GENERATION BEYOND

LAUNCH CONTROL CHALLENGE
GO OR NO GO?

EDUCATOR GUIDE

LOCKHEED MARTIN

TABLE OF CONTENTS

OVERVIEW

As Range Weather Team members in Mission Control, students will analyze meteorological data to determine the go/no-go weather status of the launch of a crewed Orion mission. The "Go/No-Go" mission status check is a critical part of any space mission. At pre-determined times, the Launch Director will poll the engineers and scientists responsible for various spacecraft systems and launch facilities as to the readiness of the vehicle and launch range. A verbal "go" indicates that each officer's system is operating as planned. "No-Go" indicates that there is an unexpected event or possible malfunction, and the launch may be put into a hold, a delay, or completely "scrubbed," or cancelled.

The accompanying presentation was created with PowerPoint so that it can be used in a variety of classrooms. If you are using a laptop with an LCD projector, simply progress through the PowerPoint by clicking to advance. All of the interactive aspects of the presentation are set to occur on click. Links to the corresponding videos can be found in the notes section of the PowerPoint. If you are using an interactive whiteboard, tap on each slide with your finger or stylus to activate the interactive aspects of the presentation. It does not matter where you tap, but you can make it appear as if you are making certain things happen by tapping them. In the notes for each slide, there will be information on how to proceed.

Some slides include Augmented Reality (AR) trigger images, which may link to video, audio or additional content designed to enhance student learning. The location and technical requirements for each AR image are noted in the PowerPoint Presentation as well as in this guide (denoted as AR). You will want to download an augmented reality app (like Aurasma) to unlock the images during the lesson.

- **Content Areas:** Earth and Space Science, Engineering Design, and Science and Technology
- **Activity Duration:** 2-3 class periods (45 minutes each)
- **Grade Level:** Grades 6–8

NEXT GENERATION SCIENCE STANDARDS ADDRESSED

MS-ESS2-5 Collect data to provide evidence for how the motions and complex interactions of air masses results in changes in weather conditions

MS-ESS2-6 Develop and use a model to describe how unequal heating and rotation of the Earth cause patterns of atmospheric and oceanic circulation that determine regional climates.

MS-ETS Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.

COMMON CORE STATE STANDARDS AND ENGLISH LANGUAGE ARTS STANDARDS (CCSS.ELA) ADDRESSED

RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks

RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

DIGITAL LESSON PLAN ORGANIZATION

The lesson plan follows the 5E model. Each step in the lesson sequence builds on skills and content learned in previous steps.

- **Engage:** Students receive a short introduction to Orion and the challenges faced in deep-space exploration.
- **Explore:** To prepare them for their upcoming task, students learn about the Go/No-Go status check and watch as an Orion Flight Director takes the final mission status poll. Students follow a launch as an overview of what will happen on "their" mission. Students learn about their job as the Range Weather team, and review basic meteorological information by activating prior knowledge. Students discover how various aspects of weather can affect the Go/No-Go status of a launch and learn about cutting-edge technology used to make weather predictions.
- **Explain:** Students join "their" mission in the final hours of the countdown. Students learn about their team's specific responsibilities within the Range Weather team and how to analyze the data that they receive in order to reach a Go/No-Go decision.
- **Elaborate:** Students receive four sets of data representing different times leading up to the launch. In their teams, students compare "real-time" data to launch parameters in order to determine the Go/No-Go Range Weather status. After the Launch Director makes a final decision, students see the "outcome" of their decision.
- **Evaluate:** Students evaluate their decisions and explain the factors that led to them. Students explain why they may have been in error, which can also lead to a discussion of the uncertainty of weather forecasts.
- **Extend:** Students investigate the ways in which the same technology that is used to predict launch weather is used to help our lives on Earth.

OBJECTIVES

Students will:

- Identify and describe the conditions of temperature, pressure, humidity, precipitation and wind make up our weather.
- Describe how weather is caused by the movement of air masses moving from high to low pressure.
- Understand that weather can be predicted within probabilistic ranges.
- Explain how weather predictions and actual conditions impact human activities.
- Demonstrate how satellite data is used to make weather predictions and monitor weather events.

USING THE DIGITAL LESSON PLAN

ENGAGE (SLIDES 2-5)

Duration	10-15 minutes
Advance Preparation	Download an Augmented Reality app Aurasma to unlock AR trigger images. Ensure that audio/speakers are turned on for AR sites.
Vocabulary	■ Cis-lunar ■ Deep space ■ Go/No-Go

DIGITAL LESSON PLAN

The *Engage* portion of the lesson (slides 2-5) introduces students to Orion and the challenges faced in deep-space exploration.

BACKGROUND INFORMATION

Orion

In order to safely transport astronauts beyond low-Earth orbit, NASA requires a spacecraft specifically designed to meet the challenges of deep space exploration. NASA contracted Lockheed Martin to design, build and test Orion, which will transport astronauts into deep space and then return them safely back to Earth. Orion's first test flight, Exploration Flight Test 1 (EFT-1) successfully took place on December 5, 2014. EFT-1 was an un-crewed flight and tested a number of technologies that are fundamental to future deep space missions such as separation events, the heat shield, guidance and navigation, radiation protection, parachutes and recovery operations. Once Orion's systems have been verified in space, the vehicle will be ready to carry a crew. Exploration Mission-2, Orion's first crewed mission, will take a crew of four astronauts into a cis-lunar orbit near the moon. For more information, see the Additional Resources links at the end of this guide.

Challenges of Space Exploration

Deep space exploration presents a number of engineering and human health challenges. Lightweight materials that can withstand the extreme forces of launch, reentry and landing are crucial in designing a spacecraft light enough to escape Earth's gravitational pull. Lightweight materials are also needed to shield humans and equipment from extreme temperature variances and dangerous radiation. Communication across the distance of space is another challenge faced by astronauts; the farther away from Earth they get, the longer the delay in communication. Human health is compromised by extended stays in microgravity, and astronauts need specialized diets, fitness equipment, and even personal reminders of home in order to stay healthy and psychologically stable while they are millions of miles from Earth. These challenges aren't insurmountable, but they do take an extraordinary level of engineering and thorough testing to ensure long-duration

spacecraft like Orion are safe, reliable and ready to transport astronauts to the moon, Mars and beyond.

Go/No-Go

The "Go/No-Go" mission status check is a critical part of any space mission. At pre-determined times during a countdown, the Launch Director will poll all engineering and scientific teams to the readiness of the vehicle, launch range, and crew. The specific teams reporting in during a status check vary according to the mission, but they represent the onboard crew, flight systems such as guidance, communications, and fuel, and launch range-specific issues such as weather. The overriding concern for each team and the Launch Director is always the safety of the onboard crew and those on the ground along the flight path.

During the status check, each team reports "Go" or "No-Go" to the Flight Director, who then reports to the Launch Director. A verbal "go" indicates that each system is operating as planned. "No-Go" indicates that there is an unexpected event or possible malfunction. Depending on the system that is "No-Go" and the time before launch at which it occurs, the countdown may proceed with caution, or the countdown may put into a hold, a delay, or completely "scrubbed," or cancelled. The Launch Director is the final authority on the Go/No-Go status of the launch.

