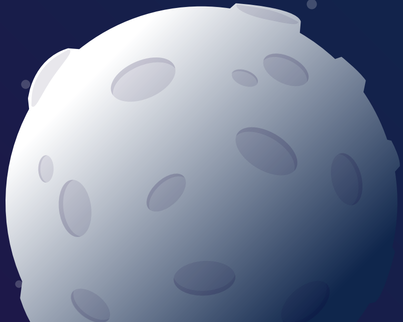
NASA's SLS Rocket: What Could Go Wrong?



What is NASA?

- National Aeronautics and Space Administration
- Agency of the U.S. Government created for the sole purpose of space research

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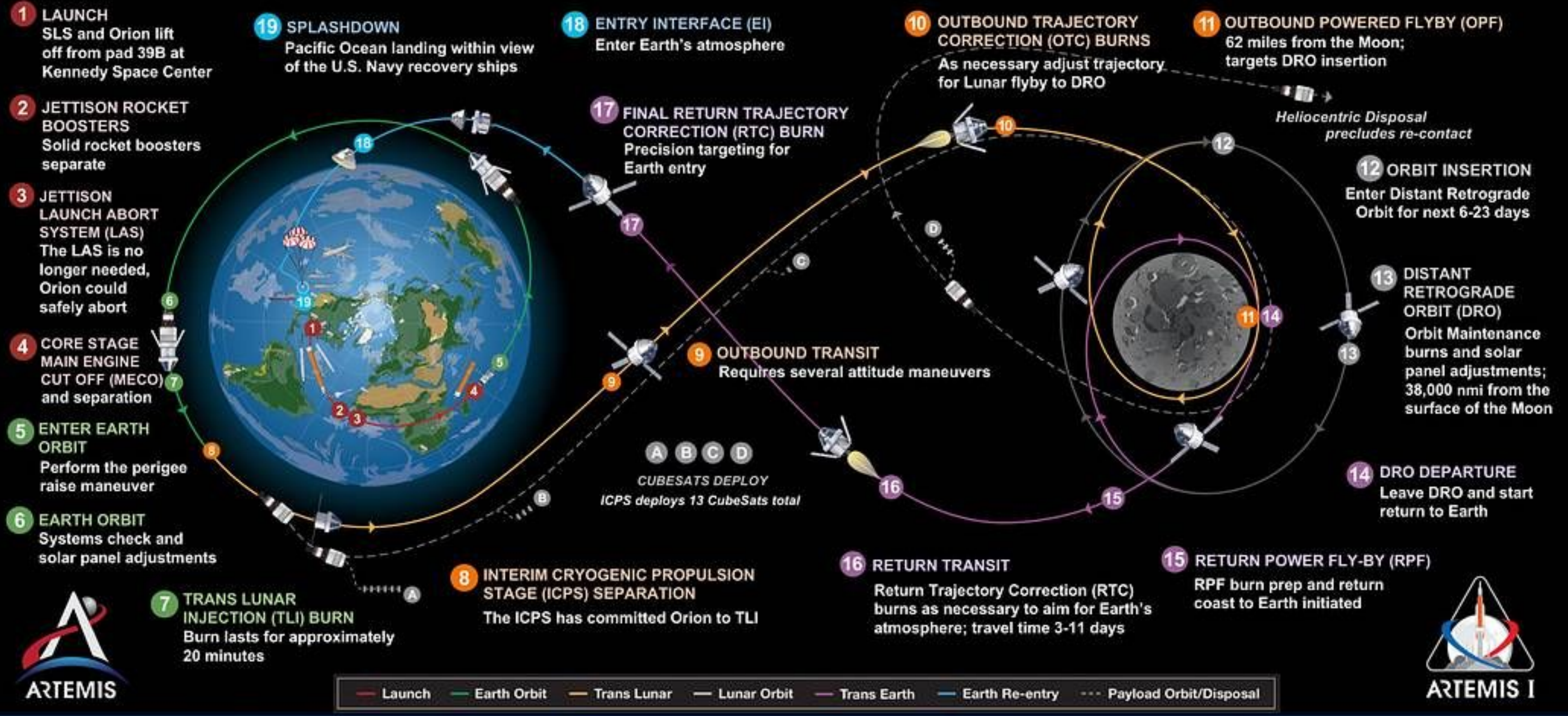
Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality and stewardship of Earth

