

4.0 WEATHER RULES.

This section contains the weather conditions which are a constraint to launching the Space Shuttle. The weather constraints stated in this section shall not be waived.

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

4.1 AMBIENT TEMPERATURE RESTRICTION AT THE MLP DECK.

Ambient temperature, relative humidity and wind speed measurements are supplied by the Launch Weather Officer.

A. Prior to External Tank Cryogenic Loading.

Propellant loading of the External Tank shall not be initiated if the 24 hour average temperature for the preceding 24 hours has been below 41 degrees Fahrenheit.

B. From Start of ET Cryogenic Loading to Exiting the Last Hold Prior to APU Start.

(1) The countdown shall not be continued nor the Shuttle launched if the ambient temperature during this time period exceeds 99 degrees Fahrenheit for more than 30 consecutive minutes based on 5 minute averages of ambient temperature.

(2) The Shuttle shall not be launched if the ambient temperature is lower than the minimum temperature limit, Tmin (Table 4.1B), for more than 30 consecutive minutes unless the preplanned contingency indicates recovery from the low temperature excursions which caused the LCC violation. The minimum temperature limits are specified in Table 4.1B as a function of wind speed and relative humidity. The 0-64% column of Table 4.1B shall be used to specify minimum ambient temperature limits if relative humidity instrumentation is non-functional. All measurements (ambient temperature, wind speed, and relative humidity) are 5-minute averages.

| Wind Speed<br>(knots) | 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 4.1B

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

Preplanned Contingency 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 Shuttle system has recovered from convective cooling excursions.

Nomenclature:

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

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

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

Tmin= Minimum ambient air temperature limit specified in Table 4.1B at the  
average measured wind speed in the time interval (units of degree F)

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Qsol= Diffuse solar flux from Table 4.1C (units of Btu/ft2-hr)

Esum= Running energy sum of convective cooling, convective heating and solar energy (Btu-minutes/ft2-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/ft2-hr-F)

sigma= summation

System Recovery Temperature Algorithm (RTA):

$$Esum \text{ (Btu-minutes/ft2-hr)} = 0.5(Btu/ft2-hr-F) \sigma ((Tamb-Tmin)(F) (\Delta t)(minutes) (X)) + 0.2 \sigma ((Qsol)(Btu/ft2-hr)(\Delta t)(minutes)(X)) - \sigma Hc(Btu/ft2-hr-F) ((Tmin-Tamb)(F) (\Delta t)(minutes) (1-X))$$

where Hc is the greater of  $Hc = 4.0(V/5.0)**0.5$  (Btu/ft2-hr-F)  
or  $Hc = 1.0$  (Btu/ft2-hr-F)

Diffuse Solar Table (Table 4.1C):

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.

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| ----- |            |          |      |                |
|-------|------------|----------|------|----------------|
| 3     | 3          | Eastern  | 3    | 3              |
| 3     | 3          | Standard | 3    | Qsol           |
| 3     | Solar Time | 3        | Time | 3 (Btu/ft2-hr) |
| ----- |            |          |      |                |
| 3     | 0:00       | 3        | 0:20 | 3 0.00         |
| ----- |            |          |      |                |

|   |       |   |       |   |       |   |
|---|-------|---|-------|---|-------|---|
| 3 | 6:40  | 3 | 7:00  | 3 | 0.00  | 3 |
| 3 | 7:00  | 3 | 7:20  | 3 | 0.04  | 3 |
| 3 | 7:20  | 3 | 7:40  | 3 | 4.54  | 3 |
| 3 | 7:40  | 3 | 8:00  | 3 | 8.79  | 3 |
| 3 | 8:00  | 3 | 8:20  | 3 | 11.43 | 3 |
| 3 | 8:20  | 3 | 8:40  | 3 | 13.14 | 3 |
| 3 | 8:40  | 3 | 9:00  | 3 | 14.32 | 3 |
| 3 | 9:00  | 3 | 9:20  | 3 | 15.16 | 3 |
| 3 | 9:20  | 3 | 9:40  | 3 | 15.79 | 3 |
| 3 | 9:40  | 3 | 10:00 | 3 | 16.26 | 3 |
| 3 | 10:00 | 3 | 10:20 | 3 | 16.62 | 3 |
| 3 | 10:20 | 3 | 10:40 | 3 | 16.90 | 3 |
| 3 | 10:40 | 3 | 11:00 | 3 | 17.11 | 3 |
| 3 | 11:00 | 3 | 11:20 | 3 | 17.26 | 3 |
| 3 | 11:20 | 3 | 11:40 | 3 | 17.36 | 3 |
| 3 | 11:40 | 3 | 12:00 | 3 | 17.42 | 3 |
| 3 | 12:00 | 3 | 12:20 | 3 | 17.44 | 3 |
| 3 | 12:20 | 3 | 12:40 | 3 | 17.42 | 3 |
| 3 | 12:40 | 3 | 13:00 | 3 | 17.36 | 3 |
| 3 | 13:00 | 3 | 13:20 | 3 | 17.26 | 3 |
| 3 | 13:20 | 3 | 13:40 | 3 | 17.11 | 3 |
| 3 | 13:40 | 3 | 14:00 | 3 | 16.90 | 3 |