Slide 2, Your Challenge

Present students with their challenge: to work in teams as Range Weather officers for the launch of Exploration Mission 2 (EM-2), the first mission on which Orion will carry astronauts to the moon. Students will receive "real-time" weather information, which they will then have to compare to accepted launch criteria in order to determine whether or not they are "Go" for launch. Use random questioning techniques (popsicle sticks, beach ball toss, etc.) to ask 3-5 students what factors they think should be considered when deciding whether or not to launch. Student responses can be recorded on the board or a large piece of paper.

Slide 3, Challenges of Deep-Space Travel

Ask students to think about some of the challenges of deep-space travel that new technology may help solve. Again, using random questioning, ask students for their ideas and have them explain why they believe these things to be a challenge. After 3-5 students have shared, use the slide animation to reveal some of the biggest obstacles that aerospace engineers and scientists are currently working to overcome, including:

- Providing the spacecraft with enough thrust and momentum to escape Earth's gravity
- Designing a spacecraft with the advanced guidance and communications to ensure the correct trajectory.
- Developing new materials to ensure protection against radiation in space and the heat of re-entry.
- Maintaining a safe, breathable atmosphere that has the proper temperature, humidity, and mix of gases.
- Ensuring that crews have the space and equipment needed to carry out mission operations and tasks of everyday life while staying healthy and happy.

Slide 4, Orion

Introduce the Orion spacecraft to students (see Background Information and Additional Resources for more details). In the interest of time, this slide focuses on Orion's role as NASA's spacecraft capable of transporting astronauts to the moon and eventually Mars. The slide also briefly describes Orion's first un-crewed test flight, as students will have a chance to see video from this test later as an example of what they will be doing.

Slide 5, Exploration Mission 2

Introduce students to "their" mission, Exploration Mission 2 (EM-2). Currently designed to be the first crewed mission to the vicinity of the moon since Apollo 17 in 1972, EM-2 will be a proving ground mission into cis-lunar orbit. Many of the technologies that will be required for extended space exploration (for example, on Mars missions) will be tested on this mission.

EXPLORE (SLIDES 6-17)

Duration	20-40 minutes
Advance Preparation	AR sites in this section may require audio.
Vocabulary	■ Weather ■ Air mass ■ Temperature ■ Humidity ■ Precipitation ■ Solar (space) weather

DIGITAL LESSON PLAN

In the *Explore* portion of the lesson (slides 6-17), students learn about the Go/No-Go status check and watch as an Orion Flight Director takes the final mission status poll. Students follow a launch as an overview of what will happen on "their" mission. Students learn about their job as the Range Weather team, and review basic meteorological information by activating prior knowledge. Students discover how various aspects of weather can affect the Go/No-Go status of a launch and learn about cutting-edge technology used to make weather predictions.

BACKGROUND INFORMATION

Range Weather meteorologists rely on many of the same technologies and types of data as Earth-based meteorologists do. They incorporate data from weather balloons, radar, and satellites to determine the safety of the weather at the launch range during the countdown and at the time of launch. Specific weather parameters must fall within acceptable ranges in order to be considered Go for launch. These criteria include ambient temperature, wind speed, precipitation,

lightning, cloud cover. Solar weather, sometimes called "space weather," may also present concerns. During solar flare or ejection events, charged particles are sent outwards from the sun towards Earth. Although everything on the ground is protected by the atmosphere, satellites in orbit that provide meteorology data or tracking information are vulnerable to disruption from these events. A spacecraft launching through these charged areas would be equally vulnerable. As a result, solar weather is also a factor in the Go/No-Go decision.

Sometimes even though the criteria fall within allowable parameters, something just doesn't seem right or a hazard condition may present itself, like rapidly-forming clouds. At this point, the launch can be placed into a hold or a No-Go status using the "Good Sense" rule. This rule 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." Again, safety should be the guiding principle that oversees all launch operations. For more information, see the Additional Resources links at the end of this guide.

Slide 6, Orion: Go for Launch

Re-emphasize to students that they will be taking part in a Go/No-Go status check today for the EM-2 mission. Have them turn to a partner to discuss the two prompts on the slide: What do you think a "Go/No-Go" status check is for, and why is it important? (see the information in the Overview for a description and importance of the Go/No-Go decision). After students have had 2-3 minutes to discuss, ask students to share their ideas. The slide animation will reveal the basic meanings behind Go and No-Go:

- "Go" = the system is performing as expected and the spacecraft is ready to launch
- "No-Go" = the spacecraft is NOT ready for launch; something in the system is not working correctly or is unexpected. No-Go often means that a launch countdown may be put into a hold, or that the mission may be scrubbed.

Slide 7, Orion: Go for Launch continued: Using AR

Open Aurasma app and enter Username GenerationBeyond and enter Password MARS123 and click the purple finder tool at bottom of app and aim at the Orion Mission Control image and the aura Orion Mission Control will display. Non-AR use: click image to launch video - https://youtu.be/u1rOp66VqpU. This is the Go/No- Go Status check the Orion Flight Test described in the prior slide. It gives students a visual and audio example of what they will be modeling later in the activity. Emphasize that this is from a mission that happened in 2014, but that "their" mission later on in class will be very similar.

Slide 8, What Needs to Be Go For Launch?

Explain to students that the Go/No-Go decision is made by hundreds of scientists and engineers working together. Some are in mission control, while others are on the phone or on an internet connection at facilities across the country. Ask students to turn to a different partner and brainstorm what types of systems or officers could be part of the Go/No-Go status check. After 2-3 minutes of discussion, ask 3-5 pairs to share ideas.

The next animation will reveal some of the many teams involved in the Go/No-Go decision. Emphasize to students that this is just a select few. Remind them that they will be taking on the role of the Range Weather Officer.

Explain to students that after all teams report in as Go/No-Go, the Launch Director makes the final decision as to whether or not the launch will be Go or No-Go. At this point, students may be informed that one (or two, as desired by the teacher) student will be playing the role of Launch Director, and will have leadership over the class and the final launch authority. Teachers may select the Launch Director(s) may randomly or based on student personalities, depending on the specific makeup of the class."

Slide 9, What Needs to Be Go For Launch? continued: Using AR

Open Aurasma app and enter Username GenerationBeyond and enter Password MARS123 and click the purple finder tool at bottom of app and aim at the image of the Orion on the launch pad and the aura Orion on the launch pad will display. Non-AR users: click image of Orion on the launch pad to play video https://vimeo.com/57487761. Explain to students that this video shows them the launch and separation of the EFT-1 mission, in which the European Space Agency worked with NASA and Lockheed Martin to provide Orion's service module. Stop the video at 0:52. Re-emphasize to students that this not "their" mission; it serves to give students "historical" perspective and a preview of what their launch may look like if they are go for launch. Unlike the EFT-1 mission however, their mission will go to the moon.