ARTEMIS

ARTEMIS I

The first uncrewed, integrated flight test of NASA's Orion spacecraft and Space Launch System rocket, launching from a modernized Kennedy spaceport

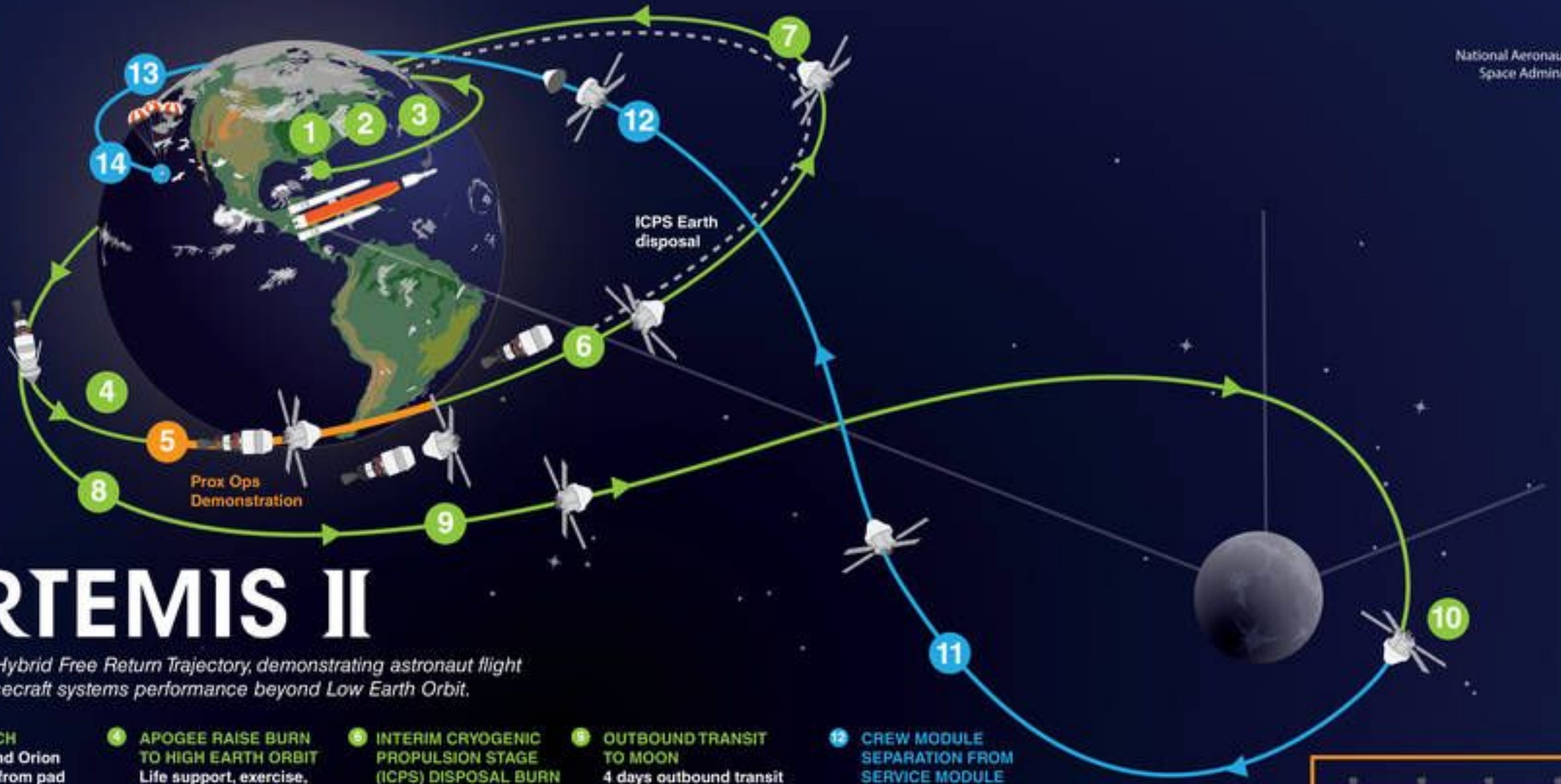


Total distance traveled: 1.3 million miles – Mission duration: 26-42 days – Re-entry speed: 24,500 mph (Mach 32) – 13 CubeSats deployed

Artemis I

- Uncrewed test of the SLS, Orion Spacecraft, and ICPS (Interim Cryogenic Propulsion System)
- Purpose: Making sure that the rocket's hardware and software are viable for a trip to the moon and back

National Aeronautics and Space Administration



ARTEMIS II

Crewed Hybrid Free Return Trajectory, demonstrating astronaut flight and spacecraft systems performance beyond Low Earth Orbit.