Table 4.1C

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| Solar Time | Eastern Standard Time | Qsol (Btu/ft <sup>2</sup> -hr) |
|------------|-----------------------|--------------------------------|
| 14:00      | 14:20                 | 16.62                          |

|   |       |   |       |   |       |   |
|---|-------|---|-------|---|-------|---|
| 3 | 14:20 | 3 | 14:40 | 3 | 16.26 | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 14:40 | 3 | 15:00 | 3 | 15.79 | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 15:00 | 3 | 15:20 | 3 | 15.16 | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 15:20 | 3 | 15:40 | 3 | 14.32 | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 15:40 | 3 | 16:00 | 3 | 13.14 | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 16:00 | 3 | 16:20 | 3 | 11.43 | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 16:20 | 3 | 16:40 | 3 | 8.79  | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 16:40 | 3 | 17:00 | 3 | 4.54  | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 17:00 | 3 | 17:20 | 3 | 0.04  | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 17:20 | 3 | 17:40 | 3 | 0.00  | 3 |
| 3 | ----- |   |       |   |       |   |
| 3 | 24:00 | 3 | 0:20  | 3 | 0.00  | 3 |
| 3 | ----- |   |       |   |       |   |

Table 4.1C (Concluded)

Rules for Use of the Recovery Temperature Algorithm (RTA):

1. The time interval for summing is 5 minutes consistent with the 5 minute average temperature values supplied by the Launch Weather Officer.
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 Space Shuttle has recovered and the LCC violation is cleared.

4.2 PRECIPITATION CONSTRAINT.

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

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4.3 SURFACE WIND LIMITS. Surface Wind Limits for Launch (Measured at 60 feet above natural grade).

Surface wind criteria is specified in SSID GSE-24.

4.4 NATURAL AND TRIGGERED LIGHTNING CONSTRAINTS.

NOTICE: ANY CHANGES TO THIS SECTION WILL REQUIRE COORDINATION WITH THE 30TH AND 45TH SPACE WING RANGE SAFETY OFFICES.

Natural and Triggered Lightning Launch Commit Criteria (LCC)

The Launch Weather Team 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 Launch Weather Team will report the threat to the Launch Director. The Launch Director may HOLD at any time based on the instability of the weather.

1. Lightning

- a) Do not launch for 30 minutes after any type of lightning occurs in a thunderstorm if the flight path will carry the vehicle within 10 NM of that thunderstorm.
- b) Do not launch for 30 minutes after any type of lightning occurs within 10 NM of the flight path unless:
  - (1) The cloud that produced the lightning is not within 10 NM of the flight path;
  - and-
  - (2) There is at least one working field mill within 5 NM of each such lightning flash;
  - and-
  - (3) The absolute values of all electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (2) above have been less than 1000 V/m for 15 minutes.

Notes:

- i) Anvils are covered in Criterion 3.
- ii) If a cumulus cloud remains 30 minutes after the last lightning occurs in a thunderstorm then Criterion 2 applies.

Definitions: Anvil, Electric Field Measurement at the Surface, Flight Path, Thunderstorm, Within

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2. Cumulus Clouds

- a) Do not launch if the flight path will carry the vehicle within 10 NM of any cumulus cloud with its cloud top higher than the -20 deg C level.
- b) Do not launch if the flight path will carry the vehicle within 5 NM of any cumulus cloud with its cloud top higher than the -10 deg C level.
- c) Do not launch if the flight path will carry the vehicle through any cumulus cloud with its cloud top higher than the -5 deg C level.

d) Do not launch if the flight path will carry the vehicle through any cumulus cloud with its cloud top between the +5 deg C and -5 deg C levels unless:

(1) The cloud is not producing precipitation;

-and-

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

-and-

(3) All electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (2) above have been between -100 V/m and +500 V/m for 15 minutes.

Note: Cumulus clouds in Criterion 2 do not include altocumulus, cirrocumulus or stratocumulus.

