National Aeronautics and Space Administration

NASA Facts

Space Shuttle Weather Launch Commit Criteria and KSC End of Mission Weather Landing Criteria

The launch weather guidelines involving the space shuttle and expendable rockets are similar in many areas, but a distinction is made for the individual characteristics of each. The criteria are broadly conservative and assure avoidance of possibly adverse conditions.

For the space shuttle, weather forecasts are provided by the U. S. Air Force Range Weather Operations Facility at Cape Canaveral beginning at launch-minus-3 days in coordination with the National Oceanic and Atmospheric Administration (NOAA) National Weather Service Space Flight Meteorology Group (SMG) at the Johnson Space Center in Houston. These include weather trends and their possible effects on launch day. A formal prelaunch weather briefing is held on launch-minus-2 days as a specific weather briefing for all areas of space shuttle launch operations.

Launch weather forecasts, ground operations forecasts, and launch weather briefings for the mission management team and the space shuttle launch director are prepared by the Range Weather Operations Facility. Forecasts that apply after launch are prepared by SMG. These include all emergency landing forecasts and the end-of-mission forecasts briefed by SMG to the astronauts, the flight director and mission management team.

During the countdown, formal weather briefings occur approximately as follows:

- L-24 hr. 0 min. – Briefing for flight director and astronauts
- L-21 hr. 0 min. – Briefing for removal of rotating service structure
- L-9 hr. 00 min. – Briefing for external tank fuel loading
- L-4 hr 30 min. – Briefing for space shuttle launch director
- L-3 hr. 55 min. – Briefing for astronauts
- L-2 hr. 10 min. – Briefing for flight director
- L-0 hr. 35 min. – Briefing for launch and Return to Launch Site (RTLS)
- L-0 hr. 13 min. – Poll all weather constraints

Basic weather launch commit criteria on the pad at liftoff

Temperature. Prior to external tank propellant loading, tanking will not begin if:

a. The 24-hour average temperature has been below 41 degrees.

b. The temperature has fallen below 33

degrees at anytime during the previous 24 hours.

After tanking begins, the countdown shall not be continued nor the shuttle launched if:

a.) The temperature exceeds 99 degrees for more than 30 consecutive minutes.

b.) The temperature is lower than the prescribed minimum value for longer than 30 minutes unless sun angle, wind, temperature and relative humidity conditions permit recovery.

The minimum temperature limit in degrees Fahrenheit is specified by the table below and is a function of the five-minute average of temperature, wind and humidity. The table becomes applicable when the observed temperature reaches 48 degrees.

Wind Speed (kts)	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

The above table can be used to determine when conditions are again acceptable for launch if parameters have been out of limits for 30 minutes or less. If longer than 30 minutes, a mathematical recovery formula of the environmental conditions is used to determine if a return to acceptable parameters has been achieved. Launch conditions have been reached if the formula reaches a positive value.

Wind

– For tanking, fueling will not begin if the wind is observed or forecast to exceed 42 knots for the next three-hour period.

– For launch, the allowable peak wind speed observed at the 60-foot level of hte fixed service structure depends on the wind directin and ranges from 19 to 34 knots.

The upper atmosphere wind profile must conform to either one of two wind-loading programs developed by the Johnson Space Center (JSC). This profile is determined by a series of Jimsphere wind-balloon releases from Cape Canaveral Air Force Station. A final recommendation is made by the JSC Launch Systems Evaluation Advisory Team to the KSC launch director at launch-minus-30 minutes. The space shuttle will not be launched within 30 minutes of the time a determination has been made that the upper wind profile will adversely affect the performance of the launch vehicle.

The Shuttle Weather Officer will notify the mission management team for their consideration if the sustained wind in the solid rocket booster recovery area is forecast to exceed 26 knots during retrieval operations or if swells will be in excess of Sea State 5 (8 to 13 feet).

Precipitation

– None at the launch pad or within the flight path.

Lightning (and electric fields with triggering potential)

– Tanking will not begin if there is forecast to be greater than a 20 percent chance of lightning within 5 nautical miles of the launch pad during the first hour of tanking. The launch director, with the concurrence of the safety director, may make an exception after consultation with the Shuttle Weather Officer.

