

Mountain View High School Aerospace & Aviation Club



SPACE LAUNCH SYSTEM

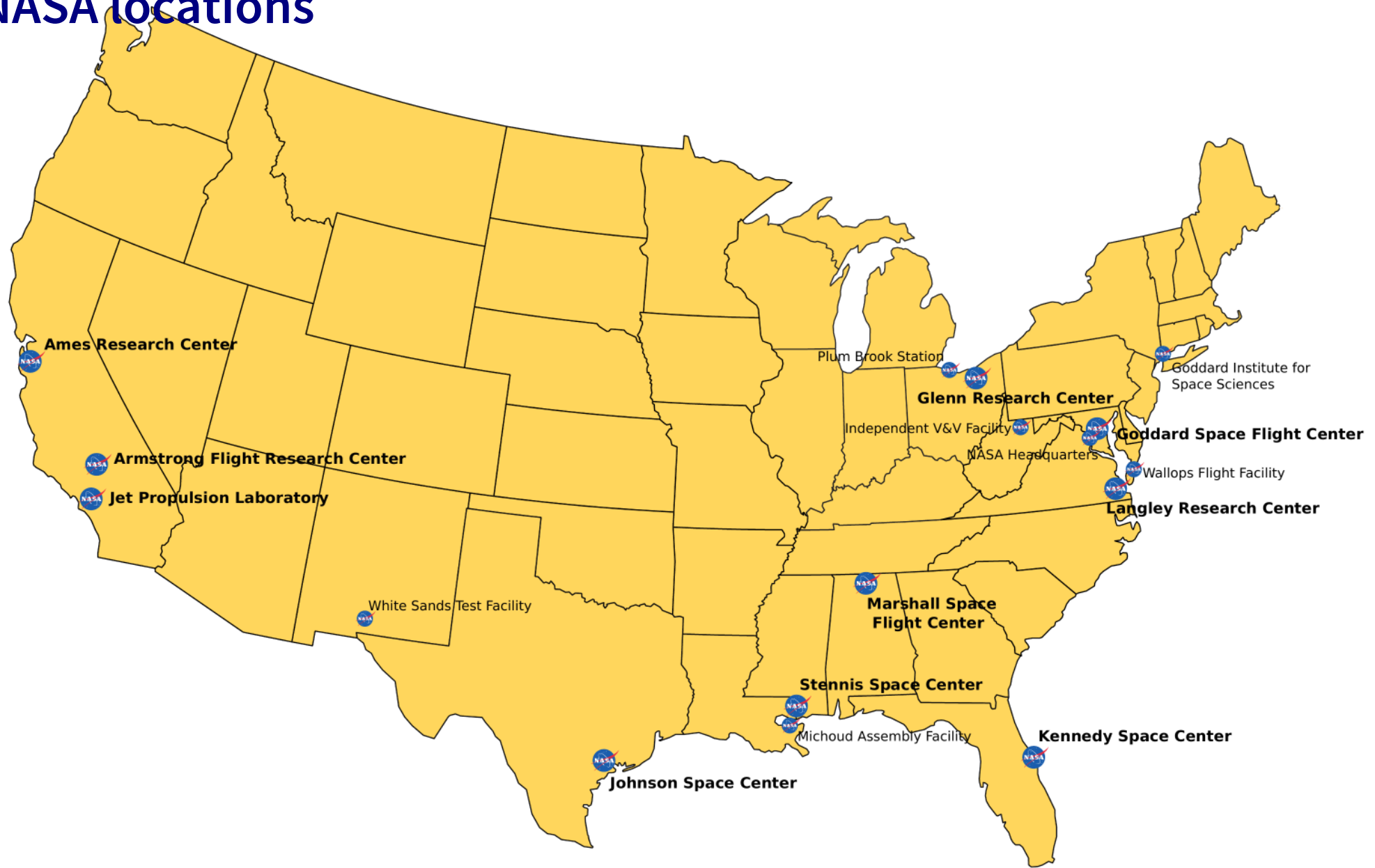
Tested, Proven,
Ready to Explore



Joshua F. Diaz

NASA Ames Computational Aerosciences

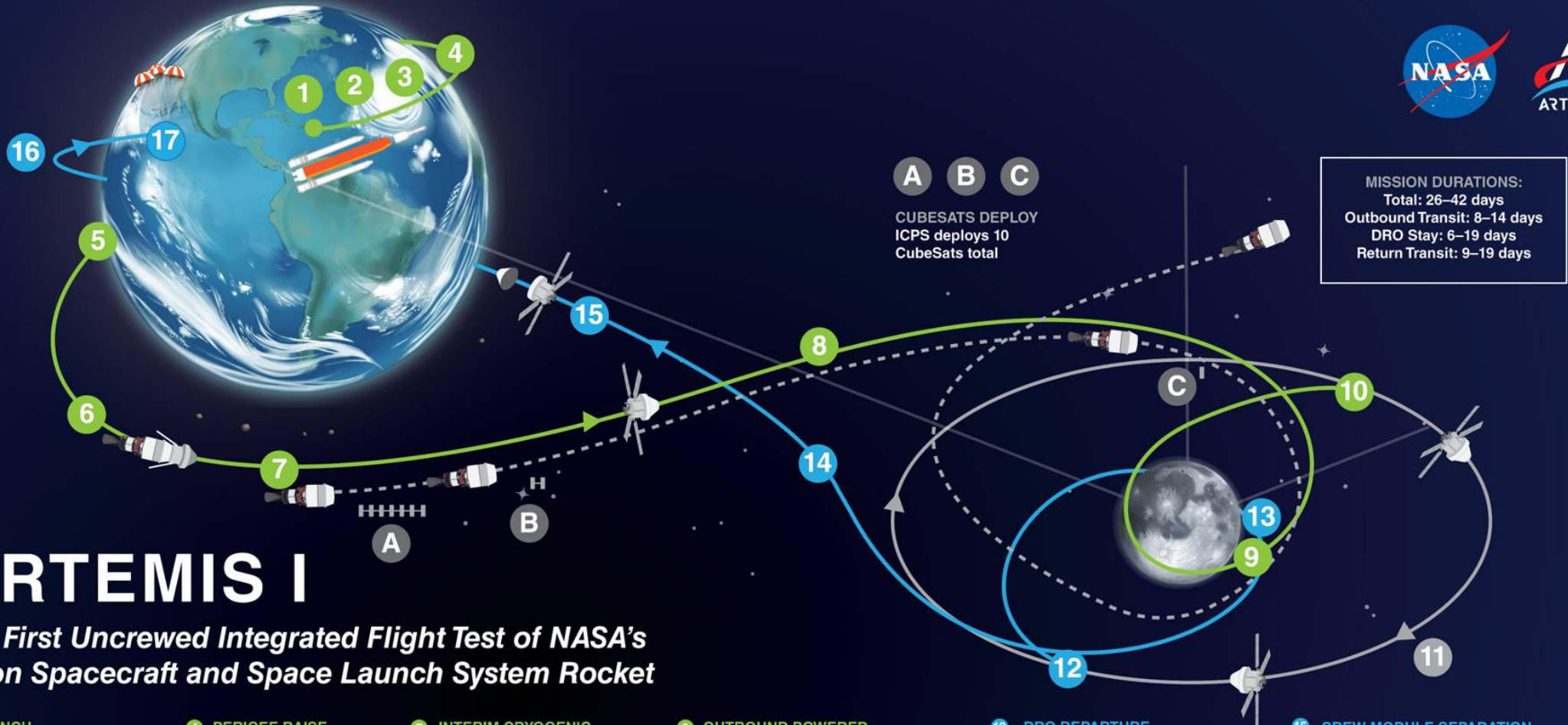
NASA locations





Artemis Missions

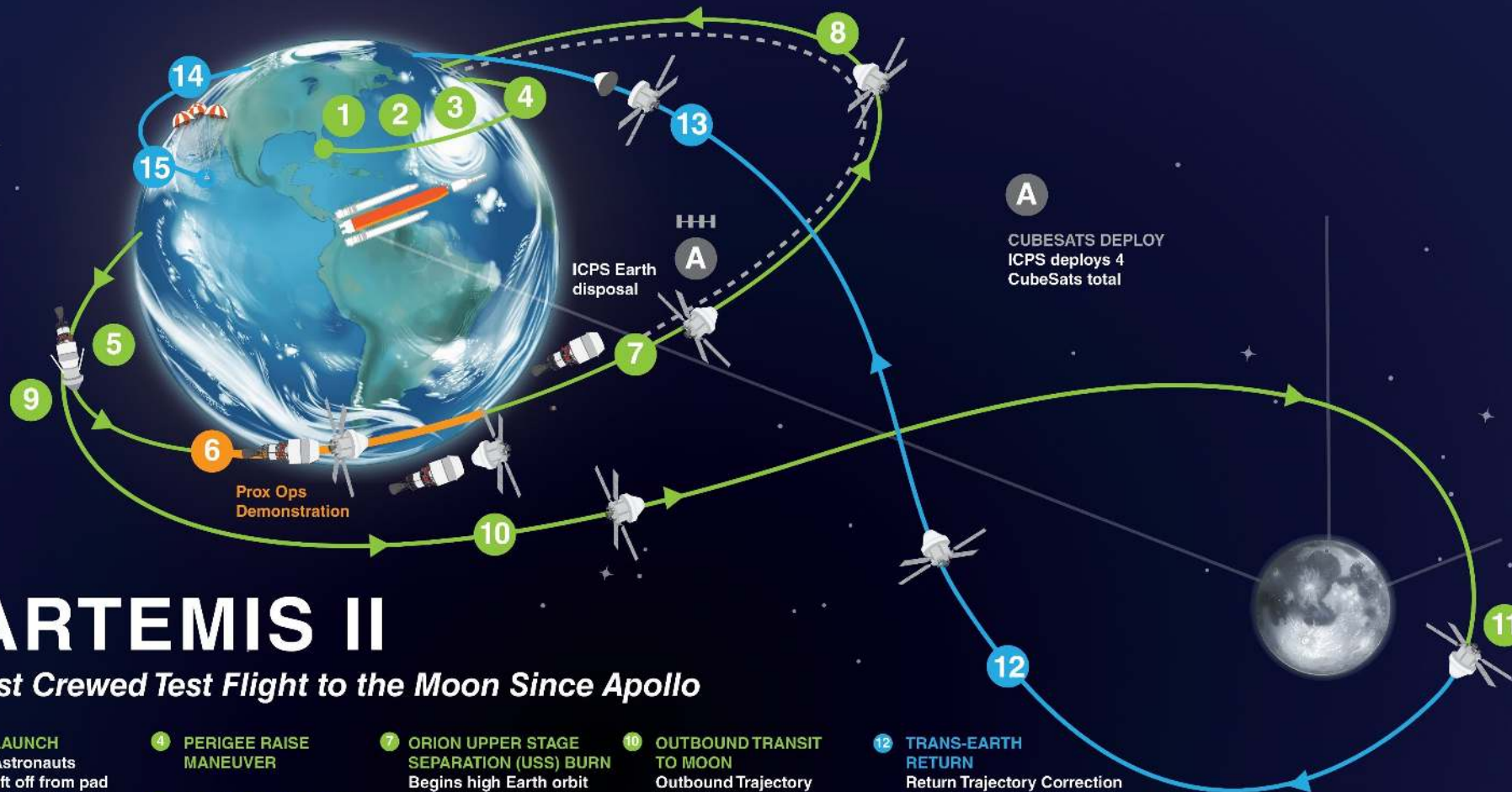
Collaborate with commercial and international partners to establish a long-term presence on the Moon.



ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

- 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 PERIGEE RAISE MANEUVER**
- 5 EARTH ORBIT**
Systems check with solar panel adjustments.
- 6 TRANS LUNAR INJECTION (TLI) BURN**
Maneuver lasts for approximately 20 minutes.
- 7 INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
ICPS commits Orion to moon at TLI.
- 8 OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS**
As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).
- 9 OUTBOUND POWERED FLYBY (OPF)**
60 nmi from the Moon; targets DRO insertion.
- 10 LUNAR ORBIT INSERTION**
Enter Distant Retrograde Orbit.
- 11 DISTANT RETROGRADE ORBIT**
Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.
- 12 DRO DEPARTURE**
Leave DRO and start return to Earth.
- 13 RETURN POWERED FLYBY (RPF)**
RPF burn prep and return coast to Earth initiated.
- 14 RETURN TRANSIT**
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.
- 15 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 16 ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.
- 17 SPLASHDOWN**