Slide 10, Your Role: Range Weather Officer

Remind students of their role as a Range Weather Officer. Direct their attention to the three questions on the slide. Complete this as a think/pair/share. Students work individually and then in small groups to

- Describe what meteorologists do
- List the criteria for a "Go" launch
- List the criteria for a "No-Go" launch

Allow each group to present their ideas. As each group reads their criteria for Go/No-Go, capture this information in an area visible to the whole class (white board, large paper) so that they can refer back to it in subsequent slides.

Once this has been completed, inform students that they are going to see a series of questions that will remind them of what they already know about meteorology. Emphasize that understanding this information is vital to the success of a Range Weather team. Students may use clickers, 1:1 devices,

or other technology to answer the questions on the following three slides.

Slide 11, What Do You Know About...Meteorologists?
To reinforce what they have just completed, ask students to choose the multiple-choice answer that correctly describes what a meteorologist does. For this and the following slides, the question and answer choices appear automatically as soon the slide is advanced by clicking. The answer can be revealed by clicking after all of the choices have been displayed, then after discussing with students click one final time to advance to the next slide.

The correct answer is "d, all of the above and more." Students will realize that meteorologists do more than just predict or report the weather. Ask students how they think meteorologists play a role on the Range Weather team. Give 1-2 minutes for students to discuss with their think/pair/share groups. If time permits, ask one or two groups to share their answers.

Slide 12, What Do You Know About...Weather?
Ask students to choose the correct answer by ruling out the vocabulary-based definition that does not describe weather. Click to reveal the correct answer (d. hot summer, cold winter, wet spring, dry fall) as well as the basic definition of weather (short-term atmospheric conditions). Ask students to decide what "short term atmospheric conditions" the Range Weather team may encounter. Give 1-2 minutes for students to discuss with their think/pair/share groups. If time permits, ask one or two groups to share their answers.

Slide 13, What Do You Know About...Air Masses
Students review that air masses have similar temperature (cold or warm) and moisture. Click to reveal the correct answer: d. all of the above. Ask students how air masses may play a role in Range Weather. Give 1-2 minutes for students to discuss with their think/pair/share groups. If time permits, ask one or two groups to share their answers.

Slide 14, Weather: Key Ideas
Remind students that the movement of air masses from high to low pressure areas cause certain conditions to develop that can be used to predict the weather. Before clicking to reveal the four major conditions that they will investigate, ask students to predict some of these characteristics. After soliciting 5-7 answers, show the four characteristics they will examine: temperature, wind, humidity and precipitation. Next, ask students how these characteristics may be used in a Go/No-Go decision. Give 1-2 minutes for students to discuss with their think/pair/share groups. If time permits, ask one or two groups to share their answers.

Slide 15, Go/No-Go Weather Parameters: Re-evaluate
Direct student attention back to the lists they created in slide 2 and challenge them to re-evaluate their Go and No-Go criteria based on what they have just discussed. Students should work with the same groups that they created these lists with originally. Give students a few minutes to rework their lists and then have groups report out. As each group reads their criteria for Go/No-Go, capture this information in a new list visible to the class (or on the same list but in a different color).

Slide 16, Weather Parameters - Go/No-Go for Orion Launch
Direct student attention to the Weather Parameters that will be used on their "upcoming" launch. If desired, individual students can read the bullets aloud. Direct student attention back to the list they just revised. Ask students how their Go/No-Go criteria compares with the "real" Go/No-Go criteria.

Slide 17, "Good Sense Rule:"
To emphasize the importance of the Good Sense rule, ask one student to read it aloud. Ask another student to paraphrase the Good Sense rule. Emphasize that NASA and aerospace companies put the safety of the crew above everything else. The Good Sense rule emphasizes that the Range Weather team should report any possible hazards to the Launch Director even if launch criteria seems to fall into the Go category. Safety should be the main priority of each team and the Launch Director.

Slide 18, How Do We Get Meteorological Data?
Ask students how they, as meteorologists, will obtain the data they need to make their Go/No-Go decisions. Direct students to use the images on the slide as a starting place. Students likely will have a wide range of prior knowledge. Answers may include satellites, radar, aircraft/weather balloons, eyewitness reports. If time permits, ask students to think about the specific instrumentation or the specific types of data that meteorologists may need. Students should volunteer, or be directed to think about factors such as precipitation, surface wind speed, upper-level wind speed, lightning, humidity, dew point, and pressure. Tell students that specific data is so critical that as Range Weather officers, their teams will be responsible for just one of these factors.

Slide 19 – The Newest Weather Prediction Tool:
GOES-16 Weather Satellite
Introduce students to NOAA's GOES-16, one of the newest weather satellites on orbit. Launched in 2016, the Lockheed Martin-built GOES-16 provides data for not only improved forecasting, tracking, and research of Earth's weather, but also provides the ability to monitor space weather, like solar storms and particle events on the sun. Instrumentation on board includes the Advanced Baseline Imager for images of Earth's land and oceans, a Geostationary Lightning Mapper to detect the presence of lightning and its location, and a Solar Ultraviolet Imager to detect solar flares and eruptions. All of this information can be used by Range Weather officers during a Go/No-Go decision.

EXPLAIN (SLIDES 20-23)

Duration	10–14 minutes
Advance Preparation	■ Group students into the following teams. All teams should have equal numbers of students except for the Launch Director(s). ■ Temperature Team ■ Wind Team ■ Precipitation Team ■ Lightning Team ■ Cloud Team ■ Solar Weather Team ■ Good Sense Team ■ Launch Director (one or two students who will "lead" the Status Check) ■ Print and/or make copies of the following reports (see Student Resources). If reports will be used multiple times, consider laminating a class set. ■ Weather Parameters (one per student) ■ Meteorology Report: T-90 Minutes (at least one per team) ■ Meteorology Report: T-60 Minutes (at least one per team) ■ Meteorology Report: T-30 Minutes (at least one per team) ■ Meteorology Report: T-5 Minutes (at least one per team) ■ AR sites in this section may require audio.
Background Infromation	Additional information on specific topics in this section is presented with the related slide below.

DIGITAL LESSON PLAN

In the *Explain* portion, students join "their" mission in the final hours of the countdown. Students learn about their team's specific responsibilities within the Range Weather team and how to analyze the data that they receive in order to reach a Go/No-Go decision.

Slide 20, EM-2 Launch Day

Tell students that, after years of planning by engineers, the history of the Orion flight test that they experienced, and meteorology training they have just completed, it is launch day for NASA and Lockheed Martin's Orion EM-2 mission to the moon. As Range Weather officers, they hold a large part of the responsibility of making the Go/No-Go decision for launch.

Using AR: Open Aurasma app and enter Username GenerationBeyond and enter Password MARS123 and click the purple finder tool at bottom of app and aim at the image of the astronaut in the Orion and the aura will display. Non-AR users: click image of astronaut in the Orion to play video. To generate student excitement, the video (https://vimeo.com/168089400) will introduce students to "their" launch vehicle for EM-2. Note: there is no audio for this video; teachers may want to ask one of their more dramatic students to narrate the video in order to add to the realism of the launch scenario. Stop the video at 30 seconds.

