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## 1.0 Weather Rules.

This section contains the weather conditions that are a constraint to launching the Space Shuttle Vehicle (SSV). The weather constraints stated in this section shall not be waived. The time effectivity of the constraints contained herein is as follows unless otherwise specified within the section text:

- Ambient Temperature Criteria (Section 1.1) - from Start of ET Cryo Tanking (T-6 hours) to Go for APU Start (T-5 minutes)
- Precipitation Criteria (Section 1.2) - from Start of ET Cryo Tanking (T-6 hours) to Go for APU Start (T-5 minutes)
- Ground Wind Criteria (Section 1.3) - reference GSE-24
- Lightning Criteria (Section 1.4) - from Start of ET Cryo Tanking (T-6 hours) to Go for SSME Ignition (T-10 seconds)

The Orbiter landing site criteria are contained in the Space Shuttle Operational Flight Rules document.

### 1.1 Ambient Temperature Restriction at the Space Shuttle Vehicle.

Ambient temperature, relative humidity and wind speed measurements are 5 minute averages supplied by the Launch Weather Officer (LWO) for the launch pad in use.-

#### A. Prior to External Tank (ET) Cryogenic Loading.

1. Propellant loading of the ET shall not be initiated if the average temperature for the 24 hours prior to tanking is below 41.3 degrees Fahrenheit (F).
2. Propellant loading of the ET shall not be initiated if the temperature anytime during the 24 hours prior to tanking drops below 33 degrees F.

Neither of the above minimum temperature requirements is based on a particular piece of flight hardware violating a specific temperature constraint. A typical diurnal profile for a day averaging 41.3 degrees F at Kennedy Space Center (KSC) reflects a minimum ambient temperature at, or above, 32.9 degrees F. This is intended to minimize the potential for ice formation on or inside the SSV flight hardware and on the launch pad. This is also consistent with the statistical 1% cold day at the KSC launch site that is used for SSV Element design assessments per NSTS 07700 Volume X. The 33 degree F minimum temperature requirement (32 degree baseline plus 1 degree for instrumentation error) was added as protection for non-typical days that may meet the 41.3 degrees average requirement but still exhibit minimum temperatures at or below 32 degrees F. By accepting these minimum temperature requirements, the Space Shuttle Program (SSP) maintains a conservative approach and does not require any SSV Project Element to perform real time thermal analysis prior to ET loading.

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B. From Start of ET Cryogenic Loading to Exiting the Last Hold Prior to Auxiliary Power Unit (APU) Start.

1. The countdown shall not be continued nor the SSV launched if the ambient temperature during this time period exceeds 99 degrees F for more than 30 consecutive minutes.
2. The SSV shall not be launched if the ambient temperature (Tamb) is lower than the minimum temperature limit (Tmin) (Table 1.1A), for more than 30 consecutive minutes unless the Preplanned Contingency Procedure (PCP) indicates recovery from the low temperature excursions that caused the Launch Commit Criteria (LCC) violation. The minimum temperature limits are specified in Table 1.1A as a function of wind speed and relative humidity. The 0-64% column of Table 1.1A shall be used to specify minimum ambient temperature limits if relative humidity instrumentation is non-functional.

Wind Speed (knots)	Minimum Ambient Temperature (Deg F), Tmin				
	Relative Humidity				
	0-64%	65-74%	75-79%	80-89%	90-100%
0-1	48	47	46	45	44
2	47	46	45	44	43
3	41	41	41	40	39
4	39	39	39	39	38
5-7	38	38	38	38	38
8-14	37	37	37	37	37
>14	36	36	36	36	36

Table 1.1A

Rationale: The ambient temperature restriction protects temperature limits specified in NSTS 07700, Volume X. Temperature constraints are based on temperature depression and measurement uncertainties.

PCP for Minimum Ambient Temperature Violations:

The following Recovery Temperature Algorithm (RTA) shall be initiated upon violation of the minimum ambient temperature LCC limit. The RTA balances energy levels for ambient air temperature deviations below the LCC versus the effect of air temperature returning above the limit. The RTA integrates a convective cooling energy term for the time the ambient air temperature is below the limit and offsets it with a convective heating term plus a diffuse solar heating term when the ambient air temperature is back above the limit. When the total energy is greater than zero, the SSV system has recovered from convective cooling excursions.

