

KENNEDY SPACE CENTER

SHUTTLE OPERATIONS TEAM NEW EMPLOYEE ORIENTATION TRAINING CLASS



The purpose of the shuttle training program is to educate new Shuttle team members on Shuttle operations so they can provide expert support and products to the Space Shuttle Program. This presentation will take you through the Shuttle Operations as they happen at KSC. Throughout today's training, we will discuss weather constraints and issues as they impact Shuttle Operations.

KSC HOME TO SHUTTLE

Space Shuttles Call Kennedy Space Center Home



For your information, here are the vision and mission for NASA.

KSC HOME TO SHUTTLE

Be familiar with other Shuttle operations:

- Ferry Flight Operations and Constraints
- Guppy Operations
- NASA Marine Operations

Understand Shuttle launch operations and launch-related requests



Training Objectives:

- Be familiar with Shuttle processing ops
- Be familiar with other Shuttle operations:
 - Ferry Flight Operations and constraints
 - Guppy Operations
 - NASA Marine Operations
- Understand Shuttle launch operations and launch-related requests

KSC OPERATIONS

- Guppy Flights
- Pad Operations
- Segment Moves
- Rollover (OPF - VAB)
- Rollout/back (VAB - Pad)
- Ships
 - SRB Recovery
 - ET Barge Operations
- Payload Lift
- RSS Retract
- Tanking
- Crew Ingress
- Launch–User Constraints
- Landing
 - RTLS
 - End of Mission
- Ferry Flight
- Post Landing Operations
 - Mate / Demate
 - Roll



We are going to discuss these operations that occur to prepare, launch and land the shuttle. While there are many different types of Shuttle crew assignments, today's training is from the perspective of the Weather Officer's perspective.

GUPPY FLIGHTS



The payload arrives in different ways, usually via aircraft. Guppy aircraft bring the payload in to the SLF. The payload is then lifted with a crane onto a transporter, and then transported to the Space Station Processing Facility (SSPF). This usually takes an entire day. Payload items cannot be transferred at KSC during peak traffic (1500 - 1700L). As you can see, this is a weather sensitive operation and the exposure time is high. In the summer time this can be one of the most difficult Shuttle operations to work due to the long exposure period and delays during peak traffic.

SOLID ROCKET BOOSTER SEGMENT MOVE



The solid rocket booster segments arrive at KSC via rail from Brigham City, UT, and are offloaded at that Rotation Processing and Surge Facility (RPSF) just north of the Vehicle Assembly Building (VAB).

SOLID ROCKET BOOSTER SEGMENT MOVE

SRB Segment Move Constraints: (1-hour forecast)

- LTG within 5NM
- Forecast LTG within 5 NM > 25%
- Wind > 34 Kts steady-state, peak 52 Kts



Then the segments are moved to the VAB. The KSC.DO will call the forecaster for a lightning and wind forecast to determine if the segment can be moved to the VAB. The main concern for the move is lightning.

EXTERNAL TANK BARGE OPS

ET Barge Operations “Concerns”:

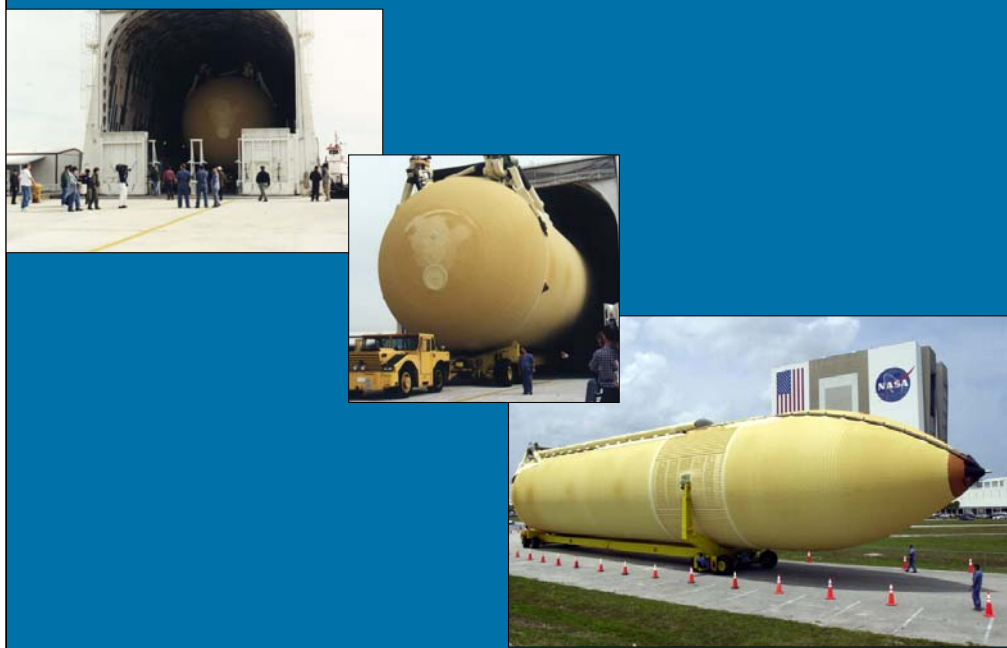
- Seas \geq 8 ft - Possible damage to ET barge
- Wind forecast \geq 15 Kts for barge transfer from Port Canaveral to KSC via Banana River