Pacific Ocean landing within view of the U.S. Navy recovery ship.



A
CUBESATS DEPLOY
ICPS deploys 4
CubeSats total

ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

- 1 LAUNCH**
Astronauts lift off from pad 39B at Kennedy Space Center.
- 2 JETTISON SOLID ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
- 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
- 4 PERIGEE RAISE MANEUVER**
- 5 APOGEE RAISE BURN TO HIGH EARTH ORBIT**
Begin 23.5 hour checkout of spacecraft.
- 6 ORION SEPARATION FROM INTERIM CRYOGENIC PROPULSION STAGE (ICPS) FOLLOWED BY PROX OPS DEMO**
Plus manual handling qualities assessment for up to 2 hours.
- 7 ORION UPPER STAGE SEPARATION (USS) BURN**
Begins high Earth orbit checkout. Life support, exercise, and habitation equipment evaluations.
- 8 PERIGEE RAISE BURN**
- 9 TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE**
Lunar free return trajectory initiated with European service module.
- 10 OUTBOUND TRANSIT TO MOON**
Outbound Trajectory Correction (OTC) burns as necessary for Lunar free return trajectory; travel time approximately 4 days.
- 11 LUNAR FLYBY**
6,479 miles (mean) lunar farside altitude.
- 12 TRANS-EARTH RETURN**
Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.
- 13 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 14 ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.
- 15 SPLASHDOWN**
Ship recovers astronauts and capsule.

PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE	
1	9
2	10
3	11
4	12
5	13
6	14
7	15
8	16
	17