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## Nomenclature:

Delta t= Time interval for summing (units of 5 minutes)

X= Switch for summing energy terms  
 X=1 for Tamb > or = Tmin  
 X=0 for Tamb < Tmin

Tamb= Average measured ambient air temperature in the time interval  
 (units of degrees F)

Tmin= Minimum ambient air temperature limit specified in Table 1.1A  
 at the measured wind speed in the time interval (units of  
 degree F)

Qsol= Diffuse solar flux from Table 1.1B (units of British Thermal  
 Unit (Btu)/Square Foot per Hour (ft<sup>2</sup>-hr))

Esum= Running energy sum of convective cooling, convective heating  
 solar energy (Btu-minutes/ft<sup>2</sup>-hr)

V= 5 minute averaged wind speed in knots

Hc= the maximum of:  $Hc=4.0(V/5.0)**0.5$  or,  $Hc=1.0$ . The lower  
 limit of 1.0 is a natural convection value and for winds  
 greater than zero, a forced value is calculated as a function  
 of wind speed in knots (units of Btu/ft<sup>2</sup>-hr-F)

sigma= summation

## System RTA:

$$Esum \text{ (Btu-minutes/ft}^2\text{-hr)} =$$

$$.5 \text{ (Btu/ft}^2\text{-hr-F)} \sigma \text{ ((Tamb-Tmin) (F) (Delta t) (minutes) (X))}$$

$$+ 0.2 \sigma \text{ ((Qsol) (Btu/ft}^2\text{-hr) (Delta t) (minutes) (X))}$$

$$- \sigma Hc \text{ (Btu/ft}^2\text{-hr-F) ((Tmin-Tamb) (F) (Delta t) (minutes) (1-X))}$$

where Hc is the greater of  $Hc = 4.0(V/5.0)**0.5$  (Btu/ft<sup>2</sup>-hr-F)  
 or  $Hc = 1.0$  (Btu/ft<sup>2</sup>-hr-F)

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Diffuse Solar Table (Table 1.1B):

The values for diffuse solar are the minimum that can be expected on the launch pad and are valid for any time of year and any amount of cloud cover.

Solar Time	Eastern Standard Time	Qsol (Btu/ft <sup>2</sup> -hr)
0:00	0:20	0.00
6:40	7:00	0.00
7:00	7:20	0.04
7:20	7:40	4.54
7:40	8:00	8.79
8:00	8:20	11.43
8:20	8:40	13.14
8:40	9:00	14.32
9:00	9:20	15.16
9:20	9:40	15.79
9:40	10:00	16.26
10:00	10:20	16.62
10:20	10:40	16.90
10:40	11:00	17.11
11:00	11:20	17.26
11:20	11:40	17.36
11:40	12:00	17.42
12:00	12:20	17.44
12:20	12:40	17.42
12:40	13:00	17.36
13:00	13:20	17.26
13:20	13:40	17.11
13:40	14:00	16.90

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Table 1.1B (Continued)

Solar Time	Eastern Standard Time	Qsol (Btu/ft <sup>2</sup> -hr)
14:00	14:20	16.62
14:20	14:40	16.26
14:40	15:00	15.79
15:00	15:20	15.16
15:20	15:40	14.32
15:40	16:00	13.14
16:00	16:20	11.43
16:20	16:40	8.79
16:40	17:00	4.54
17:00	17:20	0.04
17:20	17:40	0.00
24:00	0:20	0.00

## Rules for Use of the RTA:

1. The time interval for summing is 5 minutes consistent with the 5 minute average temperature values supplied by the LWO.
2. The RTA must sum Esum for the time period when the first 5 minute average minimum temperature excursion ( $T_{amb} < T_{min}$ ) occurs continuous through the time period where recovery occurs (Esum greater than 0).
3. Re-zero Esum if it is positive and a subsequent low temperature excursion is encountered.
4. When Esum is positive, the SSV has recovered and the LCC violation is cleared.

## 1.2 Precipitation Constraint.

The SSV will not be launched if precipitation (visible rain, virga, or minimum discernible weather radar echo) exists in the "flight path" of the SSV.

## 1.3 Surface Wind Limits. Surface wind limits for launch (Measured at 60 feet above natural grade).

Surface wind criteria are specified in LCC GSE-24.

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1.4 Natural and Triggered Lightning Constraints.