1 LAUNCH
SLS and Orion lift off from pad 39B at Kennedy Space Center.

2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM

3 CORE STAGE MAIN ENGINE CUT OFF
With separation.

4 APOGEE RAISE BURN TO HIGH EARTH ORBIT
Life support, exercise, and habitation equipment evaluations. 42 hour checkout of spacecraft.

5 PROX OPS DEMONSTRATION
Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.

6 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN

7 ORION PERIGEE RAISE BURN

8 TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE

9 OUTBOUND TRANSIT TO MOON
4 days outbound transit along free return trajectory.

10 LUNAR FLYBY
4,000 nmi (mean) lunar farside altitude.

11 TRANS-EARTH RETURN
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.

12 CREW MODULE SEPARATION FROM SERVICE MODULE

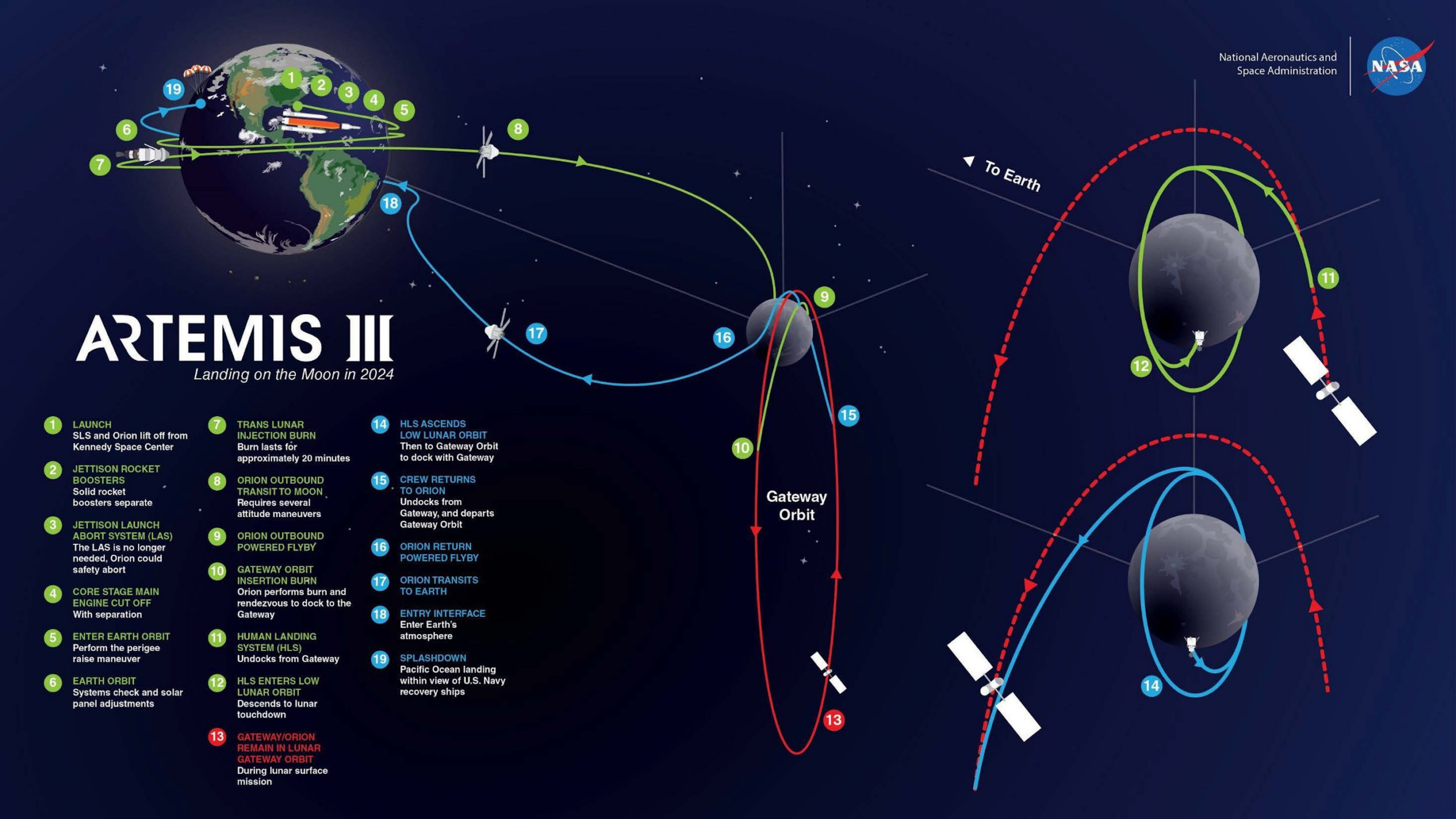
13 ENTRY INTERFACE (EI)
Enter Earth's atmosphere.