– Do not launch when lightning is observed and the cloud that produced the lightning is within 10 nautical miles of flight path. Launch may not occur until 30 minutes has elapsed since the lightning flash, or the cloud has moved more than 10 nautical miles away.

– Do not launch if lightning has been detected with 10 nautical miles of the pad or the planned flight path within 30 minutes prior to launch. Launch may occur if the source of lightning has moved more than 10 nautical miles away from the pad or the flight path if there is a field mill, used to measure electric fields, located within 5 nautical miles of the lightning flash, and if that field mill and the field mills located within 5 nautical miles of the flight path have been less than 1 kilovolt per meter for 15 minutes.

The one-minute average of the electric field mill network may not exceed -1 or +1 kilovolt per meter within 5 nautical miles of the launch pad or the lightning flash at any time within 15 minutes prior to launch. This field mill criteria becomes -1.5 or + 1.5 kilovolts per meter if there are no clouds within 10 nautical miles of the flight path except those which are transparent. Also excepted are clouds with tops below the 41 degrees F. temperature level that have

not been previously associated with a thunderstorm, or associated with convective clouds having tops above the 14 degrees F. temperature level during the last three hours.

Clouds (types known to contain hazardous electric fields)

Cumulus Clouds: Do not launch through cumulus type clouds with tops higher than the 41 degree F. temperature level. Launch may occur through clouds with tops as cold as 23 degrees F. if the cloud is not producing precipitation, there is a field mill within 2 nautical miles of the cloud, and this field mill and all field mills within 5 nautical miles of the flight path read between -100 volts per meter and +500 volts per meter for the past 15 minutes.

- Do not launch through or within 5 nautical miles of the nearest edge of cumulus type clouds with tops higher than the 14 degree F level.

- Do not launch through or within 10 nautical miles of the nearest edge of cumulus clouds with tops higher than the -4 degrees F. level.

Disturbed Weather: Do not launch if the flight path is through any non-transparent clouds that extend to altitudes at or above the 32 degrees F. level which are associated with disturbed weather producing moderate or greater precipitation, or melting precipitation, within five nautical miles of the flight path.

Thick Clouds: Do not launch if any part of the planned flight path is through a layer of clouds any part of which is within 5 nautical miles is 4,500 feet thick or greater and the temperature of any part of the layer is between 32 degrees F. and -4 degrees F. Launch may occur if the cloud layer is a cirrus-like cloud that has never been associated with convective clouds, is located entirely at temperatures of 5 degrees F. or colder, and shows no evidence of containing water droplets.

Anvil Cloud: Do not launch through an attached or detached anvil cloud if the cloud is determined to be electrified and could trigger a lightning strike by flight through it as contained in the launch criteria directives for Volume-Averaged Height-Integrated Radar Reflectivity (VAHIRR) that specify the distance, time, radar and field mill measurements required to ensure safe flight. The condition of an anvil cloud must be evaluated for these criteria when it is within 10 nautical miles of the launch pad.

Debris Cloud: Do not launch if the flight path will carry the vehicle through a debris cloud which is not transparent and less than three hours old. Launch may not occur within five nautical miles of these debris clouds unless: 1) for 15 minutes preceding launch there is at least one working field mill within five nautical miles of the debris cloud; 2) all electric field mill readings are between -1 kilovolt and + 1 kilovolt per meter within five nautical miles of the flight path for the past 15 minutes; 3) weather radar has detected less than 10 dbz of reflectivity in the debris cloud within 5 nautical miles of the flight path for 15 minutes.

Smoke Plume: 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 plume, or for the first 60 minutes after the cumulus cloud detaches from the smoke plume.

Supporting Table: KSC Seasonal Altitudes of Temperature Levels in thousands of feet

	January				July		
Temp	**Low**	**Avg**	**High**	**Temp**	**Low**	**Avg**	**High**
-4 F	21	24	26	**-4 F**	23	27	29
14	13	18	21	**14**	18	21	23
23	9	15	8	**23**	16	18	20
32	sfc	12	16	**32**	13	15	18
41	sfc	9	14	**41**	10	12	15

Range safety cloud ceiling and visibility constraints

– Direct visual observation of the shuttle is required through 8,000 feet. This requirement may be satisfied using optical tracking sites or a forward observer.