Notice: The lightning definitions, explanations and examples are a critical part of the lightning constraints and must be used when evaluating all lightning constraints in this section.

Notice: Any changes to this section will require coordination with the 45<sup>th</sup> Space Wing Range Safety Office (RSO).

The Launch Weather Team (LWT) must have clear and convincing evidence that the following hazard avoidance criteria are not violated.

Even when these criteria are not violated, if any other hazardous condition exists, the LWT will report the threat to the Launch Director (LD). The LD may Hold at any time based on the instability of the weather.

A. Surface Electric Fields

1. Do not launch for 15 minutes after the absolute value of any "electric field measurement" less than or equal to 5 Nautical Miles (NM) from the "flight path" has been greater than or equal to 1500 Volts/meter (V/m).
2. Do not launch for 15 minutes after the absolute value of any "electric field measurement" less than or equal to 5 NM of the "flight path" has been greater than or equal to 1000 V/m unless subparagraph 1.4.A.2.a. or subparagraph 1.4.2.b. is satisfied:
  - a. All "clouds" less than or equal to 10 NM from the "flight path" are "transparent";
  - or-
  - b. All "clouds" less than or equal to 10 NM from the "flight path" have "cloud tops" at altitudes where the temperature is warmer than +5 degrees Celsius and have not been part of convective "clouds" with "cloud tops" at altitudes where the temperature is colder than or equal to -10 degrees Celsius during the last 3 hours.

B. Lightning

1. Do not launch for 30 minutes after any type of lightning occurs in a "thunderstorm" if the "flight path" will carry the SSV less than or equal to 10 NM from the "thunderstorm". An attached "anvil cloud" is not considered part of its parent "thunderstorm" but is covered instead by the Attached Anvil Cloud Rule.
2. Do not launch for 30 minutes after any type of lightning occurs less than or equal to 10 NM from the "flight path" unless all three of the following conditions are satisfied:
  - a. The "cloud" that produced the lightning is greater than 10 NM from the "flight path";

-and-

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- b. There is at least one working "field mill" less than 5 NM from each such lightning discharge;

-and-

- c. The absolute values of all "electric field measurements" less than or equal to 5 NM from the "flight path", and at each "field mill" specified in subparagraph 1.4.B.2.b., have been less than 1000 V/m for 15 minutes or longer.

### C. Cumulus Clouds

For the purposes of this section, "cumulus 'clouds'" do not include cirrocumulus, altocumulus, or stratocumulus "clouds". An attached "anvil cloud" is never considered part of its parent cumulus "cloud," but is covered instead by subparagraph 1.4.D.1., Attached "Anvil Clouds". Subparagraph 1.4.D.2., Detached "Anvil Clouds" applies to any detached "anvil cloud". Section 1.4.E, "Debris Clouds" applies to "debris clouds".

1. Do not launch if the "flight path" will carry the SSV less than or equal to 10 NM from any cumulus "cloud" that has a "cloud top" at an altitude where the temperature is colder than or equal to -20 degrees Celsius.
2. Do not launch if the "flight path" will carry the SSV less than or equal to 5 NM from any cumulus "cloud" that has a "cloud top" at an altitude where the temperature is colder than or equal to -10 degrees Celsius.
3. Do not launch if the "flight path" will carry the SSV through any cumulus "cloud" with its "cloud top" at an altitude where the temperature is colder than or equal to -5 degrees Celsius.
4. Do not launch if the "flight path" will carry the SSV through any cumulus "cloud" that has a "cloud top" at an altitude where the temperature lies in the range from warmer than -5 degrees Celsius to colder than or equal to +5 degrees Celsius unless all three of the following conditions are satisfied:
  - a. The "cloud" is not producing "precipitation";

-and-

  - b. The horizontal distance from the center of the "cloud top" to at least one working "field mill" is less than 2 NM;

-and-

  - c. All "electric field measurements" less than or equal to 5 NM from the "flight path" and at each "field mill" specified in subparagraph 1.4.B.4.b. above have been greater than -100 V/m, but less than +500 V/m for 15 minutes or longer.

## D. Anvil Clouds

## 1. Attached "Anvil Clouds"

For the purpose of this section, if there has never been lightning in or from the parent "cloud" or "anvil cloud", subparagraphs

1.4.D.1.a and 1.4.D.1.b. shall be considered satisfied, but subparagraph 1.4.D.1.c. shall still apply.