Artemis II Crew



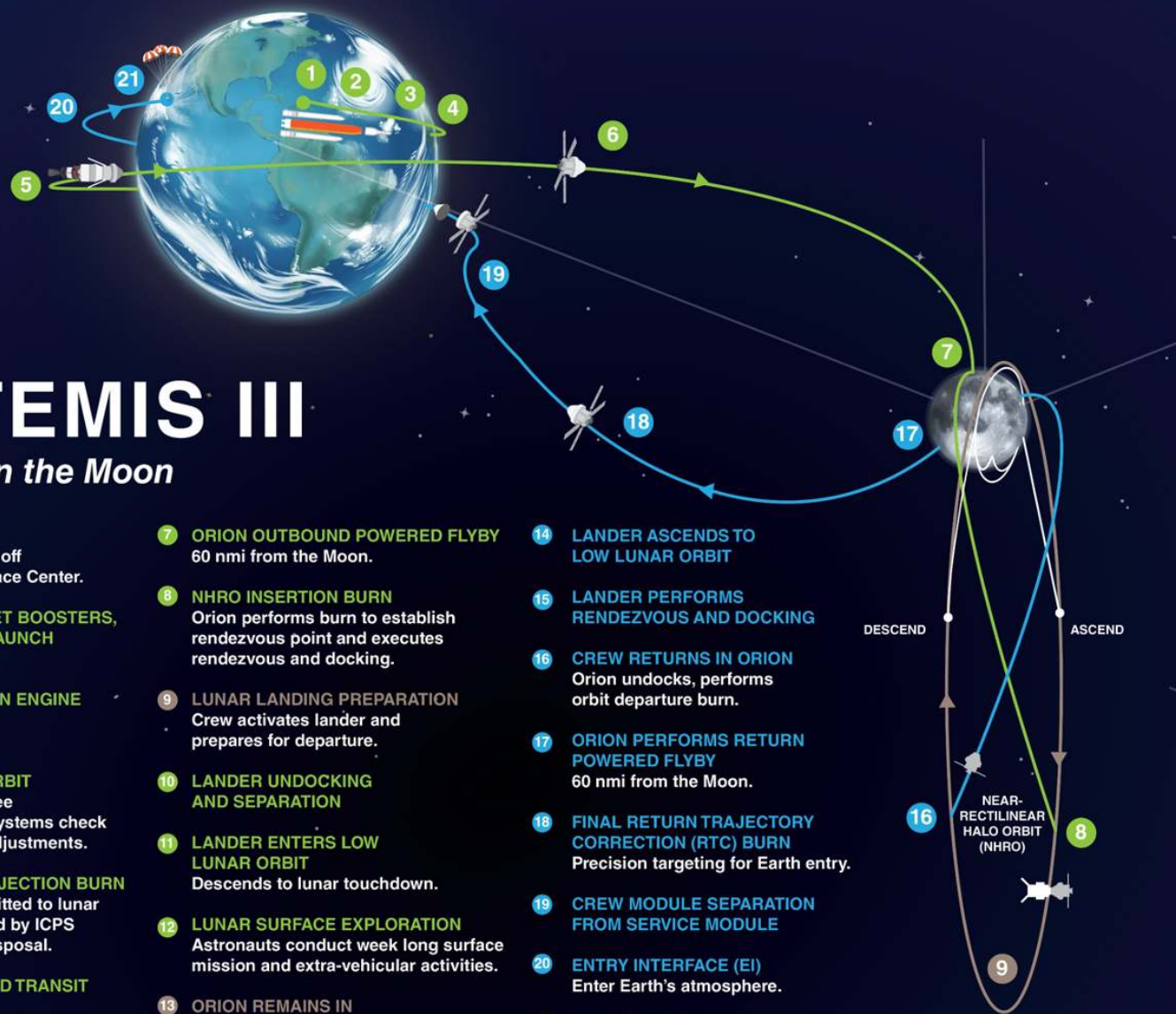
Victor Glover

Christina Koch

Jeremy Hansen

Reid Wiseman

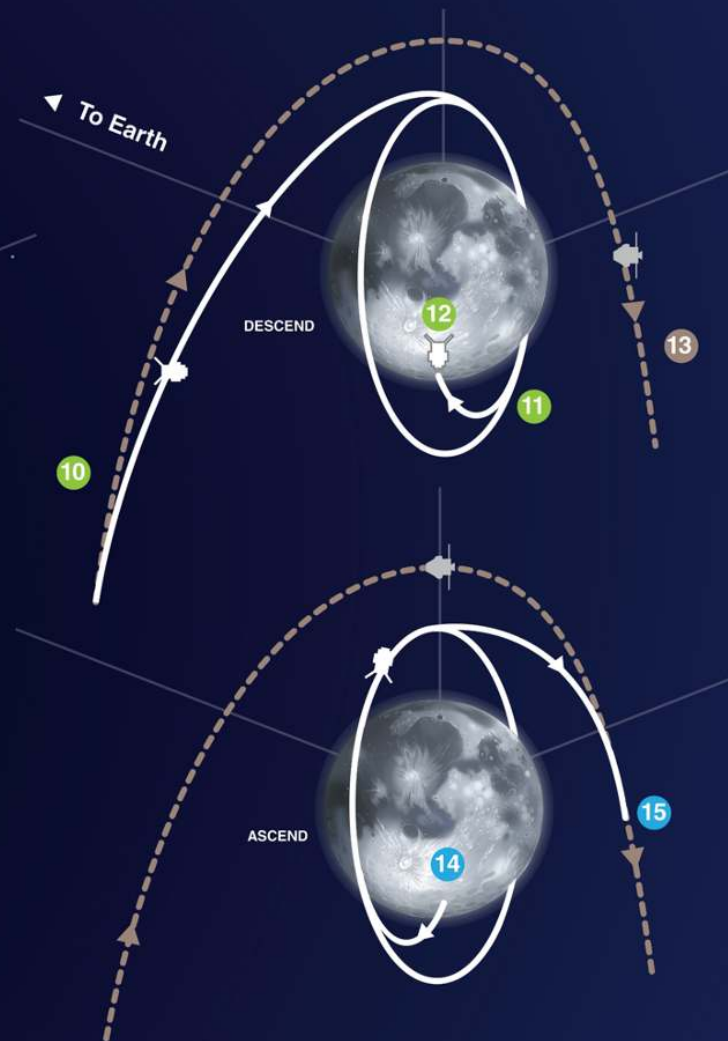




ARTEMIS III

Landing on the Moon

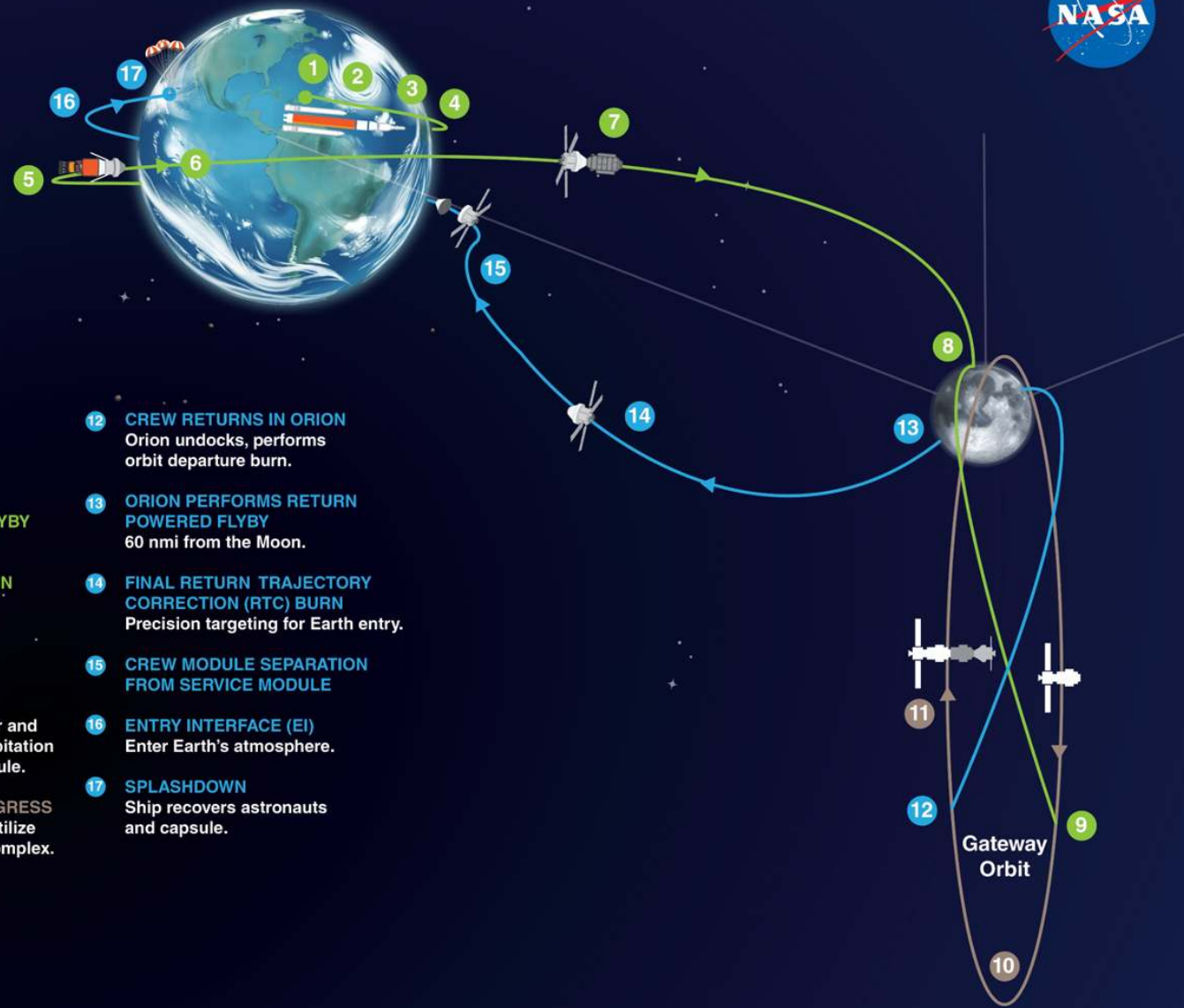
- 1 LAUNCH**
SLS and Orion lift off from Kennedy Space Center.
- 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
- 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
- 4 ENTER EARTH ORBIT**
Perform the perigee raise maneuver. Systems check and solar panel adjustments.
- 5 TRANS LUNAR INJECTION BURN**
Astronauts committed to lunar trajectory, followed by ICPS separation and disposal.
- 6 ORION OUTBOUND TRANSIT TO MOON**
Requires several outbound trajectory burns.
- 7 ORION OUTBOUND POWERED FLYBY**
60 nmi from the Moon.
- 8 NHRO INSERTION BURN**
Orion performs burn to establish rendezvous point and executes rendezvous and docking.
- 9 LUNAR LANDING PREPARATION**
Crew activates lander and prepares for departure.
- 10 LANDER UNDOCKING AND SEPARATION**
- 11 LANDER ENTERS LOW LUNAR ORBIT**
Descends to lunar touchdown.
- 12 LUNAR SURFACE EXPLORATION**
Astronauts conduct week long surface mission and extra-vehicular activities.
- 13 ORION REMAINS IN NHRO ORBIT**
During lunar surface mission.
- 14 LANDER ASCENDS TO LOW LUNAR ORBIT**
- 15 LANDER PERFORMS RENDEZVOUS AND DOCKING**
- 16 CREW RETURNS IN ORION**
Orion undocks, performs orbit departure burn.
- 17 ORION PERFORMS RETURN POWERED FLYBY**
60 nmi from the Moon.
- 18 FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
Precision targeting for Earth entry.
- 19 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 20 ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.