After the video is stopped, click to advance to the animation slide, and reveal that they must complete a Range Weather status check before the launch can proceed.

Slide 21, EM-2 Mission Status Check

One final time, explain to students their task for the day. They will work in teams to determine if the weather is Go or No- Go for the launch of EM-2. To do this, they will examine meteorological data and compare it to Launch Criteria to determine if it is within the "Go" parameter. When polled, they will report their Go/No-Go decision to the Launch Director.

Slide 22, Range Weather Teams

Announce the teams and who will play the launch director. Have students move seats so that they are sitting with their teams. If possible, have the Launch Director(s) come to the front of the room. Each team should pick a Good Sense liaison and a spokesperson. The liaison will report the team's findings to the Good Sense team, who will take this information into account when making a decision. The spokesperson gives the Launch Director the team's official Go/No-Go decision.

Ask teams to summarize their meteorological responsibility for the Launch Director. After a 30-60 second discussion, the spokesperson should describe to the Launch Director what their team is responsible for.

Slide 23, The Go/No-Go Decision

Distribute the Weather Parameters for Go/No-Go and the T-90 Meteorology Data (see Student Resources) to the teams. Explain to teams how they will make their decision. First, they need to identify their data of interest on the Meteorology Report. They then will compare this to the Weather Parameters, and decide if this data indicates that they are Go or No-Go. Once this decision has been made, the liaison should report their findings to the Good Sense team. Liaisons should not only report the team's decision, but should also let the Good Sense team know about any uncertainties or possible hazards they encounter. Remind the Good Sense team that their job is to think about safety before making a final decision.

ELABORATE (SLIDES 24-28)

Duration	20-40 minutes
Advance Preparation	■ Meteorology Reports or T-60, T-30, and T-5 should already be prepared; they will be distributed one-by-one as this activity progresses. ■ AR sites will require audio. ■ The AR video should be cued to 0:30 where the class left off in the previous section; if not, set the video to start there.
Background Information	Any additional information on specific topics in this section is presented with the related slide below.

DIGITAL LESSON PLAN

Students receive four sets of data representing different times leading up to the launch. In their teams, students compare "real-time" data to launch parameters in order to determine the Go/No-Go Range Weather status. After the Launch Director makes a final decision, students see the "outcome" of their decision.

Slide 24, EM-2 Weather Status Check, T-90

Give each team no more than 3-5 minutes to examine their specific pieces of data for T-90, compare it to the Weather Parameters page, and make a Go/No-Go decision. When this is completed, the Liaison should report their decision and any notes to the Good Sense team, who can make their final decision once all teams have reported in.

After all teams have reached their decisions, the Launch Director conducts the status check poll. The Launch Director should use the information on the slide to call on each team; when called on, each team responds with the "Go or No-Go" decision. The Launch Director should record what each team reports (see Student Resources) in order to make his or her final decision. This decision should be read in the format on the screen. Remind the Launch Director that even one team reporting No-Go means that the final decision should be No-Go. No-Go does mean that they cannot eventually launch or that the countdown has to stop; it means that if the launch were scheduled now, conditions would not safe.

The teams should report as follows. If a team reaches a different decision, work with them to reach the correct conclusion.

- Temperature: "Go"
- Wind Speed: "Go"
- Precipitation: "No-Go"
- Lightning: "No-Go"
- Cloud Cover: "No-Go"
- Solar Weather: "Go"
- Good Sense: "No-Go"
- Launch Director: At this time, we are No-Go for launch.

Explain to students that even though Range Weather may report No-Go, weather moves so quickly that a No-Go does not mean they have to stop the countdown. Because the spacecraft is operating as expected, with only Weather calling in as No-Go, the countdown will proceed.

Slide 25, EM-2 Weather Status Check, T-60

Distribute the "Meteorology Report, T-60" data set to each team. Teams should follow the same procedure as T-90 to analyze the data and report to the Good Sense team. Launch Directors then call for the status check poll.

The teams should report as follows. If a team reaches a different decision, work with them to reach the correct conclusion.

- Temperature: "Go"
- Wind Speed: "Go"
- Precipitation: "No-Go"
- Lightning: "No-Go"
- Cloud Cover: "No-Go"
- Solar Weather: "Go"
- Good Sense team: "No-Go"
- Launch Director: At this time, we are No-Go for launch.

Because the spacecraft is operating as expected, with only Weather teams calling in as No-Go, the countdown will proceed. However, if the class is embracing their role and the possibility of a launch, drama can be built by changing this announcement. Instead, announce that the Range Safety Officer is tracking an unknown vessel in the Atlantic about five miles offshore. The countdown will proceed but launch range officials are on their way to investigate this possible Range Safety violation.

Slide 26, EM-2 Weather Status Check, T-30

Distribute the "Meteorology Report, T-30" data set to each team. Teams should follow the same procedure to analyze the data and report to the Good Sense team. Launch Directors then call for the status check poll.

The teams should report as follows. If a team reaches a different decision, work with them to reach the correct conclusion.

- Temperature: "Go"
- Wind Speed: "Go"
- Precipitation: "No-Go"
- Lightning: "Go"
- Cloud Cover: "No-Go"
- Solar Weather: "Go"
- Good Sense: "No-Go"
- Launch Director: At this time, we are No-Go for launch.

Because the spacecraft is operating as expected, with only Weather calling in as No-Go, the countdown will proceed. If students were warned of a possible range safety violation, report that the launch range officials have escorted a lost fisherman out of the area, and that the Range Safety Officer now reports Go.

Slide 27 – Weather Launch Status Checklists T-5

Distribute the "Meteorology Report, T-5" data set to each team. Warn them that this is their last status check before launch, and a No-Go decision means that the launch will be postponed until tomorrow. Teams should follow the same procedure to analyze the data and report to the Good Sense team. Launch Directors then call for the status check poll.

The teams should report as follows. If a team reaches a different decision, work with them to reach the correct conclusion.

- Temperature: "Go"
- Wind Speed: "Go"
- Precipitation: "Go"
- Lightning: "Go"
- Cloud Cover: "Go"
- Solar Weather: "Go"
- Good Sense: "Go"
- Launch Director: "At this time, we are Go for launch."

Note: all teams will have data that is completely within acceptable ranges, but there is the chance that the Good Sense team will exercise too much caution and still recommend a No-Go. If this happens, facilitate a discussion between Good Sense and the team(s) that presented the problematic data. Ask the teams to report on the trends in the data, the acceptable range of data, etc. Eventually the Good Sense team should realize that all weather parameters are well within safety limits.

Slide 28, EM-2: Go For Launch!

Now that Range Weather teams have reached their final Go for launch, the responsibility has switched over to the teams that are watching over the spacecraft and launch facilities.