- a. Do not launch if the "flight path" will carry the SSV less than 10, but greater than 5 NM from any attached "anvil cloud" for the first 30 minutes after the last lightning discharge in or from the parent "cloud" or "anvil cloud" unless the portion of the attached "anvil cloud" less than or equal to 10 NM from the "flight path" is located entirely at altitudes where the temperature is colder than 0 degrees Celsius.
- b. Do not launch if the "flight path" will carry the SSV less than or equal to 5, but greater than 3 NM from any attached "anvil cloud" for the first 3 hours after the last lightning discharge in or from the parent "cloud" or "anvil cloud" unless the portion of the attached "anvil cloud" less than or equal to 5 NM from the "flight path" is located entirely at altitudes where the temperature is colder than 0 degrees Celsius.
- c. Do not launch if the "flight path" will carry the SSV less than or equal to 3 NM from any attached "anvil cloud" unless all three of the following conditions are satisfied:
  - 1) The portion of the attached "anvil cloud" less than or equal to 5 NM 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 ("VAHIRR") is less than +10 dBZ-km (+33 dBZ-kft) at every point less than or equal to 1 NM from the "flight path";
  - and-
  - 3) All of the "VAHIRR application criteria" are satisfied.

## 2. Detached "Anvil Clouds".

For the purposes of this section, detached "anvil clouds" are never considered "debris clouds".

For the purpose of this section, if there has never been lightning in or from the parent "cloud" or "anvil cloud", subparagraphs 1.4.D.2.a, 1.4.D.2.b, 1.4.D.2.c and 1.4.D.2.d.1.a shall be considered satisfied, but subparagraphs 1.4.D.2.d.1.b and 1.4.D.2.d.2 shall still apply.

- a. Do not launch if the "flight path" will carry the SSV less than or equal to 10, but greater than 3 NM from a detached "anvil



cloud" for the first 30 minutes after the last lightning discharge in or from the parent "cloud" or "anvil cloud" before detachment or after the last lightning discharge in or from the detached "anvil cloud" after detachment unless the portion of the detached "anvil cloud" less than or equal to 10 NM from the "flight path" is located entirely at altitudes where the temperature is colder than 0 degree Celsius."

- b. Do not launch if the "flight path" will carry the SSV between 0 (zero) and 3 NM inclusive, from a detached "anvil cloud" for the first 30 minutes after the time of the last lightning discharge in or from the parent "cloud" or "anvil cloud" before detachment or after the last lightning discharge in or from the detached "anvil cloud" after detachment unless all three of the following conditions are met:

- 1) The portion of the detached "anvil cloud" less than or equal to 5 NM 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 +33 dBZ-kft (+10 dBZ-km) at every point less than or equal to 1 NM from the "flight path";

-and-

- 3) All of the "VAHIRR application criteria" are satisfied.

- c. Do not launch if the "flight path" will carry the SSV between 0 (zero) and 3 NM, inclusive, from a detached "anvil cloud" less than or equal to 3 hours, but greater than 30 minutes, after the time of the last lightning discharge in or from the parent "cloud" or "anvil cloud" before detachment or after the last lightning discharge in or from the detached "anvil cloud" after detachment unless subparagraph 1.4.D.2.c.1) or subparagraph 1.4.D.2.c.2) is satisfied:

- 1) This section is satisfied if all three of the following conditions are met:

- a) There is at least one working "field mill" less than 5 NM from the detached "anvil cloud";

-and-

- b) The absolute values of all "electric field measurements" less than or equal to 5 NM from the "flight path" and at each "field mill" specified in subparagraph 1.4.D.2.c.1)a) have been less than 1000 V/m for 15 minutes;

-and-

- c) The maximum radar reflectivity from any part of the detached "anvil cloud" less than or equal to 5 NM from the "flight path" has been less than +10 dBZ for 15 minutes.