– A cloud ceiling of 6,000 feet is permitted for short-duration launch windows if all required Range Safety instrumentation systems are functioning.

– A cloud ceiling of 4,000 feet is permited if:

a.) The cloud layers between 4,000 and 8,000 feet are not more than 500 feet thick.

b.) The vehicle can be seen by the Eastern Range airborne and/or the ground forward observers through 8,000 feet and they can communicate with the Flight Control Officer.

A "**Good Sense Rule** is in effect for launch, which states:

"Even when constraints are not violated, if any other hazardous conditions exist, the launch weather officer will report the threat to the launch director. The launch director may hold at any time based on the instability of the weather."

Contingency Flight Rules Required For Launch

Weather criteria for an emergency landing must be considered along with launch criteria since the possibility exists for a Return To Launch Site abort (RTLS), landings at the Trans-Oceanic Abort Landing Sites (TAL), the Abort Once Around (AOA) sites and the first day Primary Landing Site (PLS). The NOAA National Weather Service Space Flight Meteorology Group in Houston prepares these forecasts and briefs the astronauts, flight director and mission management team. All criteria refer to observed and forecast weather conditions except for the first day PLS, which is forecast weather only.

– For RTLS with redundant Microwave Landing System (MLS) capability and a weather reconnaissance aircraft, cloud coverage 4/8 or less below 5,000 feet and a visibility of 4 statute miles or greater are required. For AOA and PLS sites, cloud coverage 4/8 or less below 8,000 feet and a visibility of 5 statute miles or greater is required. For TAL sites, cloud coverage 4/8 or less below 5,000 feet and a visibility of 5 statute miles or greater are required.

– For landing on a hard surface runway without redundant Microwave Landing System capability, all sites require a ceiling not less than 10,000 feet and a visibility of at least 7 statute miles. Landing at night on a lake bed runway may occur if the ceiling is not lower than 15,000 feet and the visibility is 7 miles or greater with at least non-redundant MLS capability.

– For the RTLS site and TAL sites, no thunderstorms, lightning or precipitation may be within 20 nautical miles of the runway, or within 10 nautical miles of the final approach path extending outward to 30 nautical miles from the end of the runway.

– For RTLS and TAL sites, rain showers with the limits listed above are acceptable if all the specific criteria listed below are met:

a.) Adequate satellite, radar and aircraft surveillance are available.

b.) No substantial increase in either coverage or intensity is forecast.

c.) The observed and forecast horizontal movement of individual rain showers and other weather features is linear or near linear.

d.) The runway meets the landing/rollout criteria and the navigational aid requirements specified in the prelaunch go/no go requirements.

e.) For a minimum of two of the four available approaches, the orbiter shall not fly through precipitation and shall maintain either a 10-nautical-mile lateral clearance or a 2-nautical-mile vertical clearance from any shower that:

1.) has moderate or greater precipitation, or

2.) has a cloud-top temperature colder than +5 degrees Celsius (41 degrees F.) or

3.) has a cloud-top temperature colder than -10 degrees Celsius (14 degrees F.) within 2.5 hours prior to launch.

– For RTLS and TAL sites, no detached opaque thunderstorm anvils less than three hours old within 15 nautical miles of the runway, or within 5 nautical miles of the final approach path extending outward to 30 nautical miles from the end of the runway.

– For AOA and PLS sites, no thunderstorms, lightning or precipitation within 30 nautical miles of the runway, or within 20 nautical miles of the final approach path extending to 30 nautical miles from the end of the runway.

– For RTLS and TAL sites, no detached opaque thunderstorm anvil cloud less than three hours old within 15 nautical miles of the runway or within 5 nautical miles of the final approach path extending outward to 30 nautical miles from the end of the runway.

– For AOA and PLS sites, no detached opaque thunderstorm anvil cloud less than three hours old within 20 nautical miles of the runway or within 10 nautical miles of the final approach path extending to 30 nautical miles from the end of the runway.