14 SPLASHDOWN
Pacific Ocean landing within view of the U.S. Navy recovery ship.

PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE

Artemis II

- Crewed test of the SLS, Orion Spacecraft, and ICPS (Interim Cryogenic Propulsion System)
- Purpose: Make sure the astronauts can follow proper procedure and ensure Orion life support functions properly
- The astronauts are NOT going to the moon, this is just a test run (but with people this time)



National Aeronautics and Space Administration
NASA
ARTEMIS III
Landing on the Moon in 2024
1 LAUNCH
SLS and Orion lift off from Kennedy Space Center
2 JETTISON ROCKET BOOSTERS
Solid rocket boosters separate
3 JETTISON LAUNCH ABORT SYSTEM (LAS)
The LAS is no longer needed, Orion could safety abort
4 CORE STAGE MAIN ENGINE CUT OFF
With separation
5 ENTER EARTH ORBIT
Perform the perigee raise maneuver
6 EARTH ORBIT
Systems check and solar panel adjustments
7 TRANS LUNAR INJECTION BURN
Burn lasts for approximately 20 minutes
8 ORION OUTBOUND TRANSIT TO MOON
Requires several attitude maneuvers
9 ORION OUTBOUND POWERED FLYBY
10 GATEWAY ORBIT INSERTION BURN
Orion performs burn and rendezvous to dock to the Gateway
11 HUMAN LANDING SYSTEM (HLS)
Undocks from Gateway
12 HLS ENTERS LOW LUNAR ORBIT
Descends to lunar touchdown
13 GATEWAY/ORION REMAIN IN LUNAR GATEWAY ORBIT
During lunar surface mission
14 HLS ASCENDS LOW LUNAR ORBIT
Then to Gateway Orbit to dock with Gateway
15 CREW RETURNS TO ORION
Undocks from Gateway, and departs Gateway Orbit
16 ORION RETURN POWERED FLYBY
17 ORION TRANSITS TO EARTH
18 ENTRY INTERFACE
Enter Earth's atmosphere
19 SPLASHDOWN
Pacific Ocean landing within view of U.S. Navy recovery ships
Gateway Orbit
To Earth

Artemis III

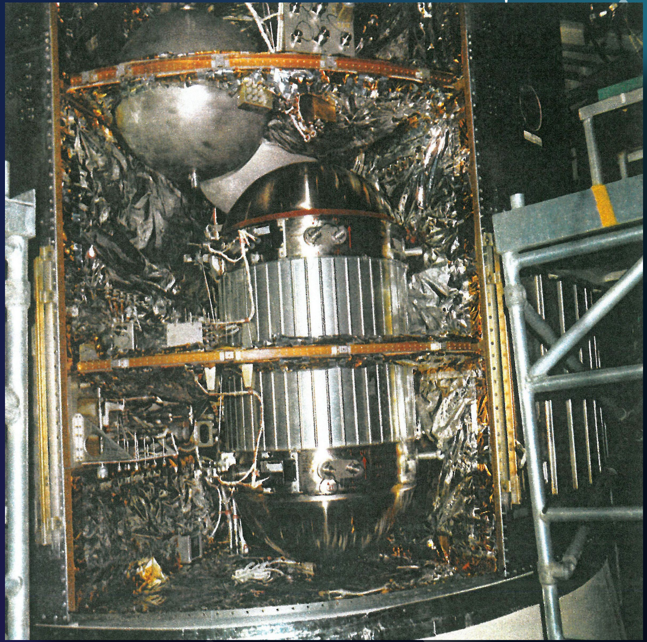
- The final stage of Artemis. Crew and systems have all been tested, and are ready for lunar landing.
- By this point, the Gateway (a lunar orbiting station) should be set up. Orion will dock here where the crew will use the Human Landing System (HLS) to get to the moon.