Using AR: Open Aurasma app and enter Username GenerationBeyond and enter Password MARS123 and click the purple finder tool at bottom of app and aim at the image of the Go for Launch and the aura will display. Non-AR users: click image of Go for launch to return to the previous video (https://vimeo.com/168089400) and pick up where the class left off (at 0:30). Launch will occur at 0:35; encourage the class to countdown with T-3, 2, 1, liftoff. Students will view the launch, separation of the Orion from the launch vehicle, and the beginning of Orion's trip to the moon. Congratulate the class on their contribution to the successful launch of EM-2.

EVALUATE (SLIDES 29–31)

Duration	5-10 minutes
Advance Preparation	No advance preparation needed.
Background Information	No additional background information is needed.

DIGITAL LESSON PLAN

Students evaluate their decisions and explain the factors that led to them. Students explain why they may have been in error, which can also lead to a discussion of the uncertainty of weather forecasts. A final writing or discussion prompt will serve as an assessment of student learning.

Slide 29–30, Range Weather Team Evaluation

Ask the Launch Director to address the chart on the slide. For each report time, the Launch Director should remind the class of the Go/No-Go decision and, if the decision was No-Go, which teams made that call (which parameters were not within allowable parameters). If necessary, the Launch Director can confer with the class to reconstruct the data. If an interactive whiteboard is available, the Launch Director can write this directly on the slide.

For each No-Go decision, ask the teams to report what data the report gave, and how this compared to acceptable parameters.

Facilitate a discussion that will summarize the activity by posing the following questions:

- Which weather parameters are measured before a launch?
- Which weather parameters were more likely to lead to a No-Go situation? Why?
- Why are certain weather conditions required in order to launch?

Depending on time constraints, these can be answered aloud individually through random calling, discussed in their groups and shared, or written individually. Students will realize that any one of a number of weather factors can lead to a No-Go decision in order to ensure safety for the spacecraft and its crew.

Slide 31, Range Weather Team Evaluation

Click the slide to proceed to the final writing prompt, to be used as assessment. Students should return to their seats and complete this reflection individually. In their answers, students should refer to the definition of weather as a short-term phenomenon (which is why they had to track the weather so carefully in the last 90 minutes), discuss the different aspects of weather that the team monitored, and describe how they had to track multiple factors in order to ensure that the weather stayed within acceptable parameters in order to ensure a safe launch.

EXTEND (SLIDE 32)

Duration	5 minutes
Advance Preparation	No advance preparation needed.

DIGITAL LESSON PLAN

In the *Extend* portion (slide 30), students investigate the ways in which the same technology that is used to predict launch weather is used to help our lives on Earth.

BACKGROUND INFORMATION

A great deal of technology originally designed to facilitate space exploration has found its way to applications on Earth. The most commonly-known examples include memory (tempered) foam, scratch-resistant lenses, and reflective emergency blankets. Some of this technology has also been used in the areas of public safety (improved predictions of monsoons, storm surges, and other extreme events), emergency response, and climate research. For specific examples of space technology applications, visit the NASA Spinoff Website (see Additional Resources for link).

Slide 32, How Does Launch Weather Technology Help Earth?

Ask students to brainstorm all of the ways we use cutting-edge weather data on Earth. Some ideas may include:

- Improved weather predictions
- Improved prediction of monsoon flash floods
- Improved prediction of storm surges
- Increase safety of aircraft flights
- Improved climate research

GENERATION BEYOND

LOCKHEED MARTIN

LESSON RESOURCES

GENERATION BEYOND

LOCKHEED MARTIN

WEATHER PARAMETERS FOR GO/NO-GO

TEMPERATURE

No-go for launch if:

- The temperature exceeds 99 degrees Fahrenheit (37 degrees Celsius) for more than 30 consecutive minutes.
- The temperature is less than 48 degrees Fahrenheit (9 degrees Celsius).

WIND

- The peak wind speed allowable is 30 knots.
- The upper atmosphere wind profile is determined by a series of wind balloon releases from Cape Canaveral Air Station. A Go/No-Go report based on this profile is provided by the Johnson Space Center.

PRECIPITATION

- Precipitation at the launch pad or within the flight path = No-Go.

LIGHTNING

- Do not launch if lightning has been detected within 10 nautical miles of the pad or the planned flight path within 30 minutes prior to launch.
- The one-minute average of the electric field mill network may not exceed -1 or +1 kilovolt per meter within five nautical miles of the launch pad or the lightning flash at any time within 15 minutes prior to launch.

CLOUDS

- Do not launch if any part of the planned flight path is through a layer of clouds that is 4,500 feet (1372 meters) thick or greater and the temperature of any part of the layer is between 32 degrees Fahrenheit and -4 degrees Fahrenheit (0 degrees Celsius and -20 degrees Celsius). 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 Fahrenheit (-15 degrees Celsius) or colder, and shows no evidence of containing water droplets.
- Do not launch through cumulus type clouds with tops higher than 41 degree Fahrenheit (5 degrees Celsius). Launch may occur through clouds as cold as 23 degrees Fahrenheit (-5 degrees Celsius) if the cloud is not producing precipitation, and all field mills within 5 nautical miles of the flight path and at least one field mill within 2 nautical miles of the cloud center read between -100 volts per meter and +500 volts per meter.
- Do not launch through an attached anvil cloud. If lightning occurs in the anvil or the associated main cloud, do not launch within 10 nautical miles for the first 30 minutes after lightning is observed, or within 5 nautical miles from 30 minutes to 3 hours after lightning is observed.
- Do not launch if the flight path will carry the vehicle through a thunderstorm or cumulonimbus debris cloud which is not transparent and less than three hours old.

SOLAR WEATHER:

- No-Go for launch if large Solar Energetic Particles (SEP) events are predicted.

GENERATION BEYOND

LOCKHEED MARTIN

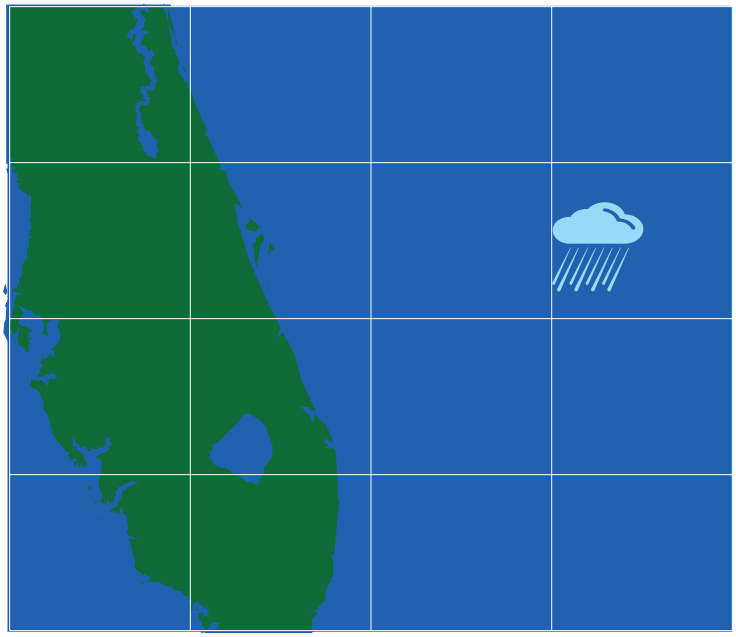
ORION

METEOROLOGY REPORT: T-90 MINUTES

TEMPERATURE
The temperature reported in the Launch Pad area is 64°F (18°C)