External tanks are transported to KSC via one of the SRB recovery ships. The ship departs KSC with the ET barge, spends 5 days traveling to Michoud Mississippi, picks up the tank, and returns to KSC with the tank.

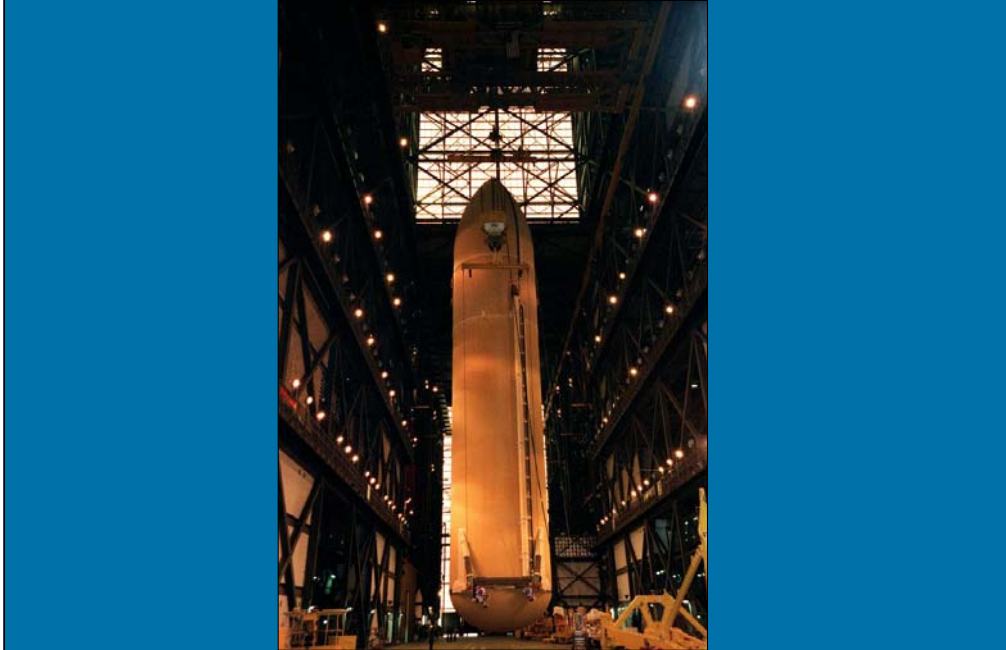
Seas are the main concern during the transport, and then wind when coming up the river.

ET BARGE OPS



The ET barge is then taken up the river, offloaded at an area near the Press Site, and transported to the VAB.

STACK ET IN VAB



The ET is then stacked with the SRBs in the VAB.

PAYLOAD TRANSPORT AND LIFTING OPS

Transport Constraints:

- Pad Wind > 34 Kts sustained
- LTG within 5NM



As we approach the launch date, the payload is installed in the orbiter. This is either accomplished at the OPF in a horizontal configuration or at the Shuttle Pad in a vertical configuration.

To install the payload at the pad, it must first be transported to that location. The transport weather constraints are not too tough—wind and especially lightning are concerns.