Definitions: Cloud Top, Electric Field Measurement at the Surface, Flight Path, Precipitation, Within

### 3. Anvil Clouds

a) Attached anvils:

(1) Do not launch if the flight path will carry the vehicle through nontransparent parts of attached anvil clouds.

(2) Do not launch if the flight path will carry the vehicle within 5 NM of nontransparent parts of attached anvil clouds for the first 3 hours after the time of the last lightning discharge that occurs in the parent cloud or anvil cloud.

(3) Do not launch if the flight path will carry the vehicle within 10 NM of nontransparent parts of attached anvil clouds for the first 30 minutes after the time of the last lightning discharge that occurs in the parent cloud or anvil cloud.

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b) Detached Anvils:

(1) Do not launch if the flight path will carry the vehicle through nontransparent parts of a detached anvil cloud for the first 3 hours after the time that the anvil cloud is observed to have detached from the parent cloud.

(2) Do not launch if the flight path will carry the vehicle through nontransparent parts of a detached anvil cloud for the first 4 hours after the time of the last lightning discharge that occurs in the detached anvil cloud.

(3) Do not launch if the flight path will carry the vehicle within 5 NM of nontransparent parts of a detached anvil cloud for the first 3 hours after the time of the last lightning discharge

that occurs in the parent cloud or anvil cloud before detachment or in the detached anvil cloud after detachment unless:

- (a) There is at least one working field mill within 5 NM of the detached anvil cloud;

-and-

- (b) The absolute values of all electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (a) above have been less than 1000 V/m for 15 minutes;

-and-

- (c) The maximum radar return from any part of the detached anvil cloud within 5 NM of the flight path has been less than 10 dBZ for 15 minutes.

- (4) Do not launch if the flight path will carry the vehicle within 10 NM of nontransparent parts of a detached anvil cloud for the first 30 minutes after the time of the last lightning discharge that occurs in the parent cloud or anvil cloud before detachment or in the detached anvil cloud after detachment.

Note: Detached anvil clouds are never considered DEBRIS CLOUDS, nor are they covered by Criterion 4.

Definitions: Anvil, Debris Cloud, Flight Path, Nontransparent, Thunderstorm, Within

#### 4. Debris Clouds

- a) Do not launch if the flight path will carry the vehicle through any nontransparent parts of a debris cloud during the 3-hour period defined below.

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- b) Do not launch if the flight path will carry the vehicle within 5 NM of any nontransparent parts of a debris cloud during the 3-hour period defined below, unless:

- (1) There is at least one working field mill within 5 NM of the debris cloud;

-and-

- (2) The absolute values of all electric field measurements at the surface within 5 NM of the flight path and at the mill(s) specified in (1) above have been less than 1000 V/m for 15 minutes;

-and-

- (3) The maximum radar return from any part of the debris cloud within 5 NM of the flight path has been less than 10 dBZ for 15



minutes.

The 3-hour period in a) and b) above begins at the time when the debris cloud is observed to have detached from the parent cloud or when the debris cloud is observed to have formed from the decay of the parent cloud top below the altitude of the -10 deg C level. The 3-hour period begins anew at the time of any lightning discharge that occurs in the debris cloud.

Definitions: Cloud Top, Debris Cloud, Electric Field Measurement at the Surface, Flight Path, Nontransparent, Within

5. Disturbed Weather

Do not launch if the flight path will carry the vehicle through any nontransparent clouds that are associated with a weather disturbance having clouds that extend to altitudes at or above the 0 deg C level and contain moderate or greater precipitation or a radar bright band or other evidence of melting precipitation within 5 NM of the flight path.

Definitions: Associated, Flight Path, Moderate Precipitation, Nontransparent, Weather Disturbance, Within

6. Thick Cloud Layers

Do not launch if the flight path will carry the vehicle through nontransparent parts of a cloud layer that is:

- (1) Greater than 4,500 ft thick and any part of the cloud layer along flight path is located between the 0 deg C and the -20 deg C levels;

-or-

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- (2) Connected to a cloud layer that, within 5 NM of the flight path, is greater than 4,500 ft thick and has any part located between the 0 deg C and the -20 deg C levels;

unless the cloud layer is a cirriform cloud that has never been associated with convective clouds, is located entirely at temperatures of -15 deg C or colder, and shows no evidence of containing liquid water (e.g., aircraft icing).

Definitions: Associated, Cloud Layer, Flight Path, Nontransparent

7. Smoke Plumes

Do not launch if the flight path will carry the vehicle 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 have detached from the smoke plume.