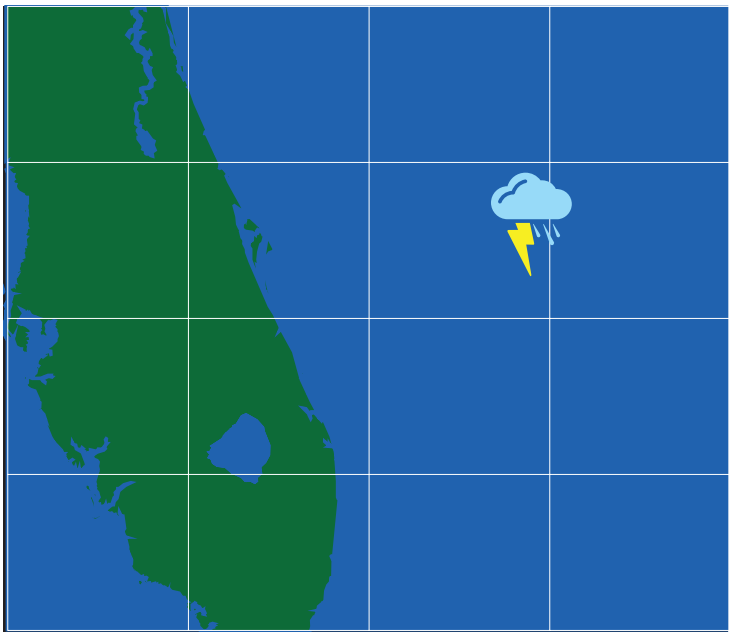
WIND SPEED
The wind speed reported in the Launch Pad area at is 30 knots (35 mph)

PRECIPITATION
Precipitation 10 nautical miles away

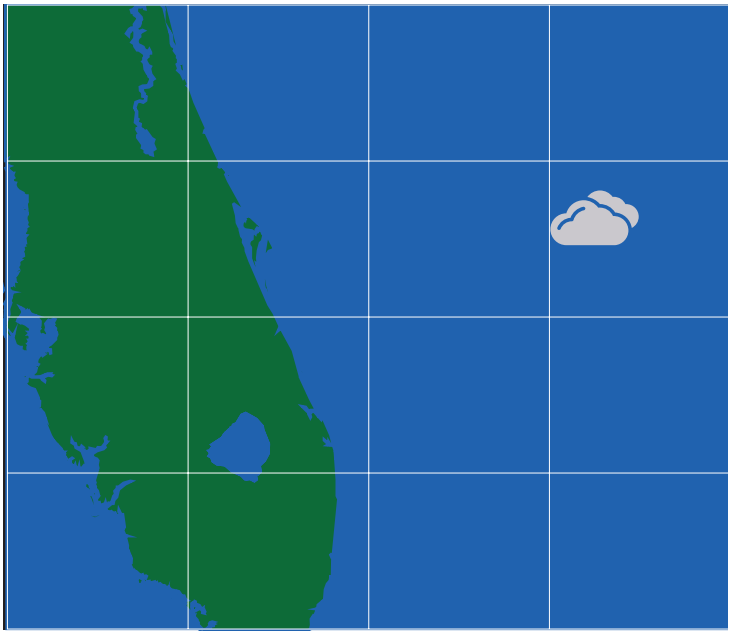


5 Nautical Miles

LIGHTNING
Lighting strikes 8 nautical miles away



CLOUD COVER
Cloud cover 10 nautical miles away



SOLAR WEATHER
No large Solar Energetic Particles (SEP) events detected

GENERATION BEYOND

LOCKHEED MARTIN

ORION

METEOROLOGY REPORT: T-60 MINUTES

TEMPERATURE

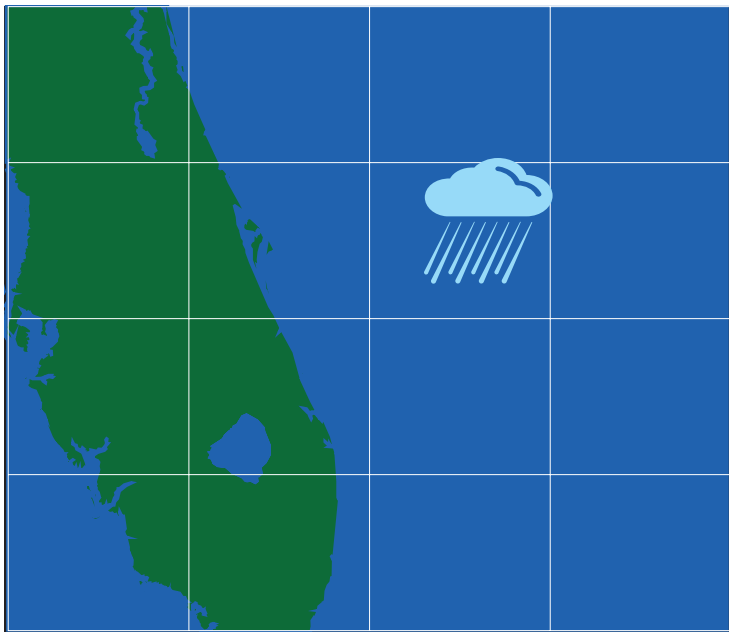
The temperature reported in the Launch Pad area is 58°F (14°C)

WIND SPEED

The wind speed reported in the Launch Pad area is 20 knots (23 mph)