PAYLOAD LIFT OPS



Lift Constraints:

- Pad Wind > 17 Kts steady-state, Peak 26 kts @ 60' level
- LTG within 5NM

The payload can be lifted at the pad either before or after the Shuttle is rolled out. This is possible because it is first installed in the clean room at the launch pad, which is part of the Rotating Service Structure (RSS). After the vehicle arrives (if it isn't already there), the RSS is extended over the top of the orbiter where the payload bay doors can be opened and the payload can be installed into the payload bay of the orbiter.

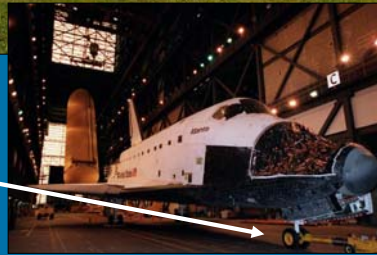
The main weather concerns for the lift are winds and lightning.

ROLLOVER

Rollover Constraints:

(2 - hour forecast)

- LTG within 5NM
- Temp < 36F
- Any Precip
- On transporter: Wind > 30 Kts Peak
- On landing gear: Wind > 42 P 64 Kts



Of course, the vehicle cannot be rolled out until the stack is complete, and right now we still need to get the orbiter to the VAB for the stack. "Rollover" is the term we use when rolling the orbiter from the OPF to the VAB. During rollover, the vehicle does not have power and, therefore, is not pressurized. Since it's not pressurized, the orbiter cannot be exposed to ANY rain in this configuration to prevent moisture intrusion. Also, the wing leading edges could get moisture under them as well.

The wind constraint for the rollover is pretty high, dependent on the horizontal roll configuration. Sometimes orbiters are moved to the VAB for storage rather than for a stack. In this case, the orbiter is on its landing gear as opposed to the transporter. The wind constraint is slightly different for this case.

Usually the main concern during this operation is precipitation. The Shuttle Launch Weather Officer is in constant contact with the firing room during this operation.

ROLLOUT /ROLLBACK



Rollout/back Constraints: (12 - hour forecast)

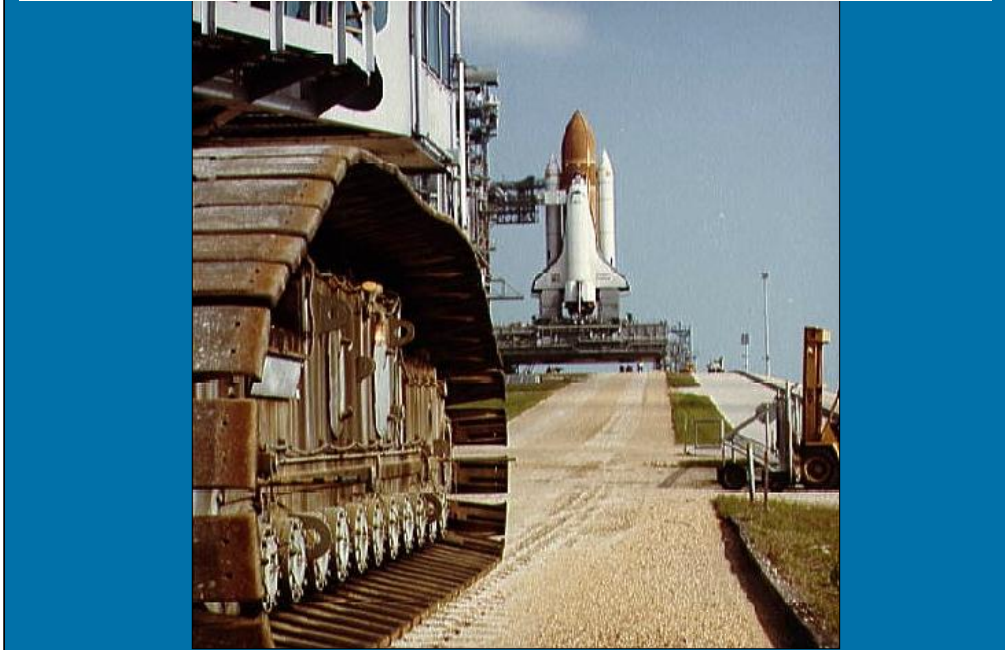
- LTG within 20 NM
- Forecast LTG within 20NM > 10%
- Wind 40 P 60Kts



After the vehicle is stacked in the VAB (about 1 week in the VAB), it is then rolled out to the pad. Many people think this is an extremely weather sensitive operation, but really the main concern is lightning. The wind constraint is very high and usually is easy to avoid (unless rolling back for a hurricane), and there is not a precip constraint.