Note: Cumulus clouds that have formed above a fire but have been detached from the smoke plume for more than 60 minutes are considered CUMULUS CLOUDS and are covered in Criterion 2.

Definitions: Flight Path

8. Surface Electric Fields

- a) Do not launch for 15 minutes after the absolute value of any electric field measurement at the surface within 5 NM of the flight path has been greater than 1500 V/m.
- b) Do not launch for 15 minutes after the absolute value of any electric field measurement at the surface within 5 NM of the flight path has been greater than 1000 V/m unless:
  - (1) All clouds within 10 NM of the flight path are transparent;
  - or-
  - (2) All nontransparent clouds within 10 NM of the flight path have cloud tops below the +5 deg C level and have not been part of convective clouds with cloud tops above the -10 deg C level within the last 3 hours.

Notes:

- i) Electric field measurements at the surface are used to increase safety by detecting electric fields due to unforeseen or unrecognized hazards.
- ii) For confirmed failure of one or more field mill sensors, the countdown and launch may continue.

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Definitions: Cloud Top, Electric Field Measurement at the Surface,  
Flight Path, Nontransparent, Transparent, Within

9. Definitions:

- a) Anvil: Stratiform or fibrous cloud produced by the upper level outflow or blow-off from thunderstorms or convective clouds.
- b) Associated: Used to denote that two or more clouds are causally related to the same weather disturbance or are physically connected. ASSOCIATED is not synonymous with occurring at the same time. An example of clouds that are NOT associated is air mass clouds formed by surface heating in the absence of organized lifting. Also, a cumulus cloud formed locally and a physically separated cirrus layer generated by a distant source are not associated, even if they occur over or near the launch site at the same time.

Subsidiary Definition: Weather Disturbance

- c) Bright Band: An enhancement of radar reflectivity caused by frozen hydrometeors falling through the 0 deg C level and beginning to melt.
- d) Cloud Edge: The visible cloud edge is preferred. If this is not

possible, then the 10 dBZ radar reflectivity cloud edge is acceptable.

- e) Cloud Layer: A vertically continuous array of clouds, not necessarily of the same type, whose bases are approximately at the same level.
- f) Cloud Top: The visible cloud top is preferred. If this is not possible, then the 10 dBZ radar reflectivity cloud top is acceptable.
- g) Cumulonimbus Cloud: Any convective cloud with any part above the -20 deg C temperature level.
- h) 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.

Subsidiary Definition: Cumulonimbus Cloud

- i) Electric Field Measurement at the Surface: The one-minute arithmetic average of the vertical electric field ( $E_z$ ) at the ground 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 the ground is the same as the dominant charge overhead.

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Note: Electric field contours shall not be used for the electric field measurement at the surface.

- j) Flight Path: The planned flight path including its uncertainties ("error bounds").
- k) Moderate Precipitation: A precipitation rate of 0.1 inches/hr or a radar reflectivity factor of 30 dBZ.
- l) Nontransparent: Opposite of Transparent. Sky cover through which forms are blurred, indistinct, or obscured is nontransparent.

Note: Nontransparency must be assessed for launch time. Sky cover through which forms are seen distinctly ONLY through breaks in the cloud cover is considered nontransparent. Clouds with a radar reflectivity of 10 dBZ or greater are also considered nontransparent.

Subsidiary Definition: Transparent

- m) Optically Thin: Having a vertical optical thickness of unity or less at visible wavelengths.
- n) Precipitation: Detectable rain, snow, sleet, etc., at the ground, or virga, or a radar reflectivity greater than 18 dBZ.
- o) Transparent: Synonymous with optically thin. Sky cover is

transparent if higher clouds, blue sky, stars, the disk of the sun, etc., can be distinctly seen from below, or if the sun casts distinct shadows of objects on the ground, or if terrain, buildings, lights on the ground, etc., can be distinctly seen from above.

Note: Visible transparency is required. Transparency must be assessed for launch time. Sky cover through which forms are seen distinctly ONLY through breaks in the cloud cover is considered NONtransparent.

Subsidiary Definitions: Nontransparent, Optically Thin

- p) Thunderstorm: Any convective cloud that produces lightning.
- q) Weather Disturbance: 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.
- r) Within: Used as a function word to specify a margin in all directions (horizontal, vertical, and slant separation) between the cloud edge or top and the flight path. For example, "WITHIN 10 NM of a thunderstorm cloud" means that there must be a 10 NM margin between every part of a thunderstorm cloud and the flight path.

Subsidiary Definitions: Cloud Edge, Cloud Top, Flight Path

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