PRECIPITATION

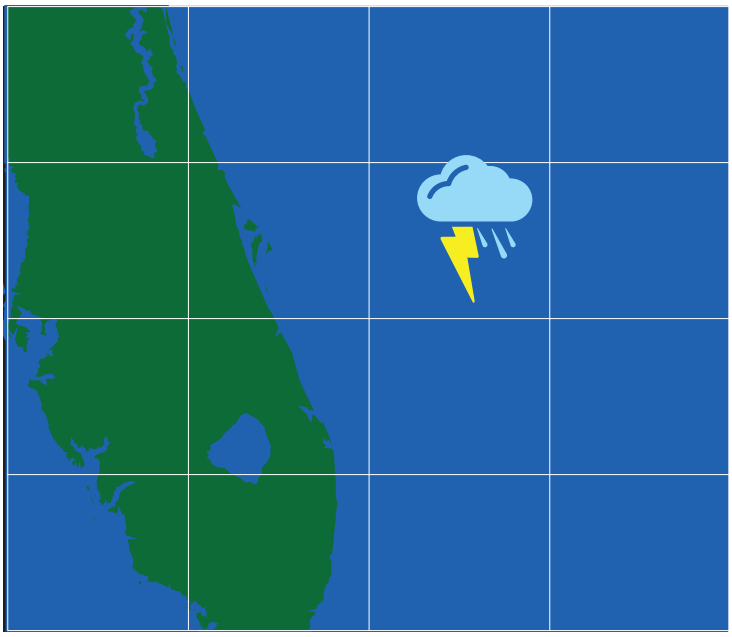
Precipitation 5 nautical miles away



5 Nautical Miles

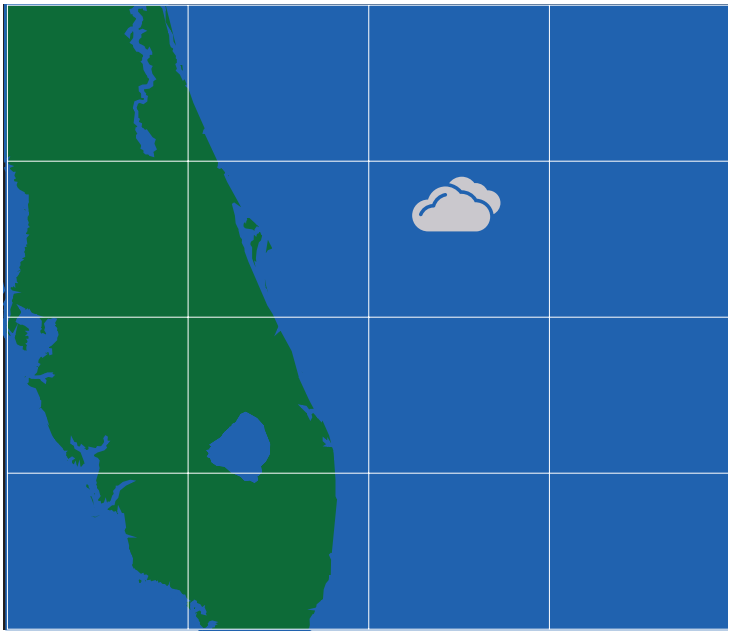
LIGHTNING

Lighting strikes 6 nautical miles away



CLOUD COVER

Cloud cover 5 nautical miles away



SOLAR WEATHER

No large Solar Energetic Particles (SEP) events detected

GENERATION BEYOND

LOCKHEED MARTIN

ORION

METEOROLOGY REPORT: T-30 MINUTES

TEMPERATURE

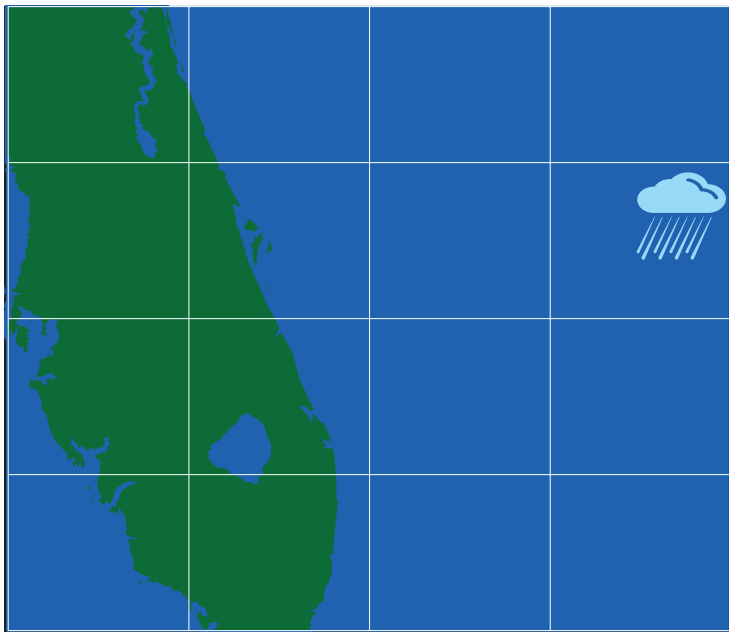
The temperature reported in the Launch Pad area is 55°F (13°C)

WIND SPEED

The wind speed reported in the Launch Pad area is 20 knots (23 mph)