– The RTLS, TAL, AOA and PLS crosswind component may not exceed 15 knots. For RTLS, if the astronaut flying weather reconnaissance in the Shuttle Training Aircraft flies the approach and considers the landing conditions to be acceptable, the daytime limit may be increased to 17 knots.

– Headwind: not to exceed 25 knots.

– Tailwind: not to exceed 10 knots average, 15 knots peak.

– Turbulence: conditions must be less than or equal to moderate intensity.

KSC End-of-Mission Landing Weather Flight Rules

The end of mission landing weather forecast is prepared by the NOAA National Weather Service Space Flight Meteorology Group in Houston for the astronauts, flight director and mission management team. All criteria refer to observed and forecast weather conditions. Decision time for the de-orbit burn is 70 - 90 minutes before landing. The weather criteria are as follows:

– Cloud coverage of 4/8 or less below 8,000 feet and a visibility of 5 miles or greater are required.

– The peak crosswind cannot exceed 15 knots, 12 knots at night. If the mission duration is greater than 20 days, the limit is 12 knots, day and night.

– Headwind cannot exceed 25 knots.

– Tailwind cannot exceed 10 knots average, 15 knots peak.

– No thunderstorm, lightning or precipitation activity is within 30 nautical miles of the landing site.

– Detached opaque thunderstorm anvils less than three hours old must not be within 20 nautical miles of the landing site, or within 10 nautical miles of the flight path when the orbiter is within 30 nautical miles of the runway.

– Turbulence must be less than or equal to moderate intensity.

– Consideration may be given for landing with a "no go" observation and a "go" forecast if, at decision time, analysis clearly indicates a continuing trend of improving weather conditions, and the forecast states that all weather criteria will be met at landing time.

Weather instrumentation

The weather equipment used by the forecasters to develop the launch and landing forecasts is below :

♦ **Radar.** Launch forecasters located at Cape Canaveral Air Force Station and landing forecasters located in Houston can access displays from two different radars. One is located at Patrick Air Force Base near Cocoa Beach, Fla. The other, located in Melbourne, Fla., at the NOAA National Weather Service, is a NEXRAD Doppler radar. Each radar provides rain intensity and cloud-top information out to a distance as far as 200 nautical miles. The NEXRAD radar can also provide estimates of total rainfall and radial wind velocities.

♦ **Launch Pad Lightning Warning System (Field Mill Network).** Thirty-one advanced field mill sites around KSC and Cape Canaveral Air Force Station provide data on lightning activity and surface electric fields induced by charge aloft. This data helps forecasters determine when electric charge aloft may be sufficient to create triggered lightning during launch, and to determine when to issue and cancel lightning advisories and warnings..

♦ **Cloud-to-Ground Lightning Surveillance System (CGLSS).** The system detects and plots cloud-to-ground lightning strikes within 125 nautical miles of the Kennedy Space Center. Location accuracy is optimum within 30 nautical miles. Locations of strikes are color coded according to time of occurrence.

♦ **Lightning Detection And Ranging (LDAR).** Developed by NASA at the Kennedy Space Center, LDAR plots intracloud, cloud-to-cloud and cloud-to-ground lightning in three dimensions within 60 nautical miles of the Kennedy Space Center. Location accuracy is very high within 25 nautical miles. LDAR data is important in determining the beginning and end of lightning conditions.

♦ **National Lightning Detection Network.** This equipment plots cloud-to-ground lightning nationwide. It is used to help ensure safe transit of the space shuttle orbiter atop the Shuttle Carrier Aircraft between Edwards Air Force Base in California and the Kennedy Space Center in Florida. It is also used to assess lightning beyond the 125-mile range of the Lightning Detection System.

♦ **Rawinsonde.** This is a GPS-tracked weather balloon having a tethered instrument package that radios its altitude to the ground together with temperature, dewpoint and humidity, wind speed and direction. Rawinsondes reach altitudes exceeding 100,000 feet.

♦ **Jimsphere balloon.** A reflective balloon made of mylar tracked by radar, which provides highly accurate information on wind speed and wind direction up to 60,000 feet.