- 21 SPLASHDOWN**
Ship recovers astronauts and capsule



ARTEMIS IV

International Habitation Module delivery to Gateway

- 1 LAUNCH**
SLS with I-HAB payload and crewed Orion lift-off from Kennedy Space Center.
- 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
- 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
- 4 ENTER EARTH ORBIT**
Exploration Upper Stage performs circularization of Low Earth Orbit. Systems check and solar panel adjustments.
- 5 TRANS LUNAR INJECTION BURN**
Exploration Upper Stage commits Astronauts in Orion and I-HAB to lunar trajectory.
- 6 ORION TUGS I-HAB TO MOON**
Orion separation from USA, docking with I-HAB and extraction from USA followed by Orion tug of I-HAB to NRHO and EUS disposal.
- 7 ORION OUTBOUND TRANSIT TO MOON**
Requires several outbound trajectory burns.
- 8 ORION OUTBOUND POWERED FLYBY**
60 nmi from the Moon.
- 9 GATEWAY ORBIT INSERTION BURN**
Orion performs burn to establish rendezvous point and executes rendezvous and docking.
- 10 INTERNATIONAL HABITATION MODULE ARRIVAL AT GATEWAY**
I-HAB docking with Orion to Power and Propulsion Element (PPE) and Habitation and Logistic Outpost (HALO) module.
- 11 I-HAB ACTIVATION AND CREW INGRESS**
Astronauts ingress, activate and utilize I-HAB as part of larger Gateway complex.
- 12 CREW RETURNS IN ORION**
Orion undocks, performs orbit departure burn.
- 13 ORION PERFORMS RETURN POWERED FLYBY**
60 nmi from the Moon.
- 14 FINAL RETURN TRAJECTORY CORRECTION (RTC) BURN**
Precision targeting for Earth entry.
- 15 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 16 ENTRY INTERFACE (EI)**
Enter Earth's atmosphere.
- 17 SPLASHDOWN**
Ship recovers astronauts and capsule.