What could go wrong?

All of them use the SLS, Orion, and ICPS Technology!
Could this result in potential failure?

Apollo 13

- Damaged oxygen tank was overlooked and placed on Apollo 13
- Routine maintenance resulted in a spark that ignited the liquified oxygen tank
- System rapidly lost electricity as Apollo 13 began to lose functionality



What else could go wrong?

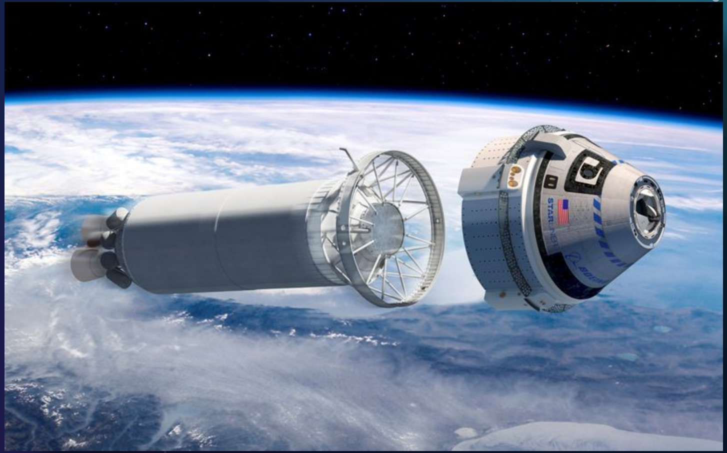
The software could be buggy!

Concerns for NASA's Software

- Aerospace Safety Advisory Panel (ASAP) are greatly concerned as to how NASA is testing their software
- Using only modular forms of emulation and simulation rather than a holistic approach
- Did not learn much from the Starliner incident in 2019

Starliner Incident

- Goal: Dock on the International Space Station
- A software error that came to light only once the Starliner reached orbit ultimately caused controllers to terminate the mission (Flight computers were 11 hours off)
- After being brought down, analysis of the code found another bug that could have resulted in danger to the crew.



NASA's Response & New Concerns

- NASA pushed back against ASAP's concern of their software testing, claiming that they are conducting strict end-to-end integrated testing
- Skepticism about the quality of their code also arose from shifts in timeline
  - Originally, Artemis I was set to launch in 2028. Due to White House Pressures, the timeline was accelerated and launch is now expected late 2021
  - This could potentially cause engineers to development a rushed product, ultimately reducing the quality simply due to time constraints
- NASA maintains that safety is a priority

Key Takeaways & Future Applications

- Modular testing is good for local debugging but integrated testing should always be done
- Ensure that the test parameters properly match the situation at hand
- Artemis is the first set of missions (in awhile) that will push the bounds of exploration. This codebase could be the basis for software that could be used for future deep space missions or commercial space flights.

Thank you! :)

Any questions?

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Assignment 10 Article Review

This article touches upon modern rocket technology, emphasizing fears surrounding NASA's flight software. Author Christian Davenport points out how the Aerospace Safety Advisory Panel has brought up "great concern about the end-to-end integrated test capability...for flight software." There are multiple, separate labs running tests on specific subsets of the software, yet no integrated test appears to be scheduled. This modular form of testing may help locate subset-specific bugs, but the true effectiveness of the software is unknown unless there is end-to-end testing. Davenport also describes how similar testing was used for the Starliner program—testing that missed two bugs capable of causing a mission failure.

The matter is further complicated by the White House's acceleration of NASA's timeline, forcing engineers to develop the software as quickly as possible. Though not directly discussed by Davenport, this acceleration will likely increase the margin of error by reducing the time available for debugging and streamlining code.

Overall, it is quite clear that modular testing works when trying to clean subsets of code, but integrated testing is necessary to ensure the software works holistically. To maximize testing, there must be efficient management of time and a reasonable timeline must be given.

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