



Low-Earth Orbit Flight Test
of an Inflatable Decelerator

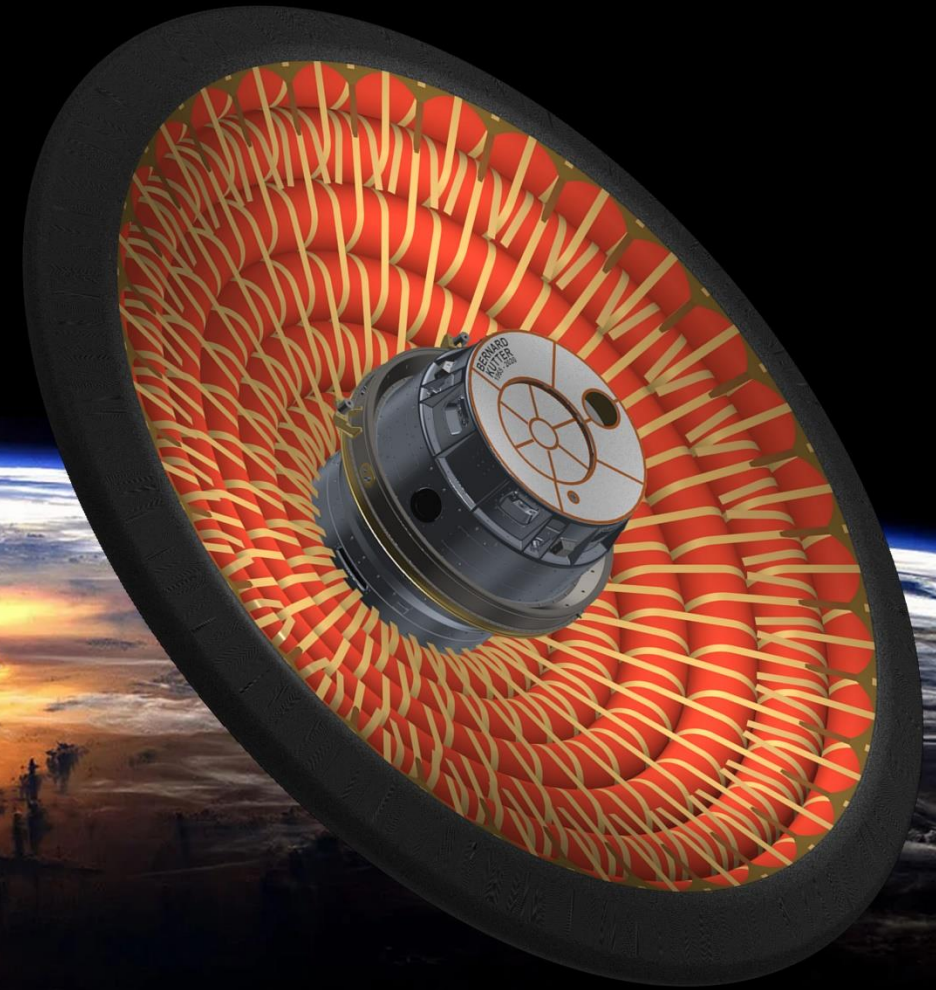
National Aeronautics and
Space Administration



Flight Mechanics Analysis of Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID)

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NASA Langley Research Center



AFM-12: Low-Earth Orbit Flight Test of an Inflatable Decelerator II: Flight Sciences (Invited)
AIAA SciTech Forum
January 10, 2024



Background



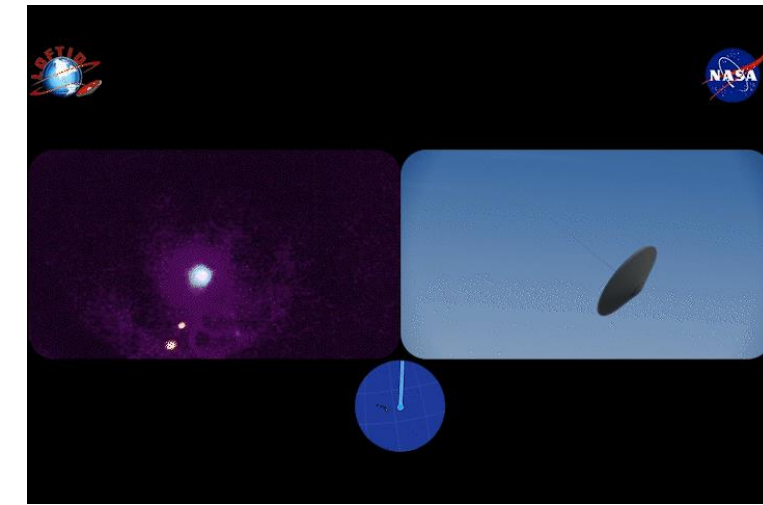
- **Low-Earth Orbit Flight Test of an Inflatable Decelerator (LOFTID) successfully conducted entry, descent, and landing of the largest aeroshell to-date (6m)**