The lightning within 20NM constraint is tougher, especially since we are talking about 20NM as opposed to the Phase 2, 5NM lightning criteria. Due to this lightning concern, the vehicle is rolled out during the night in the summer. In the winter, the vehicle rolls out during the morning daylight hours. The Shuttle Launch Weather Officer supports this roll by arriving 4 hours before the roll begins, briefs the launch NASA Test Director 3 hours before roll start, and briefs the Launch Director 2 hours prior to the roll start time. The Launch Director makes the final decision to roll at that briefing.

ROLLOUT /ROLLBACK



The crawler carries the shuttle to the launch pad at approximately 1 MPH. The roll takes 5-6 hours. The RSS is then extended over the Shuttle within an hour unless other operations are scheduled (e.g. Auxiliary Power Unit hot fire).

PAD OPERATIONS



Pad Ops Constraints:

Generally

(Shuttle not necessarily on pad)

- LTG within 5NM
- Wind > 17 Kts (many thresholds)
- Heavy Precipitation
- Hail-any
- Cold Temperatures
- Severe Weather

Weather Constraints covered by
45 WS wx warnings/advisories

Whether the vehicle is on the pad or not, we have weather constraints that protect personnel working at any location at KSC. We protect personnel and resources with warnings, watches, and advisories for Lightning, Wind, Precip, Hail, Temperatures, and Severe Weather.

HURRICANES

HURRICANE WILMA

Shuttle Hurricane Information Form

Source: National Hurricane Center Advisory # 32, 23/0500L

Current Storm Information: Source--National Hurricane Center (NHC)

Location:	22.1 N 86.6 W 223 deg @ 510 NM from KSC
Movement:	45 deg @ 3 Kts
Strength:	Winds: 85 G 105 Kts (Cat: 2) Pressure: 961 mb

NHC Storm Forecast: Based on attached NHC forecast plot of storm track.

- Forecast speed and intensity of storm at each point on attached NHC forecast:

Point	Current - 23/1400L	23/1400L- 24/0200L	24/0200L- 24/1400L	24/1400L- 25/0200L	25/0200L- 26/0200L	26/0200L- 27/0200L	27/0200L- 28/0200L
Speed	9 Kts	14 Kts	22 Kts	34 Kts	32 Kts	16 Kts	18 Kts
Wind	90G110Kt	85G105Kt	65G80Kt	60G75Kt	55G65Kt	55G65Kt	55G65Kt
40Kt Radii	150 150 110	170 160 110	170 190 100	170 190 100	170 190 100	170 190 100	170 190 100
NE SE SW NW	140	120	120	120	120	170	120

The NHC forecast has Wilma making landfall on the SW Florida coast Monday, ~0800L, SE of Naples as a Cat 2 storm, exiting the SE Florida coast between Stuart and West Palm Beach Monday, ~1200L as a Cat 1 storm. Tropical Storm force winds are forecast at KSC from 0600L to 1700L Monday; Wilma's 50 knot sustained wind radii pass the KSC/Cape border ~1200L Monday. Hurricane force winds are forecast to pass ~40NM SSE of KSC.

KSC Threat: Based on NHC's forecast, products, and published forecast errors.

Probability of 40 Kt sustained wind @ LC 39:	70%
Probability of 70 Kt peak wind @ LC 39 within 72 hrs:	40%

40-Knot Simulation: Note: This is a simulation. The official forecast is the NHC's current forecast.

Timing assumes the storm tracks toward KSC.