- 2) This section is satisfied if all three of the following

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conditions are met:

- a) The portion of the detached "anvil cloud" less than or equal to 5 NM from the "flight path" is located entirely at altitudes where the temperature is colder than 0 degrees Celsius;
  - and-
  - b) The "VAHIRR" is less than +33 dBZ-kft (+10 dBZ-km) at every point less than or equal to 1 NM from the "flight path";
  - and-
  - c) All of the "VAHIRR application criteria" are satisfied.
- d. Do not launch if the "flight path" will carry the SSV through a detached "anvil cloud" unless subparagraph 1.4.D.2.d.1) or subparagraph 1.4.D.2.d.2) is satisfied:
- 1) This section is satisfied if both of the following conditions are met:
    - a) At least 4 hours have passed since the last lightning discharge in or from the detached "anvil cloud";
    - and-
    - b) At least 3 hours have passed since the time that the "anvil cloud" is observed to be detached from the parent "cloud".
  - 2) This section is satisfied if all three of the following conditions are met:
    - a) The portion of the detached "anvil cloud" less than or equal to 5 NM from the "flight path" is located entirely at altitudes where the temperature is colder than 0 degrees Celsius;
    - and-
    - b) The "VAHIRR" is less than +33 dBZ-kft (+10 dBZ-km) everywhere along the "flight path";
    - and-
    - c) All of the "VAHIRR application criteria" are satisfied.

#### E. Debris Clouds

The 3-hour time period defined in this section must begin again at the time of any lightning discharge in or from the "debris cloud".

1. Do not launch if the "flight path" will carry the SSV between 0 and 3 NM, inclusive, from a debris cloud for 3 hours after the debris cloud is observed to be detached from the parent cloud or after the debris cloud is observed to have formed from the collapse of the parent cloud top to an altitude where the temperature is warmer than -10 degrees Celsius unless subparagraph 1.4.E.1.a. or subparagraph 1.4.E.1.b. is satisfied:

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- a. This section is satisfied if all three of the following conditions are met:
- 1) There is at least one working "field mill" less than 5 NM from the debris cloud;
- and-
- 2) The absolute values of all "electric field measurements" less than or equal to 5 NM from the "flight path" and at each "field mill(s)" employed by subparagraph 1.4.E.1.a.1) of this section has been less than 1000 V/m for 15 minutes or longer;
- and-
- 3) The maximum radar reflectivity from any part of the debris cloud less than or equal to 5 NM of the "flight path" has been less than +10 dBZ for 15 minutes or longer.

- b. This section is satisfied if all three of the following conditions are met:
- 1) The portion of the debris cloud less than or equal to 5 NM 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 +33 dBZ-kft (+10 dBZ-km) at every point less than or equal to 1 NM from the "flight path";
- and-
- 3) All of the "VAHIRR application criteria" are satisfied.

2. Do not launch if the "flight path" will carry the SSV through any "debris cloud" during the 3-hour period defined in Section 1.4.E.1, unless all three of the following conditions are met:

- a. The portion of the "debris cloud" less than or equal to 5 NM from the "flight path" is located entirely at altitudes where the temperature is colder than 0 degrees Celsius;
- and-
- b. The "VAHIRR" is less than +33 dBZ-kft (+10 dBZ-km) everywhere along the "flight path";
- and-
- c. All of the "VAHIRR application criteria" are satisfied.

#### F. Disturbed Weather

1. Do not launch if the "flight path" will carry the SSV through a "cloud" associated with "disturbed weather" that has "clouds" with "cloud tops" at altitudes where the temperature is colder than or equal to 0 degrees Celsius and that contains, less than or equal to 5 NM from the "flight path", either:
  - a. "Moderate precipitation" or greater;

-or-

  - b. Evidence of melting "precipitation" such as a "radar bright" band.

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### G. Thick Cloud Layers

For the purpose of this section neither attached nor detached "anvil clouds" are considered "thick cloud layers".

1. Do not launch if the "flight path" will carry the SSV through a "cloud layer" that is either:
  - a. Greater than or equal to 4,500 feet thick and any part of the "cloud layer" along "flight path" is located at an altitude where the temperature is between 0 degrees Celsius and -20 degrees Celsius, inclusive;
  - or-
  - b. Connected to a "cloud layer" that, less than or equal to 5 NM from the "flight path", is greater than or equal to 4,500 feet thick and has any part located at an altitude where the temperature is between 0 degrees Celsius and -20 degrees Celsius, inclusive.
2. A launch operator need not apply the lightning commit criteria in subparagraph 1.4.G.1.a. and subparagraph 1.4.G.1.b. of this section if the "thick cloud layer" is a cirriform "cloud layer" that has never been "associated" with convective "clouds", is entirely at altitudes where the temperature is colder than or equal to -15 degrees Celsius and shows no evidence of containing liquid water.