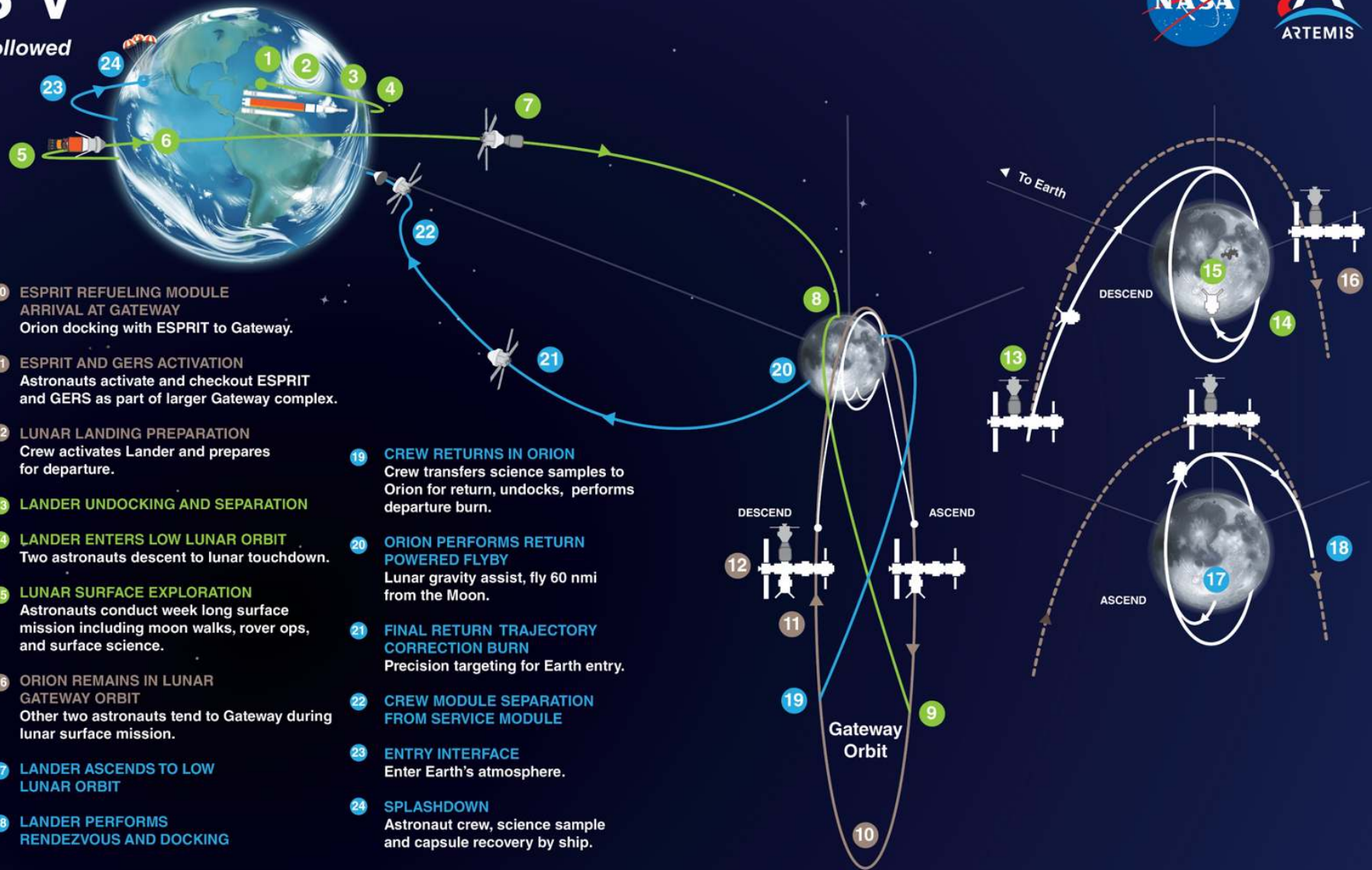
ARTEMIS V

ESPRIT delivery to Gateway followed by Crewed Lunar Landing

- 1 LAUNCH**
SLS with ESPRIT payload and crewed Orion lift-off from Kennedy Space Center.
- 2 JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
- 3 CORE STAGE MAIN ENGINE CUT OFF**
With separation.
- 4 ENTER EARTH ORBIT**
Exploration Upper Stage performs circularization of Low Earth Orbit. Systems check and solar panel adjustments.
- 5 TRANS LUNAR INJECTION BURN**
Exploration Upper Stage commits Astronauts in Orion and ESPRIT to lunar trajectory.
- 6 ORION TUGS ESPRIT TO MOON**
Orion separation from USA, docking with ESPRIT and extraction from USA followed by Orion tug of ESPRIT to Gateway orbit and EUS disposal.
- 7 ORION OUTBOUND TRANSIT TO MOON**
Perform periodic outbound trajectory correction maneuvers.
- 8 ORION OUTBOUND POWERED FLYBY**
Lunar gravity assist, fly 60 nmi from the Moon.
- 9 GATEWAY ORBIT INSERTION BURN**
Orion performs burn to establish rendezvous point and executes rendezvous.

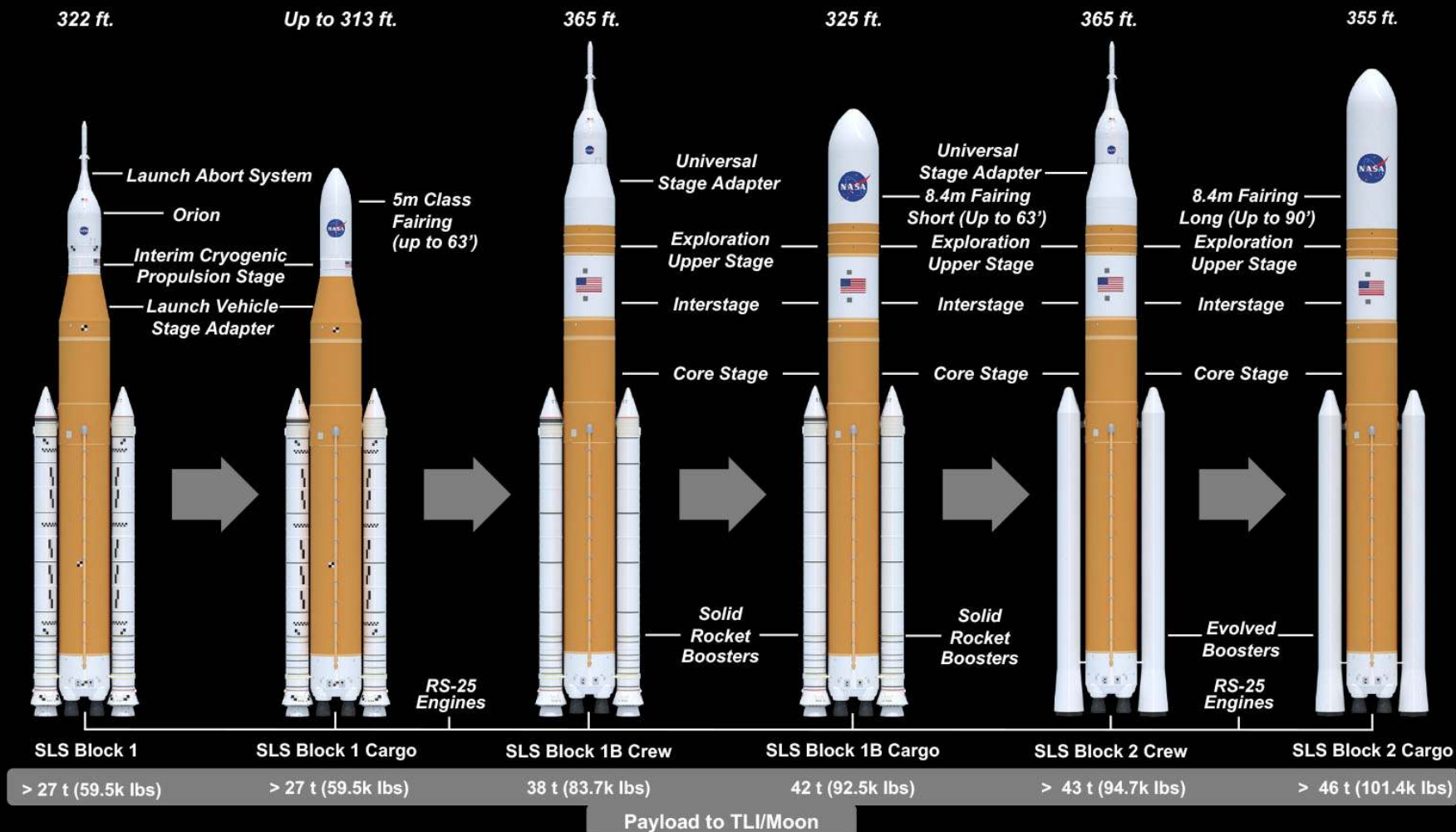
- 10 ESPRIT REFUELING MODULE ARRIVAL AT GATEWAY**
Orion docking with ESPRIT to Gateway.
- 11 ESPRIT AND GERS ACTIVATION**
Astronauts activate and checkout ESPRIT and GERS as part of larger Gateway complex.
- 12 LUNAR LANDING PREPARATION**
Crew activates Lander and prepares for departure.
- 13 LANDER UNDOCKING AND SEPARATION**
- 14 LANDER ENTERS LOW LUNAR ORBIT**
Two astronauts descent to lunar touchdown.
- 15 LUNAR SURFACE EXPLORATION**
Astronauts conduct week long surface mission including moon walks, rover ops, and surface science.
- 16 ORION REMAINS IN LUNAR GATEWAY ORBIT**
Other two astronauts tend to Gateway during lunar surface mission.
- 17 LANDER ASCENDS TO LOW LUNAR ORBIT**
- 18 LANDER PERFORMS RENDEZVOUS AND DOCKING**

- 19 CREW RETURNS IN ORION**
Crew transfers science samples to Orion for return, undocks, performs departure burn.
- 20 ORION PERFORMS RETURN POWERED FLYBY**
Lunar gravity assist, fly 60 nmi from the Moon.
- 21 FINAL RETURN TRAJECTORY CORRECTION BURN**
Precision targeting for Earth entry.
- 22 CREW MODULE SEPARATION FROM SERVICE MODULE**
- 23 ENTRY INTERFACE**
Enter Earth's atmosphere.
- 24 SPLASHDOWN**
Astronaut crew, science sample and capsule recovery by ship.