♦ **Weather Reconnaissance Aircraft.** A T-38 jet and the Shuttle Training Aircraft are flown by an astronaut to observe actual conditions for evaluation by the Shuttle Weather Officer, a weather support astronaut located in the firing room with the mission management team, and the Space Flight Meteorology Group in Houston.

♦ **50 MHz Doppler Radar Wind Profiler.** This profiler is located at the Shuttle Landing Facility and measures upper level wind speed and direction over Kennedy Space Center from approximately 7,000 feet to 60,000 feet. The data, received every 3 to 5 minutes, is used to ensure the upper winds used to calculate wind loads on the shuttle vehicle have not significantly changed between balloon soundings. If data from the Doppler Radar Wind Profiler indicates a possible significant change, another Jimsphere balloon is released.

♦ **915 MHz Doppler Radar Wind Profiler Network:** A system of five wind profilers located on Kennedy Space Center and Cape Canaveral Air Force Station provide measurements every 15 minutes of the wind speed and direction from approximately 300 to 10,000 feet. These are used to forecast conditions favorable for development of showers and thunderstorms, and to help assess Range Safety launch and flight constraints. The profiler located near the shuttle launch pads can ensure the lower level winds used to calculate wind effects on the vehicle have not significantly changed between balloon soundings. The profilers located at each end of the Shuttle Landing Facility runway are used to assist in the assessment of the landing winds for the orbiter.

♦ **Satellite Images and Data.** These are provided directly to the satellite terminal at USAF Range Weather Operations and NOAA National Weather Service Space Flight Meteorology Group in Houston by the geostationary GOES weather satellites. In addition high resolution images are received from spacecraft in low earth orbit including both the NOAA and the Defense Meteorological Support Program (DMSP) polar orbiting satellites.

♦ **Meteorological Interactive Data Display System (MIDDS).** This system integrates diverse weather data on a single display terminal — satellite images, radar, computer-generated graphics of surface and upper-air map features, numerical weather models, current weather observations, data from meteorological towers, lightning strikes and field mill information.

♦ **Towers.** There are 33 meteorological towers located on Kennedy Space Center and Cape Canaveral Air Force Station, including two at each launch pad and three at the Shuttle Landing Facility. In addition to wind, most towers are also instrumented with temperature and moisture sensors.

The 60-foot towers at the launch pads and the 33-foot towers at the Shuttle Landing Facility are closely monitored for launch and landing criteria. There are also four 200-foot instrumented weather towers and one 500-foot tower that relay weather data at various heights.

In addition, on the mainland, there is a network of 19 wind towers that extend outward an additional 20 miles. Tower data is an important short-term forecasting tool and also helps determine the direction and distance of toxic corridors in the event of a mishap.

♦ **Buoys.** Meteorological buoys are anchored in the Atlantic Ocean 20 nautical miles east of Cape Canaveral and 120 nautical miles east of Ponce De Leon Inlet in Florida. These buoys relay hourly measurements via satellite of temperature, wind speed and direction, barometric pressure, precipitation, sea water temperature, wave height and period. Buoy data is used for launch, landing, solid rocket booster retrieval and daily operational weather forecasts for the Kennedy Space Center and Cape Canaveral Air Force Station.

♦ **Solid Rocket Booster Retrieval Ships.** These vessels radio observed weather conditions and sea state from the booster impact area located 140 nautical miles downrange.

05/31/2002 – Space Shuttle Endeavour is poised for launch at Pad 39A after mission managers postponed today's scheduled launch of mission STS-111. Forecasters' predictions that weather would prohibit a launch attempt due to severe thunderstorms and rain showers within the vicinity of the launch pad were accurate as depicted by the raindrops obscuring the photographer's view.

This and other KSC fact sheets and publications can be found on the Web at:

http://www-pao.ksc.nasa.gov/kscpao/nasafact/docs.htm

A powerful electrical storm created an eerie tapestry of light in the skies near Space Shuttle Launch Complex 39A in the hours preceding the launch of Challenger on mission STS-8 at 2:32 a.m. EDT. Driving rains and the dazzling lightning display ceased after this photograph was taken by a remote camera set up by Sam Walton of United Press International and mission officials were able to proceed with the launch.

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