Given Storm Speed	Arrival Time at given storm speed					
	20 Kts	18 Kts	16 Kts	15.5 Kts	15 Kts	12 Kts
Time until arrival of 40 Kt winds	17 hrs	19 hrs	21 hrs	22 hrs	23 hrs	28 hrs
Date/Time of arrival of 40 Kt winds	23/2200L	24/0000L	24/0200L	24/0300L	24/0400L	24/0900L
	Sun	Mon	Mon	Mon	Mon	Mon

In an effort to answer the questions that come from Shuttle Processing Managers with each hurricane bulletin, the Shuttle Launch Weather Officer and Shuttle Managers worked together to create this product that provides shuttle managers information on the current location, forecast, timing, and risk to KSC of any storm that threatens us. Shuttle managers use this as a decision tool to make decisions on when to act when a hurricane approaches.

ROLLBACK!



If necessary, a rollback will be directed by the Launch Director to protect the vehicle from a hurricane.

A rollback may also occur if there are any problems with the vehicle during launch preparation.

PRE-LAUNCH OPS



As we approach the launch date, many pre-launch operations occur. This includes an APU hotfire which requires RSS retract, a Terminal Countdown Demonstration Test, a barge move, SRB recovery operations, and RSS retract in preparation for launch. Also, the Shuttle Launch weather officer must produce many forecasts and provide several briefings. Let's discuss some of these now.

CREW INGRESS TCDT

Terminal Countdown Demonstration Test



Two to three weeks before launch, the astronauts arrive for their training. They spend three days at KSC training, the last day of which is a practice countdown. During the countdown, they perform all the actions they will do on launch day, but without actual tanking or RSS retract.

The Shuttle Launch Weather Officer is on console and in communication with the Launch Director, providing updates to weather constraints as if it were a countdown. When the crew ingresses to the shuttle, there can be no lightning within 5NM of the VAB and Pad. After the countdown is complete, the crew remains at the launch pad for egress training, so lightning is still a concern until they complete their training.

BARGE MOVE



During the week before launch, the External Tank Barge must be moved across the small bay by the press site to clear the press site so the news cameras can get a good shot of the launch. This move is accomplished by small tug boats, and the main weather constraint is less than 5 knots of wind so that the Tugs pull the barge rather than the other way around! This is a tough forecast but if the winds are less than 10 knots they usually make a real-time call on site to determine if they can accomplish the move. After launch the ET barge is moved back to the dock at the press site.

SRB RECOVERY OPS

Depart ~24 Hours Before Launch



Approximately 24 hours before launch, the SRB recovery ships depart for the SRB recovery area, about 150NM off the coast of east of Jacksonville, depending upon the inclination of the launch..

ROTATING SERVICE STRUCTURE RETRACT



RSS Retract Constraints (1 hr forecast):

- Pad wind > 40 kts steady-state @ 60' level
- LTG within 5NM
- Forecast LTG within 5NM > 20%
- Heavy Rain (worker safety issue)
- Potential Severe Wx or any hail
- Orbiter exposed–Orbiter, tiles, or ET could be damaged

Another forecast that KSC Duty Officer will call the duty forecaster for is the RSS Retract forecast. This is a 1-hour forecast and the main concern is lightning and winds. Heavy rain can also be a concern for the safety of personnel on the pad since there are approximately 40 people on the structure and pad spotting this operation. Finally, severe weather, particularly hail, is a problem because the vehicle will be exposed, so even if the retract weather looks good, if hail is expected during the time between the retract and tanking before the tanking briefing, the forecaster should mention this as well in their forecast.

Again, the Launch Weather Officer, before leaving for crew rest, provides the forecaster with the page from the book that covers this call-out from the KSC Duty Officer. This, again, will include a Sequence number and a script in which the forecaster 'fills in the blanks'. You can also fill in the page and fax it to the firing room. The LWO will have the fax number on the form.

TANKING



Tanking Constraints:

- Pad Wind > 42 Kts @ 60' level
- LTG within 5NM
- 24 hr average temp < 41F



Approximately 12 1/2 hours before launch, the tanking LWO comes on duty to support the tanking operations (filling the ET with liquid hydrogen and oxygen). The LWO prepares a forecast for tanking and provides an update to the NASA Mission Management Team. After the weather briefing from the Shuttle LWO and the SMG forecaster, the Mission Management Team makes the final decision on whether to continue the count and begin tanking operations. The constraints for tanking include winds, lightning, and an average temperature over the past 24 hours <41F.

At approximately 9 hours prior to launch, tanking begins. The tanking is completed in about 4 1/2 hours.