### H. Smoke Plumes

1. Do not launch if the "flight path" will carry the SSV through any 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.
2. Section 1.4.C. Cumulus "Clouds" applies to cumulus "clouds" that have formed above a fire but have been detached from the smoke plume for more than 60 minutes.

### I. Definitions, Explanations and Examples:

For the purpose of the Natural and Triggered Lightning LCC, distance from an electric "field mill" is measured differently than distance from any other object or measurement point: Distance between a "radar reflectivity" or "VAHIRR" measurement point and any object or the "flight path" is the SHORTEST SEPARATION (horizontal, vertical, or slant range) between that point and the NEAREST PART of the object or "flight path". Similarly, distance between the "flight path" and any object is the SHORTEST SEPARATION between any point on the "flight path" the NEAREST PART of that object. For example, "every point less than or equal to 1 NM from the 'flight path'" [see subparagraph 1.4.D.1.c.2) Attached Anvil Clouds] means that the "VAHIRR" threshold must be satisfied at every point throughout the entire volume defined by a 1 NM radius from every point on the "flight path". In contrast, distance between a "field mill" or an "electric field measurement" and

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any object or the "flight path" is always measured HORIZONTALLY between that mill or measurement point and the nearest part of the VERTICAL PROJECTION of the object or "flight path" onto the surface of Earth. For example, "from the center of the 'cloud top' to at least one working 'field mill'" [see subparagraph 1.4.C.4.b. Cumulus "Clouds"] means that the HORIZONTAL distance between the "field mill" and a point on the surface directly beneath the center of the "cloud top" must be less than 2 NM.

1. Anvil Cloud: Stratiform or fibrous "cloud" produced by the upper level outflow or blow-off from "thunderstorms" or "convective clouds" having tops at altitudes where the temperature is colder than or equal to -10 degrees Celsius.
2. Associated: When two or more "clouds" are causally related to the same "disturbed weather" system or are physically connected. "Clouds" occurring at the same time are not necessarily "associated". A cumulus "cloud" formed locally and a cirrus layer that is physically separated from that cumulus "cloud" and that is generated by a distant source are not "associated," even if they occur over or near the launch point at the same time.
3. Average cloud thickness is the altitude difference (in kilometers, km hereafter) between the average top and the average base of all "clouds" in the "specified volume." The cloud base to be averaged is the higher of (1) the 0 degree Celsius level and (2) the lowest extent (in altitude) of all "radar reflectivity" measurements of 0 dBZ or greater. Similarly, the cloud top to be averaged is the highest extent (in altitude) of all "radar reflectivity" measurements of 0 dBZ or greater. Given the grid-point representation of a typical radar processor, allowance must be made for the vertical separation of grid points in computing "average cloud thickness": The cloud base at any horizontal position shall be taken as the altitude of the corresponding base grid point minus half of the grid-point vertical separation. Similarly, the cloud top at that horizontal position shall be taken as the altitude of the corresponding top grid point plus half of this vertical separation. Thus, a cloud represented by only a single grid point having a "radar reflectivity" equal to or greater than 0 dBZ in the "specified volume" would have an "average cloud thickness" equal to the vertical grid-point separation in its vicinity.
4. Bright Band: 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.
5. Cloud: A visible mass of suspended water droplets or ice crystals. The "cloud" is considered to be the entire volume enclosed by the visible, "nontransparent cloud" boundary as seen by an observer, or, in the absence of a visual observation, by the 0 dBZ "radar reflectivity" boundary. A visual evaluation of transparency is preferred whenever possible.

Distance from the "cloud" to a point in question refers to the separation between the point and the nearest part of that "cloud." Specifically, the wording, "less than or equal to 10 NM from any cumulus 'cloud'" means that the "flight path" must not penetrate

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either the INTERIOR of the "cloud" itself or the volume between 0 and 10 NM, inclusive, OUTSIDE the "cloud" boundary [for example, see Section 1.4.C., Cumulus "Clouds"]. On the other hand, "between 0 and 3 NM, inclusive, from" refers ONLY to the volume at a distance that is greater than or equal to 0, but less than or equal to 3, NM OUTSIDE the "cloud" boundary, specifically omitting the interior of the "cloud" itself [for example, see Section 1.4.E, "Debris Clouds"].

