity is less than or equal to 3000 feet/second,

(b) Paragraph (a) of this section does not apply if either:

(1) The launch vehicle is treated for surface electrification so that:

(i) All surfaces of the launch vehicle susceptible to ice particle impact are such that the surface resistivity is less than 10^9 Ohms per square; and

(ii) All conductors on surfaces, including dielectric surfaces that have been coated with conductive materials, are bonded to the launch vehicle by a resistance that is less than 10^5 ohms; or

(2) A launch operator demonstrates by test or analysis that electrostatic discharges on the surface of the launch vehicle caused by triboelectrification will not be hazardous to the launch vehicle or the spacecraft.

G417.25 MEASUREMENT OF CLOUD RADAR REFLECTIVITY, COMPUTATION OF VAHIRR, AND MEASUREMENT OF ELECTRIC FIELD

(a) *Radar reflectivity measurement.* A launch operator who measures radar reflectivity to comply with this appendix must employ a meteorological radar and ensure that—

(1) The radar wavelength is greater than or equal to 5 cm;

(2) A reflectivity measurement is due to a meteorological target;

(3) The spatial accuracy and resolution of a reflectivity measurement is 1 kilometer or better;

(4) Any attenuation caused by intervening precipitation or by an accumulation of water or ice on the radome is less than or equal to 1 dBZ; and

(5) A reflectivity measurement contains no portion of the cone of silence above the radar antenna, nor any portion of any sector that is blocked out for payload safety reasons.

(b) *Computation of VAHIRR.* A launch operator who measures VAHIRR to comply with this appendix must ensure that—

(1) A digital signal processor provides radar reflectivity measurements on a three-dimensional Cartesian grid having a maximum grid-point-to-grid-point spacing of one kilometer in each of the three dimensions;

(2) The specified volume is the volume bounded in the horizontal by vertical, plane, perpendicular sides located 5.5 kilometers (3 nautical miles) north, east, south, and west of the point where VAHIRR is to be evaluated; on the bottom by the 0 degree Celsius level; and on the top by an altitude of 20 kilometers;

(3) Volume-averaged radar reflectivity is the arithmetic average of the radar reflectivity measurements in dBZ at grid points within the specified volume. A launch operator must include each grid point within the specified volume in the average if and only if that grid point has a radar reflectivity measurement equal to or greater than 0 dBZ. If fewer than 10% of the grid points in the specified volume have radar reflectivity measurements equal to or greater than 0 dBZ, then the volume-averaged radar reflectivity is either the maximum radar reflectivity measurement in the specified volume, or 0 dBZ, whichever is greater.

(4) Average cloud thickness is the difference in kilometers or thousands of feet between an average top and an average base of all clouds in the specified volume, computed as follows:

(i) The cloud base to be averaged is the higher, at each horizontal position, of either

(A) The 0 degree Celsius altitude, or

(B) The lowest altitude of all radar reflectivity measurements of 0 dBZ or greater.

(ii) The cloud top to be averaged is the highest altitude of all radar reflectivity measurements of 0 dBZ or greater at each horizontal position.

(iii) A launch operator must—

(A) Take the cloud base at any horizontal position as the altitude of the corresponding base grid point minus half of the grid-point vertical separation;

(B) Take the cloud top at that horizontal position as the altitude of the corresponding top grid point plus half of this vertical separation.

(5) All VAHIRR-evaluation points in the flight path itself are:

(i) Greater than a slant distance of 10 nautical miles from any radar reflectivity of 35 dBZ or greater at altitudes of 4 kilometers or greater above mean sea level; and

(ii) Greater than a slant distance of 10 nautical miles from any type of lightning that has occurred in the previous 5 minutes.

(iii) A launch operator need not apply paragraph (b)(5) of this section to VAHIRR evaluation points outside the flight path but within one nautical mile of the flight path.

(6) VAHIRR is the product, expressed in units of dBZ-km or dBZ-kft, of the volume-averaged radar reflectivity defined in paragraph (b)(3) of this section and the average cloud thickness defined in paragraph (b)(4) of this section in the specified volume defined in paragraph (b)(2) of this section.

(c) *Electric field measurement.* A launch operator who measures an electric field to comply with this appendix must—

(1) Employ a ground-based field mill,

(2) Use only the one-minute arithmetic average of the instantaneous readings from that field mill,

(3) Ensure that all field mills are calibrated so that the polarity of the electric field measurements is the same as the polarity of a voltage placed on a test plate above the sensor,

(4) Ensure that the altitude of the flight path of the launch vehicle is equal to or less than 20 kilometers (66 thousand feet) everywhere above a horizontal circle of 5 nautical miles centered on the field mill being used,

(5) Use only direct measurements from a field mill, and

(6) Not interpolate based on electric-field contours.

[Amdt. 417–2, 76 FR 33149, June 8, 2011]

APPENDIX H TO PART 417 [RESERVED]

APPENDIX I TO PART 417—METHODOLOGIES FOR TOXIC RELEASE HAZARD ANALYSIS AND OPERATIONAL PROCEDURES

I417.1 GENERAL

This appendix provides methodologies for performing toxic release hazard analysis for the flight of a launch vehicle as required by §417.229 and for launch processing at a launch site in the United States as required by §417.407(f). The requirements of this appendix apply to a launch operator and the launch operator's toxic release hazard analysis unless the launch operator clearly and convincingly demonstrates that an alternative approach provides an equivalent level of safety.

I417.3 IDENTIFICATION OF NON-TOXIC AND TOXIC PROPELLANTS

(a) *General.* A launch operator's toxic release hazard analysis for launch vehicle flight (section I417.5) and for launch processing (section I417.7) must identify all propellants used for each launch and identify whether each propellant is toxic or non-toxic as required by this section.

(b) *Non-toxic exclusion.* A launch operator need not conduct a toxic release hazard analysis under this appendix for flight or launch processing if its launch vehicle, including all launch vehicle components and payloads, uses only those propellants listed in Table I417–1.

Table I417-1, Commonly Used Non-Toxic Propellants

Item	Chemical Name	Formula
1	Liquid Hydrogen	H_2
2	Liquid Oxygen	O_2
3	Kerosene (RP-1)	$CH_{1.96}$