The Shuttle Launch Weather Officer comes on console approximately 8 hours prior to launch, or an hour or two less if there is a long launch window.

PATRICK AFB FORECASTER

Provides weather support to rescue aircrews supporting Shuttle launch



In addition to having forecasters at the Range Weather Operations during launch, we also have a duty forecaster at Patrick AFB during Shuttle Launches as well. This forecaster provides aircrew briefings to the rescue squadron who are prepared to rescue astronauts in the event of a mishap.

CREW INGRESS

Launch

Crew Ingress Constraints

No Ltg within 5NM



Just under 3 hours before launch, the crew ingresses to the Shuttle just as they did during the Terminal Countdown demonstration test a few weeks earlier. Although they can ingress if we are RED on launch constraints, the crew cannot ingress if we have lightning within 5NM of the VAB or launch Pad.

Again, Crew satellite photos were sent to the crew similar to TCDT. This is accomplished by the Tanking Launch Weather Officer as is on the LWO checklist.

NASA T-38

Monitors Pad
and SLF
~L - 3:00



About the time the crew ingresses to the vehicle, a NASA T-38 aircraft takes off to monitor weather conditions at the launch Pad and SLF. An astronaut is the aircraft commander of the T-38.

SHUTTLE TRAINING AIRCRAFT

~L - 1:40



The RECCE aircraft commander eventually lands the T-38 and then takes off in the Shuttle Training Aircraft approximately 1 hour 40 minutes before launch. The Shuttle Training Aircraft is an aircraft modified to fly and handle similarly to the Orbiter, and the astronauts use this to train for flight. The STA aircraft is used to monitor weather conditions at the Pad and determine the approach conditions at the SLF.

ICE TEAM

L-3, 2, 1 Day Forecasts (LWO)



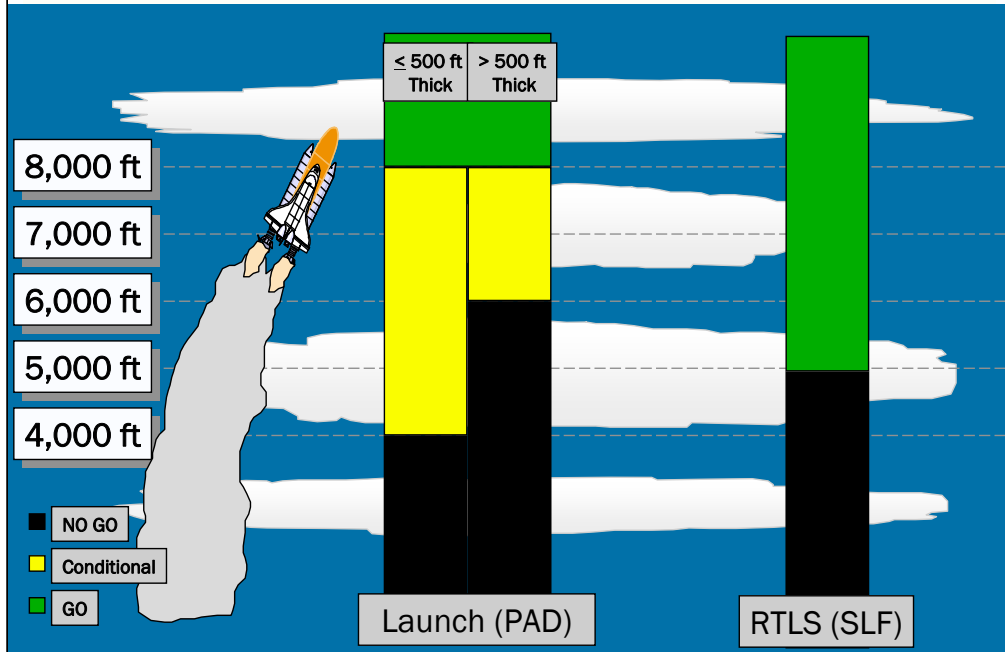
Ice Team performs inspection of ET after tanking