6. Cloud Layer: A vertically continuous array of clouds, not necessarily of the same type, whose bases are approximately at the same level.
7. Cloud Top: The visible top of the cloud, or, in the absence of a visual observation, the 0 dBZ radar top. A visual evaluation of "cloud top" is preferred whenever possible.
8. Cone of Silence: The volume in an inverted circular cone centered on the radar that is generated by all elevation angles greater than the maximum elevation angle used in the radar scan strategy. For the purpose of "VAHIRR" calculation this volume is capped by the observed maximum "cloud top" height, the observed tropopause height, or an altitude of 20 km (66 kft), whichever is lowest.
9. Cumulonimbus Cloud: Any convective "cloud" with any part at an altitude where the temperature is colder than -20 degrees Celsius.
10. Debris Cloud: 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".
11. Disturbed Weather: A weather system where dynamical processes destabilize the air on a scale larger than the individual "clouds" or cells. Examples of disturbances are fronts, troughs and squall lines.
12. Electric Field Measurement at the Surface: The one-minute arithmetic average of the vertical electric field ( $E_z$ ) at the surface of Earth, measured by a ground-based "field mill". The polarity of the electric field is the same as that of the potential gradient; that is, the polarity of the field at Earth's surface is the same as the dominant charge overhead. Do not use interpolated electric field contours for purposes of this appendix. An "'electric field measurement' less than or equal to 5 NM from the 'flight path'" [e.g., Section 1.4.A. Surface Electric Fields] is not applicable if the altitude of the "flight path" everywhere above the 5 NM circle around the "field mill" in question is greater than 20 km (66 kft).
13. Field Mill: A specific class of 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.

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14. Flight Path: The planned nominal flight trajectory, including its vertical and horizontal uncertainties specified by the three-sigma guidance and performance deviations.
  15. Moderate Precipitation: A precipitation rate of 0.1 inches/hour or a radar reflectivity factor of 30 dBZ.
  16. Nontransparent: "Cloud" cover is "nontransparent" if one or more of the following conditions is present:
    - (a) Objects above, including higher "clouds", blue sky, and stars, are blurred, indistinct, or obscured as viewed from below; or objects below, including terrain, buildings, and lights on the ground, are blurred, indistinct, or obscured as viewed from above; when looking through the "cloud" cover at visible wavelengths (the sun and moon may not be used to evaluate transparency);
    - (b) Such objects are seen distinctly only through breaks in the "cloud" cover; or
    - (c) The "cloud" cover has a "radar reflectivity" factor of 0 dBZ or greater.
  17. Precipitation: Detectable rain, snow, hail, graupel, or sleet at the ground; virga; or a "radar reflectivity" factor greater than 18 dBZ at any altitude above the ground.
  18. Radar Reflectivity: The radar return from hydrometeors, in dBZ, measured by a meteorological radar operating at a wavelength greater than or equal to 5 cm. A "radar reflectivity" measurement is valid only in the absence of significant attenuation by intervening "precipitation" or by water or ice on the radome.
  19. Specified Volume: The volume bounded in the horizontal by vertical planes with perpendicular sides located 5.5 km (3 NM) north, east, south, and west of the point at which "VAHIRR" is being computed. The volume is bounded on the bottom at the altitude where the temperature is 0 degrees Celsius, and on the top by a fixed altitude of 20 km (66 kft).
  20. Thick Cloud Layer: One or more "cloud layers" whose combined vertical extent from the base of the bottom layer to the "cloud top" of the uppermost layer exceeds a thickness of 4,500 feet. "Cloud layers" are combined with neighboring layers for determining total thickness only when they are physically connected by vertically continuous "clouds", as, for example, when towering "clouds" in one layer contact or merge with "clouds" in a layer (or layers) above.
  21. Thunderstorm: Any convective cloud that produces lightning.
  22. Transparent: Any "cloud" that is not "nontransparent" is "transparent".
  23. (reserved)
  24. (reserved)