Nov 10, 2022 launch at Vandenberg Space Force Base as secondary payload on Atlas V



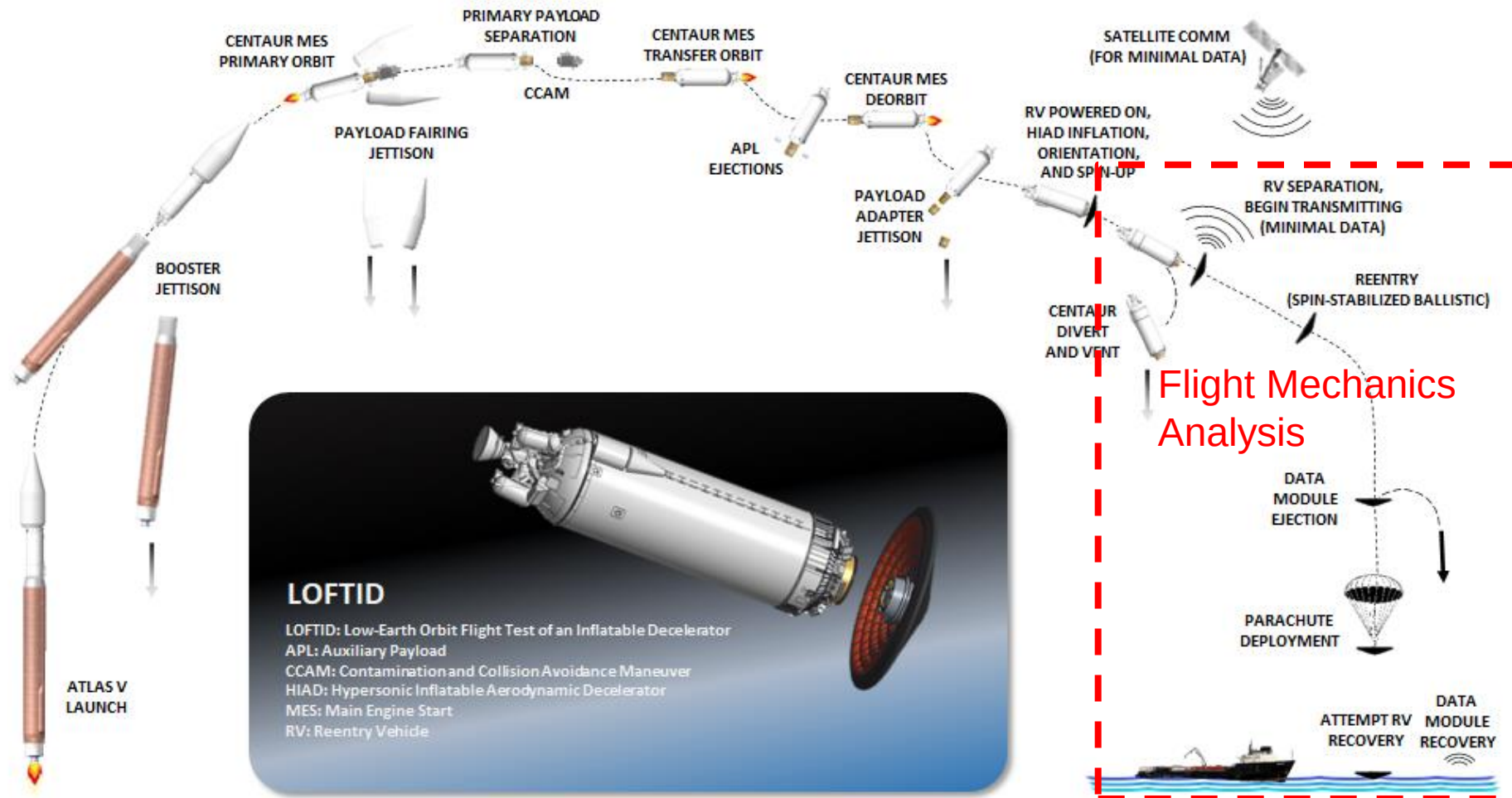
Successful inflation of the 6m diameter aeroshell