PRECIPITATION

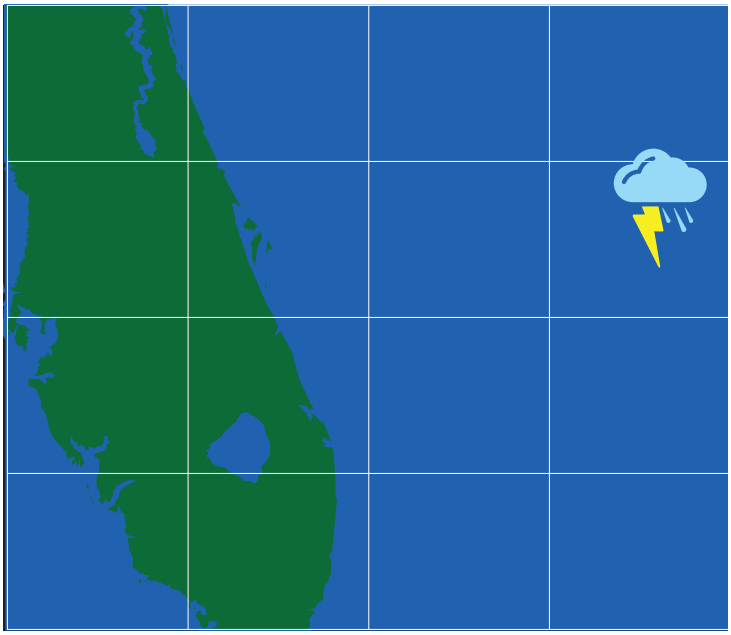
Precipitation 13 nautical miles away



5 Nautical Miles

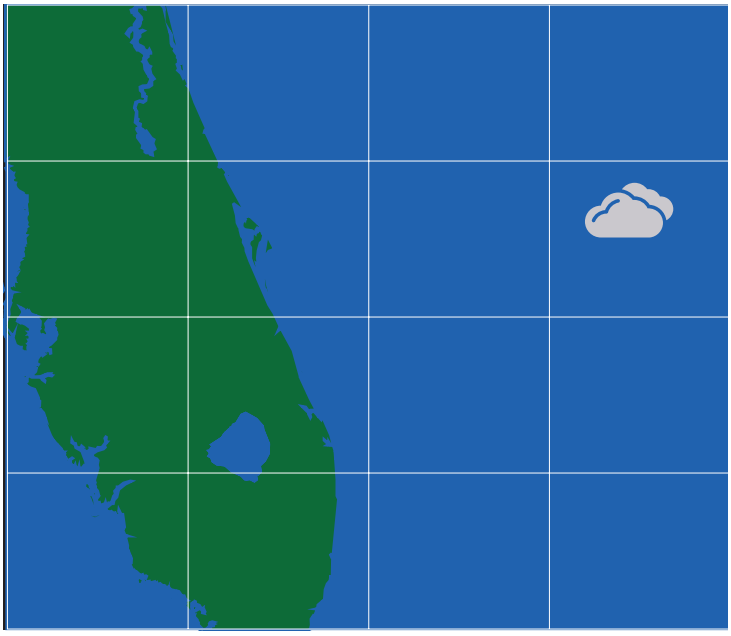
LIGHTNING

Lighting strikes 16 nautical miles away



CLOUD COVER

Cloud cover 14 nautical miles away



SOLAR WEATHER

No large Solar Energetic Particles (SEP) events detected

GENERATION BEYOND

LOCKHEED MARTIN

ORION

METEOROLOGY REPORT: T-5 MINUTES

TEMPERATURE

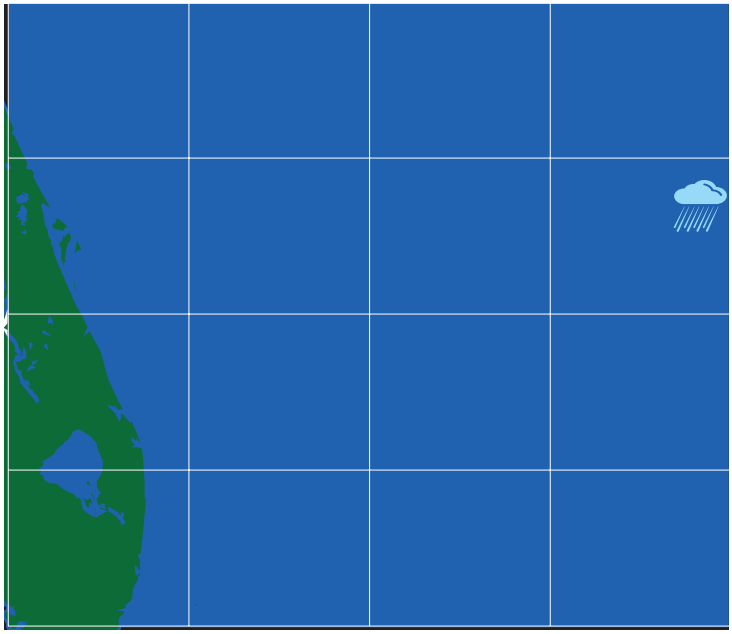
The temperature reported in the Launch Pad area is 54°F (12°C)

WIND SPEED

The wind speed reported in the Launch Pad area is 15 knots (17 mph)

PRECIPITATION

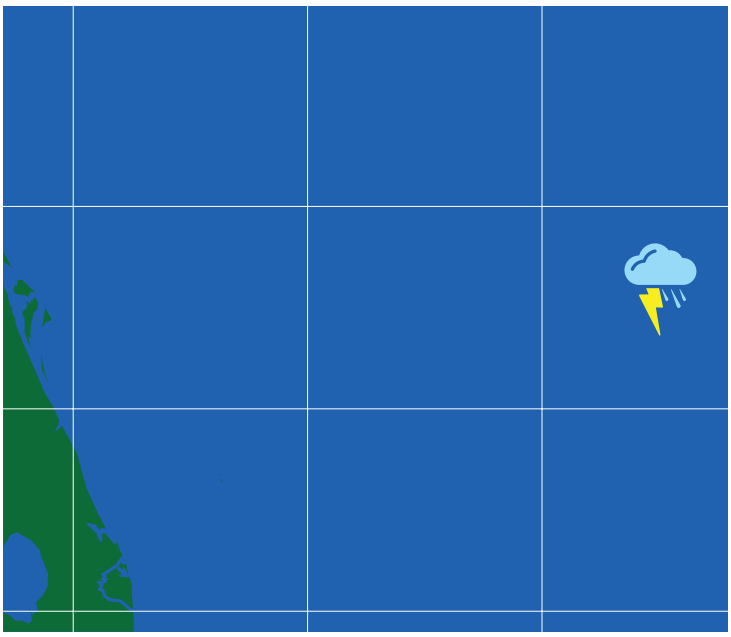
Precipitation 22 nautical miles away



5 Nautical Miles

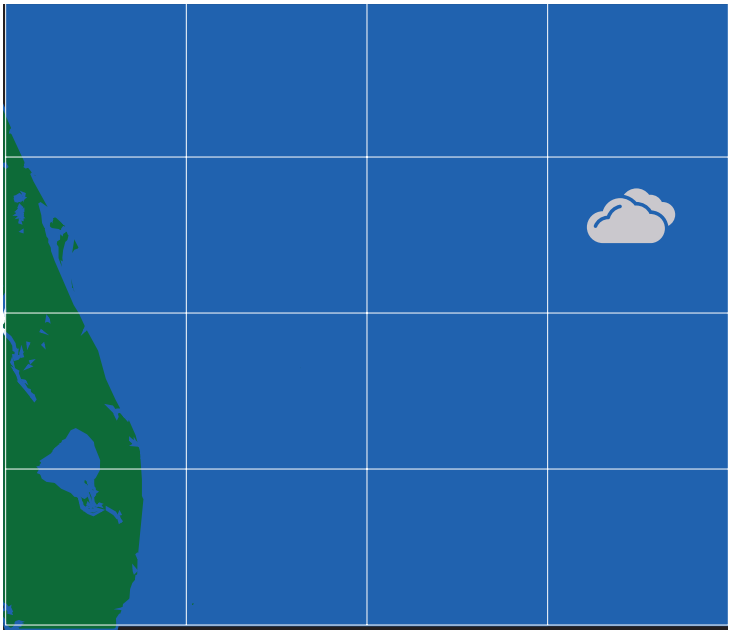
LIGHTNING

Lighting strikes 25 nautical miles away



CLOUD COVER

Cloud cover 20 nautical miles away



SOLAR WEATHER

No large Solar Energetic Particles (SEP) events detected

ADDITIONAL RESOURCES

Orion Spacecraft

Current research and future plans for the Orion spacecraft. Includes research articles, press releases, images and videos.

Links:

- Orion spacecraft home page at NASA: https://www.nasa.gov/exploration/systems/orion/index.html
- Orion spacecraft home page at Lockheed Martin: http://www.lockheedmartin.com/orion
- Information about Orion's successful Exploration Flight Test 1 (EFT-1) http://www.lockheedmartin.com/us/ssc/orion-eft1.html

GOES-16 Weather Satellite

Mission, spacecraft, and instrument information. Includes research articles, press releases, images and videos.

Links:

- GOES-16 from NASA/NOAA, includes factsheets and instrumentation: http://www.goes-r.gov/
- Pre-launch GOES-R from Lockheed Martin: http://www.lockheedmartin.com/us/products/geostationary-operational-environmental-satellite-r-series--goes.html

Weather for Space Launches

Weather parameters, and support systems, and "The Good Sense Rule" for space launches.

Links:

- USAF 45th Space Wing homepage (responsible for Launch Weather predictions): http://www.patrick.af.mil/About-Us/Weather
- Launch Commit and End-of-Mission Weather Criteria (for Space Shuttle): https://www.nasa.gov/pdf/290109main_167477main_WeatherRules-08R%5B1%5D.pdf

NASA Space Spinoffs

Searchable databases and interactive website of NASA technologies that are benefit on Earth in the form of commercial products.

Links:

- NASA Technology Transfer Program: https://technology.nasa.gov/
- NASA Spinoffs: https://spinoff.nasa.gov/