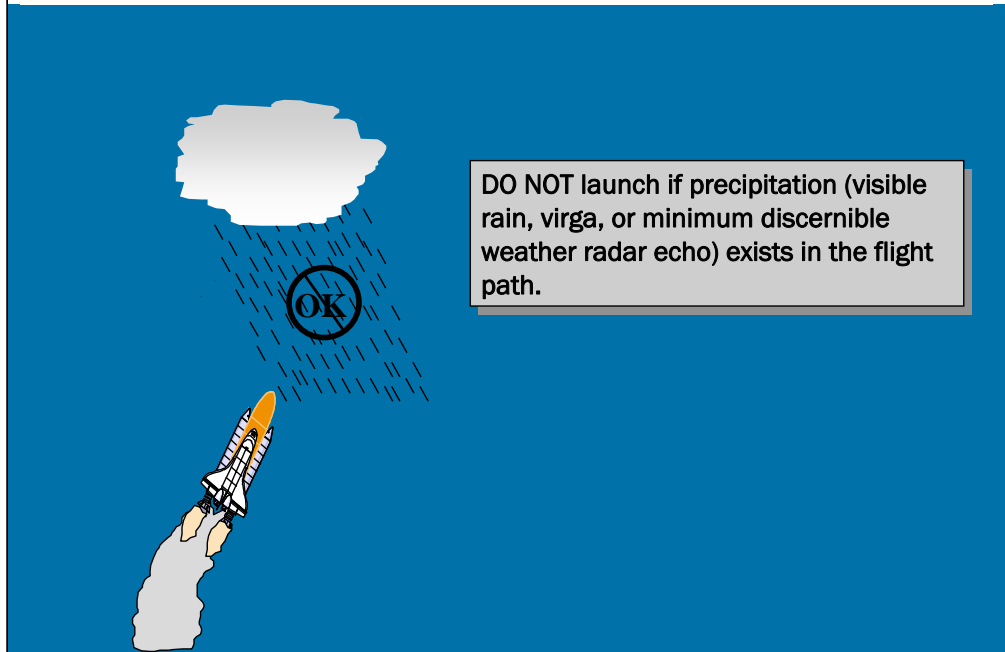
After tanking and while the RECCE aircraft is checking out the weather, the ice team goes to the pad to determine the conditions on the external tank. The Shuttle Launch Weather Officer provides ice team forecasts each of the three days prior to launch, each morning, providing the temp, humidity, and winds each hour for 9 hours up to launch. The ice team uses this forecast with an algorithm to determine what the ice conditions on the ET will be on launch day.

NASA has an LCC for ice on the ET. If the ice is too thick in the wrong areas, the Shuttle cannot be launched due to the risk of the ice hitting the thermal protection on the orbiter.

SHUTTLE CEILING CONSTRAINTS



SHUTTLE PRECIPITATION RULE



SHUTTLE TEMPERATURE RULES

Ambient Air Temp, Deg F

	48	47	46	45	44	43	42	41	40	39	38	37	36
0 to 1	≥ 0	≥ 65	≥ 75	≥ 80	≥ 90	Red							
2	≥ 0		≥ 65	≥ 75	≥ 80	≥ 90	Red						
3	Green							≥ 0	≥ 80	≥ 90	Red		
4	Green									≥ 0	≥ 90	Red	
5-7	Green										≥ 0	Red	
8-14	Green											≥ 0	
≥ 15	Green												≥ 0

VALUES IN TABLE ARE RELATIVE HUMIDITY IN %

Key:

- Green - i.e., no violation
- Conditional - i.e., Green or Red depending upon relative humidity
- Red - i.e., violation of minimum air temp criteria

SHUTTLE PAD WIND CONSTRAINTS

DO NOT launch if peak winds exceed wind criteria listed in NSTS 16007

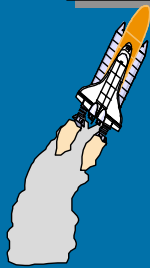
Criteria determined by SSMEs:

- One or More Block II SSMEs

vs.

- Three Non-Block II SSMEs

- Pad Peak Wind Speed range: 24 - 34 knots, depending upon wind direction



LAUNCH!



(Just a nice picture of a launch!)