SLS EVOLVABILITY

FOUNDATION FOR A GENERATION OF DEEP SPACE EXPLORATION



Artemis Launch Environments

Stage 2:

- Near-vacuum
- Separation events



Booster separation:

- Many dimensions
- 10k or more sims



Abort:

- Can happen at any time
- Chemistry is important
- Highly unsteady

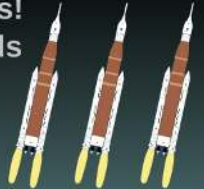
Ascent (steady):

- Relatively simple CFD
- But do it 1000+ times!
- Wide range of speeds



Ascent (unsteady):

- Buffet, acoustics
- Mostly wind-tunnel



Ascent (aerothermal)

- Predict heating
- Separate sims



Subsonic abort

Lift-off:

- High energy!
- Multi-phase
- (Water, throat plug...)
- Acoustics



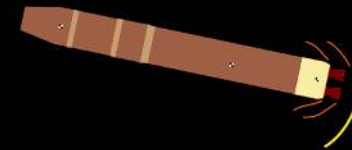
Pad abort

Pre-launch:

- High winds
- (Hurricane Nicole?)
- Vehicle only held at 10 points

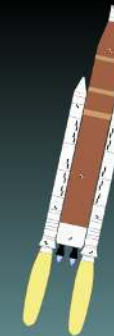
Core Stage Reentry

- Predict debris
- In a different ocean



Headless Stack

- Similar to CS reentry
- Upper stage present
- Descent or reentry

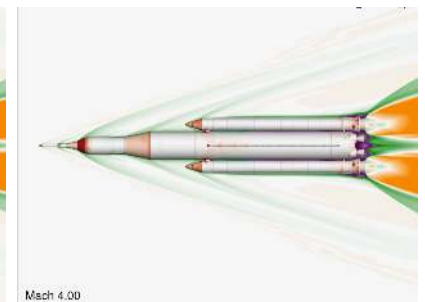
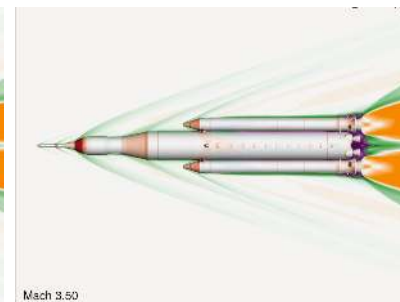
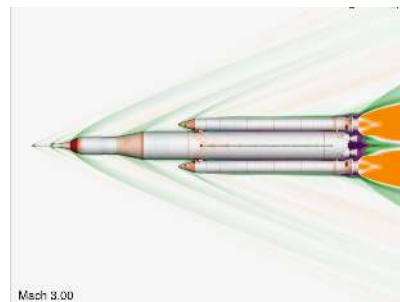
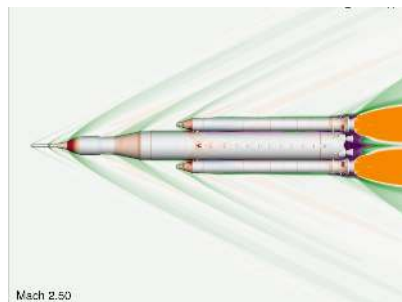
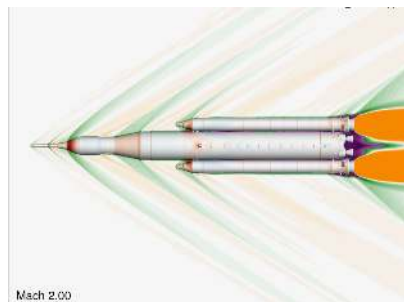
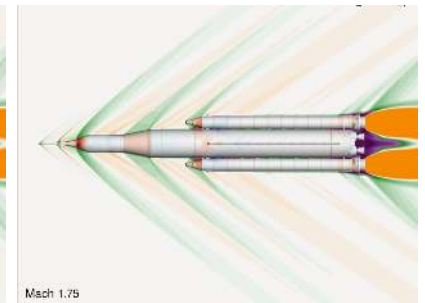
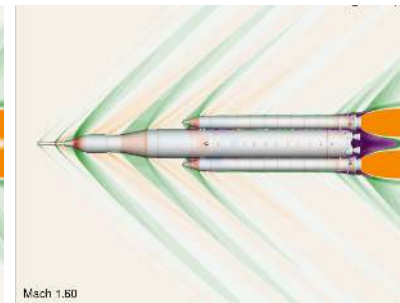
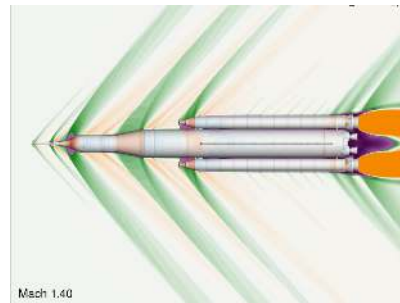
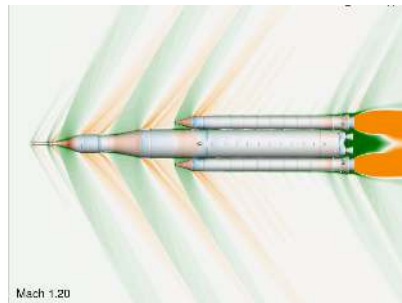
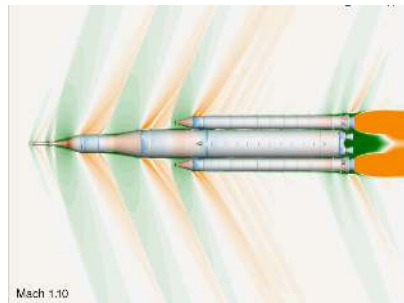
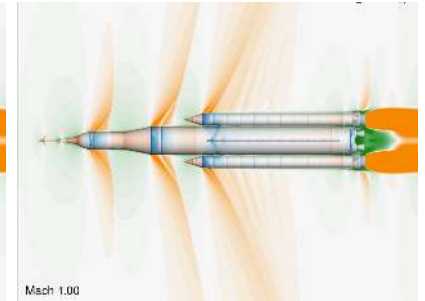
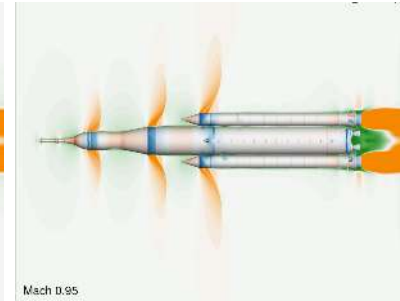
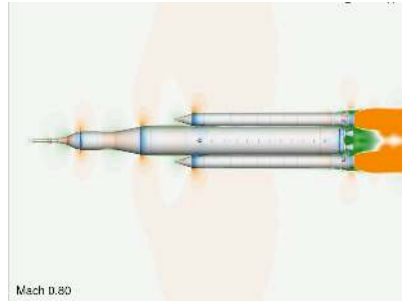
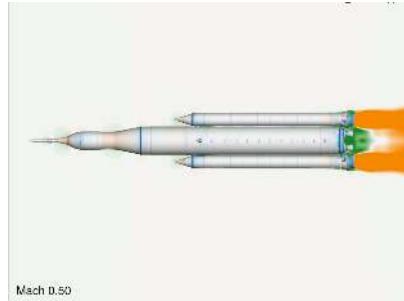