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25. Volume-Averaged, Height-Integrated Radar Reflectivity (VAHIRR). The product of the "volume-averaged radar reflectivity" and the "average cloud thickness" in a "specified volume" surrounding any point at which "VAHIRR" is being computed (units of dBZ-km). The "specified volume" must not contain any portion of the "cone of silence" above the radar, nor any portion of any sectors that may have been blocked out for payload-safety reasons.
26. VAHIRR Application Criteria: The individual grid-point reflectivity measurements used to determine either the "volume-averaged radar reflectivity" or the "average cloud thickness" must be meteorological "radar reflectivity" measurements. For "VAHIRR"-evaluation points along the "flight path" itself (not those at a prescribed distance away from the "flight path"), the "volume-averaged, height-integrated radar reflectivity" is not applicable at any point that is less than or equal to 10 NM from any "radar reflectivity" of 35 dBZ or greater at altitudes of 4 km (13 kft) or greater above mean sea level, nor is it applicable at any point that is less than or equal to 10 NM from any type of lightning that has occurred in the previous 5 minutes.
27. Volume-Averaged Radar Reflectivity: the arithmetic average (in dBZ) of the "radar reflectivity" in the "specified volume." Normally, a radar processor will report reflectivity values interpolated onto a regular, three-dimensional array of grid points. Any such grid point in the "specified volume" is included in the average if and only if it has a "radar reflectivity" 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" (in dBZ) in the "specified volume," or 0 dBZ, whichever is greater.

#### J. Interim Instructions for Implementation of VAHIRR

The "VAHIRR" quantity referred to in Section 1.4.C. and the definitions require computation of both a volume average reflectivity and an average cloud thickness. These quantities are then multiplied to produce the "VAHIRR". Neither of these quantities is available yet as a product on the WSR-88D and WSR-74C radar systems used to support launch operations. This instruction provides a methodology for evaluating "VAHIRR" criteria with currently available radar products. The methodology provides a result that is more conservative than a direct "VAHIRR" computation, but it should still permit the launch users to achieve much of the benefit of the "VAHIRR" feature.

1. Part I. Determination of average cloud thickness. The definition of "VAHIRR" requires determination of the average cloud top and the average cloud base above the height of the 0C isotherm within a square having sides 5.5 km (3 NM) north, east, south, and west of the ground projection of each point in the flight track. Average cloud thickness is defined as the difference of these two numbers. If the average cloud thickness cannot be determined at each point on the flight track, the maximum thickness within 5.5 km (3 NM) of the flight track may be used.

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To determine the average cloud top height, the launch weather team may use any existing radar product that gives the height of the 0 dBZ cloud top, including "maximum height of reflectivity" and cross section products. If the average height cannot be determined, the maximum height of the 0 dBZ reflectivity may be used. If the maximum height cannot be determined, use 18 km (60 kft) for the average cloud top.

The average height of the cloud base should be derived from radar data. It is the average of the higher of (a) the bottom of the portion of the cloud producing a radar reflectivity of 0 dBZ or greater or (b) the height of the 0C isotherm where the 0 dBZ reflectivity extends below that level. If the average height of the cloud base cannot be determined, use the higher of (a) the height of the 0 degree C isotherm or (b) the lowest portion of the cloud producing a radar reflectivity of 0 dBZ or greater anywhere within each 5.5 km (3 NM) square defined above.

2. Part II. Volume Averaged Radar Reflectivity (VARR). There is no operationally feasible way to use existing radar products to compute a volume average reflectivity. A conservative substitute is the maximum reflectivity since the volume average will always be smaller than the maximum. The WSR-88D has a "User Selectable Layer Composite Reflectivity (URL)" product and the WSR-74C has a "Max" product with user selectable base and top. The Launch Weather Team should configure these products with the bottom of the layer at the height of the 0 degree C isotherm and the top above the height of the highest radar beam within 7.8 km (4.2 NM) of the ground-projected flight track in the scan strategy being used. The WSR-88D product will have to be configured at the Radar Product Generator (RPG) and included in the product scheduler for the Principal User Processor (PUP) used by the launch weather team.
3. Part III. Evaluating the constraint. The "VAHIRR" constraint is satisfied for a point on the flight track if the "URL" or "Max" radar product (see Part II above) everywhere within the corresponding square (defined above) is less than 10 dBZ-km divided by the average cloud thickness in km within the same square (see Part I above). (In English units, this threshold would become 33 dBZ-kft divided by the average cloud thickness in kft.) This constraint must be satisfied for every point on the flight track.

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