SRB RECOVERY OPS

SRB Recovery



SRB Recovery "Concerns"

- Seas \geq 10 ft
(@ 10 ft seas recovery forces crew into survival mode)
- Steady-state wind forecast \geq 26 Kts
(higher probability of booster damage upon impact)



2 minutes and 6 seconds after launch, the SRB's have done their job and separate from the vehicle. Chutes then deploy from the SRBs and they float down to a splashdown to the ocean. There, the SRB recovery ships are waiting for them. The ships then find their splashdown location and begin recovery operations. These operations take several hours. After much preparation, scuba divers dive down to the bottom of the Solid Rocket Boosters (143' long!), and put a plug in the bottom of the booster. Then, air is pumped into the booster through a connection to the plug and the booster is floated horizontally and then attached to the ship. The ships then drag them back to KSC.

During the hours prior to launch, the Launch Recovery Director is in contact with the SRB ships and is providing real-time observations to the Shuttle Launch Weather Officer and receiving updates on the forecast from the Shuttle LWO to pass back to the ships.

SRB RECOVERY OPS



Hopefully this prevents any unexpected conditions from affecting the ships!

EXTERNAL TANK



Not recovered



8 minutes and 43 seconds after launch, the external tank is separated from the orbiter and drops into the sea. The tank takes significant damage during this decent and is not recovered. NASA schedulers send out notices to personnel in this area to protect them from this debris.

ON-ORBIT

SMG provides daily forecasts for KSC, EDW, NOR



While the Orbiter is on-orbit, Spaceflight Meteorology Group issues daily landing forecasts in the event an unexpected situation occurs and the shuttle needs to land early than planned.

LANDING



SMG provides continuous Wx updates until landing

45 WS LWO supports SMG and provides LD updates for post-landing preparation

*SMG=Spaceflight Meteorology Group
FD = Flight Director
TD = Touch down
hrs = hours
LWO = Launch Weather Officer*

And then, finally, when the mission comes to an end and it's time for the orbiter to land, Spaceflight Meteorology Group is the primary contact for weather support for landing. The Shuttle LWO supports them during landing operations and is also in contact with the Shuttle Launch Director to provide landing weather information and information for post-landing processing. A team of KSC personnel is waiting for the landing to accomplish the post-landing processing and roll to the OPF, and a team of KSC personnel is also at Edwards in the event the landing is waived off from KSC to Edwards AFB.

POST FLIGHT OPS

Post-Flight Processing Constraints:

(1 hour desired lead time)

- Lightning within 5NM
- Surface winds > 40 P 60 Kts
- Hail, Any Size
- Any precip



If weather is a concern, the Shuttle Launch Weather Officer supports the post landing processing. If the weather is most likely not going to be a problem, the Shuttle LWO often asks the forecaster to monitor the weather for the processing and provides the constraint and contact information. The post-landing processing takes 3.5 - 6 hours. The most sensitive constraint is the fact that the vehicle cannot take precip.

FERRY FLIGHT OPS



If the Orbiter lands at Edwards, a team of people are out there to recover the Orbiter and mate it to one of two of the NASA 747s that carry the orbiter back to KSC (SCA: Shuttle Carrier Aircraft). Another team of people are deployed to Edwards to Ferry the Orbiter back. This team includes 2-3 weather forecasters including a Ferry Weather Officer and one or two forecasters.

THIS COULD BE YOU!!



The team then works hard to determine the best plan for getting the Ferry Flight to KSC. They also fly on the Pathfinder aircraft leading the Ferry and determining the best path for the Ferry aircraft.

MATE / DEMATE OPS



Eventually the Ferry Flight does return to KSC and then must be demated from the Shuttle Carrier aircraft.

PATHFINDER



The team flies on the pathfinder which is either this aircraft or a DOD C-141.

HERE WE GO AGAIN!



Rolling shuttle in after landing while rolling out the next mission!

And by then the process for the next mission has already begun!

TERMINOLOGY/ACRONYMS

FD - Flight Director

TD - Touch Down

HRS - Hours

LWO - Launch Weather Officer

SMG - Space Flight Meteorology Group at
Johnson Space Center in Houston, Texas

EDW - Edwards

AFB - Air Force Base

SSPF - Space Station Processing Facility

RPSF - Rotation Processing & Surge Facility

TERMINOLOGY/ACRONYMS

SMG - Space Meteorology Group

APU - Auxiliary Power Unit

NM - Nautical Miles

LTG - Lighting

WX - Weather

NHC - National Hurricane Center

OWP - Orbiter Weather Protection