Booster Descent

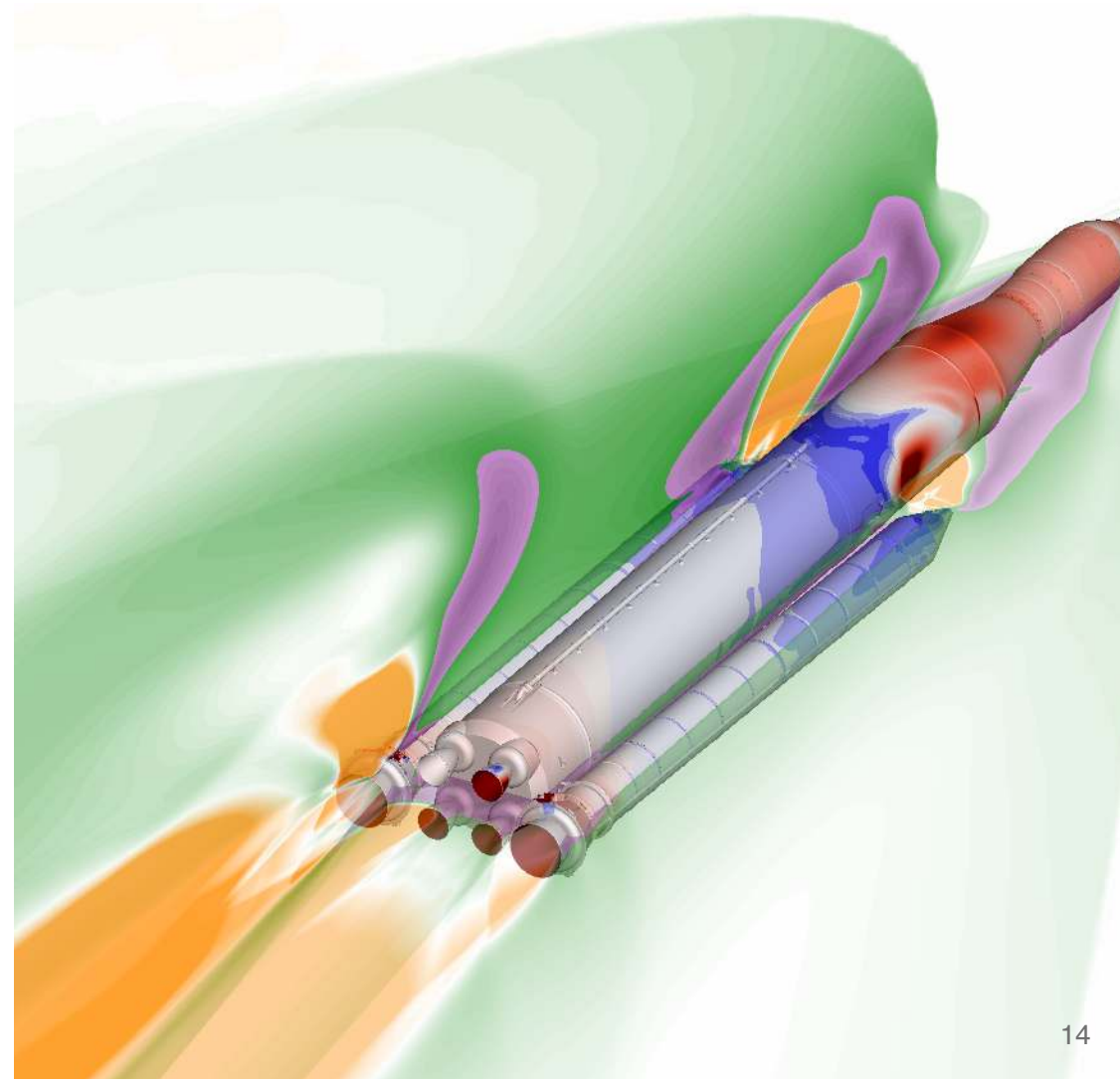
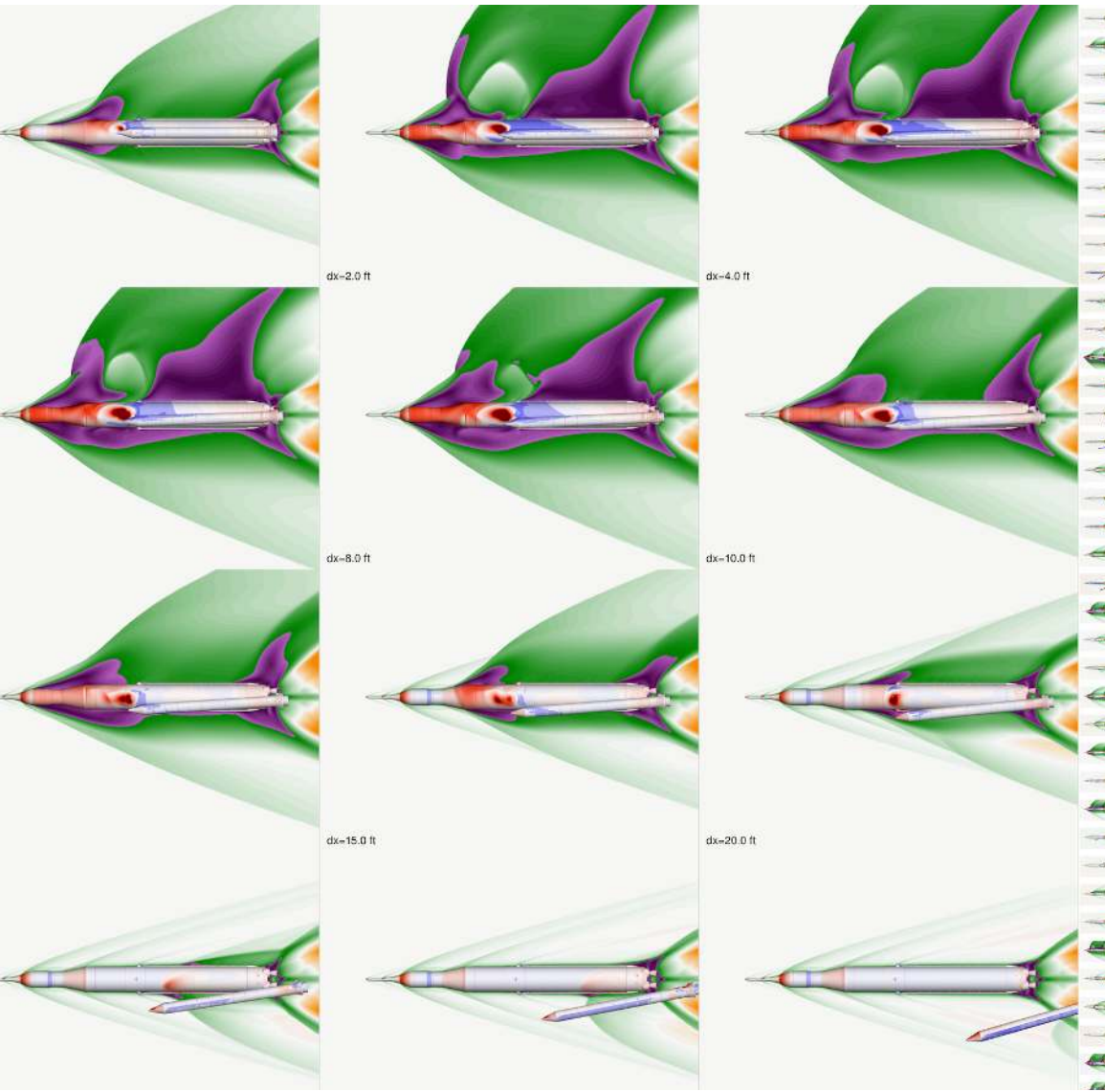
- SRBs not recovered
- Predict impact in ocean



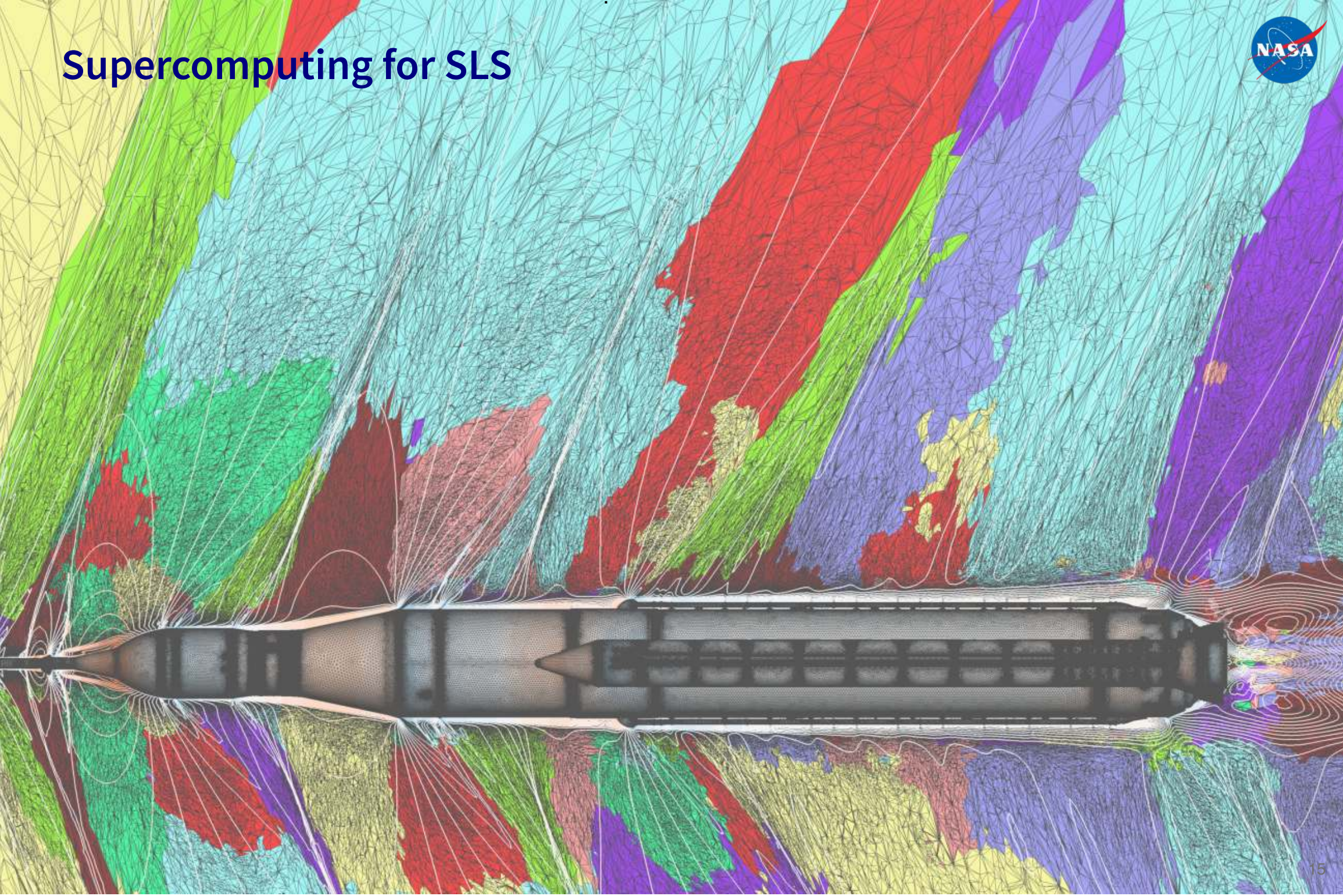
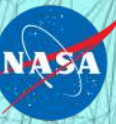
Ascent (steady)



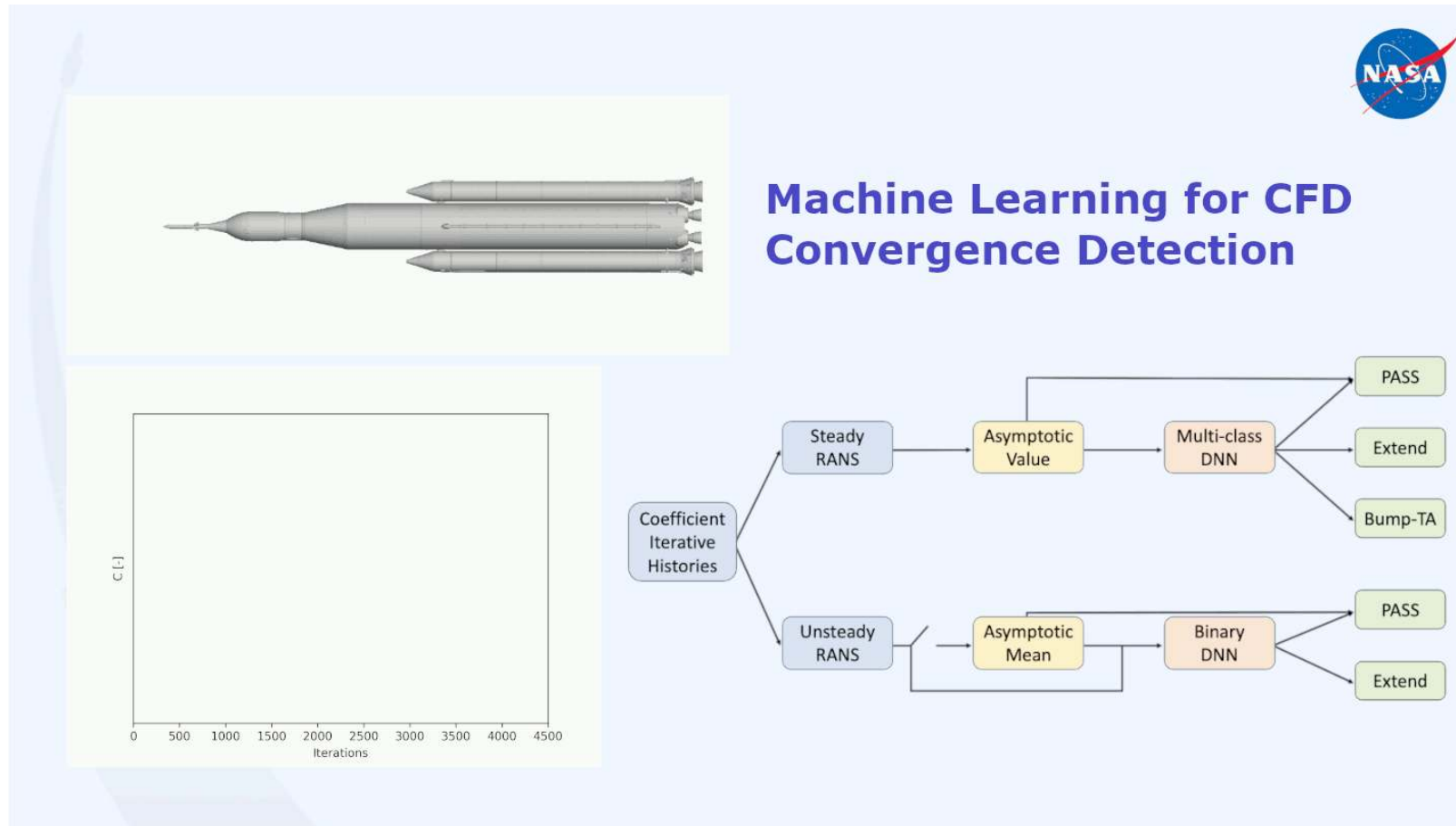
Booster Separation



Supercomputing for SLS



Automating Workflow - PYCNIC





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