Successful EDL sequence and splashdown ~2 hrs after launch

Motivation

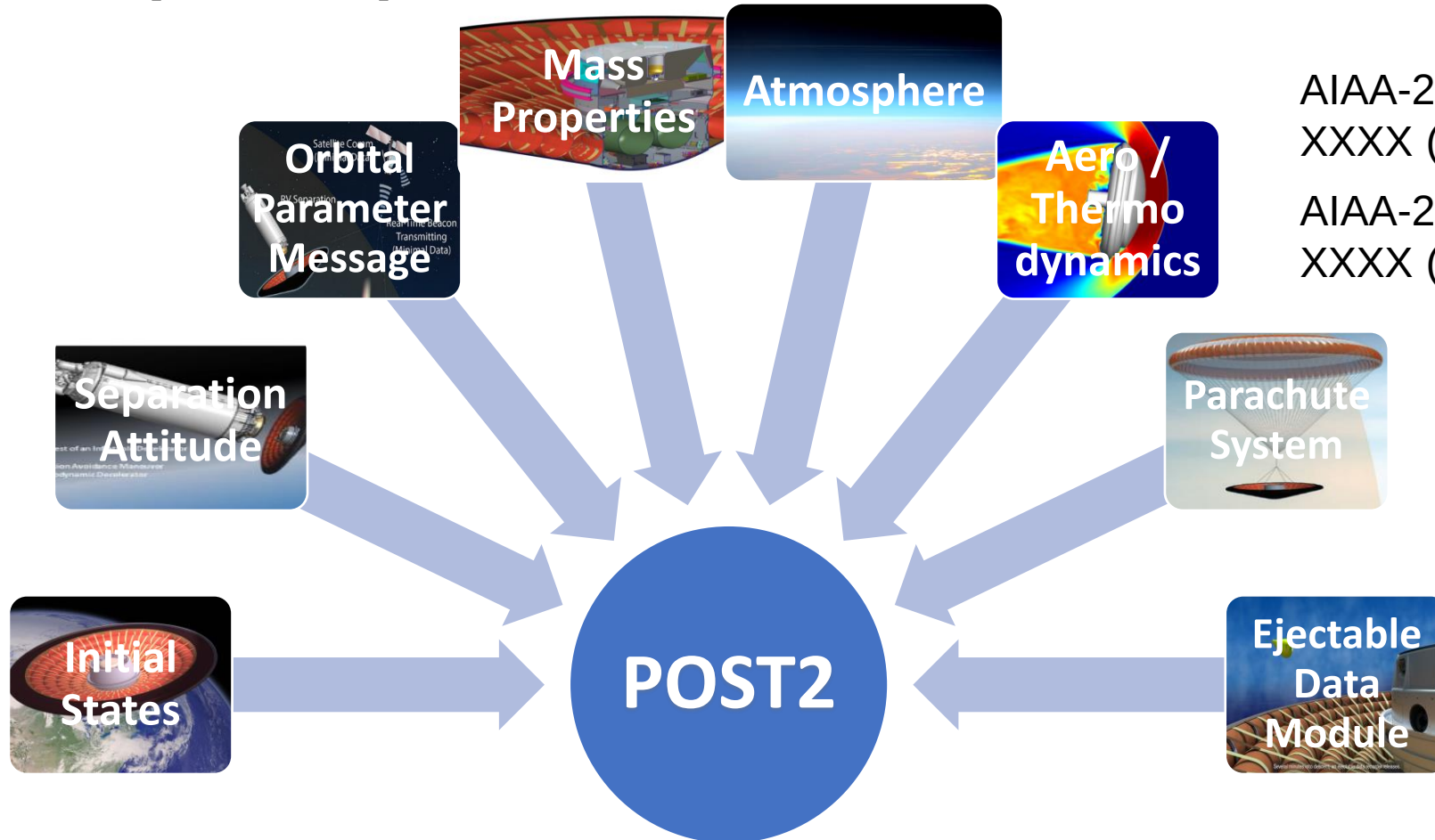
- **Objective: Present flight mechanics processes after RV separation that support flight operations of LOFTID**





Trajectory Simulation Modeling

➤ Flight Mechanics modeling using Program to Optimize Simulated Trajectories II (POST2)



AIAA-2024-XXXX (Korzun)

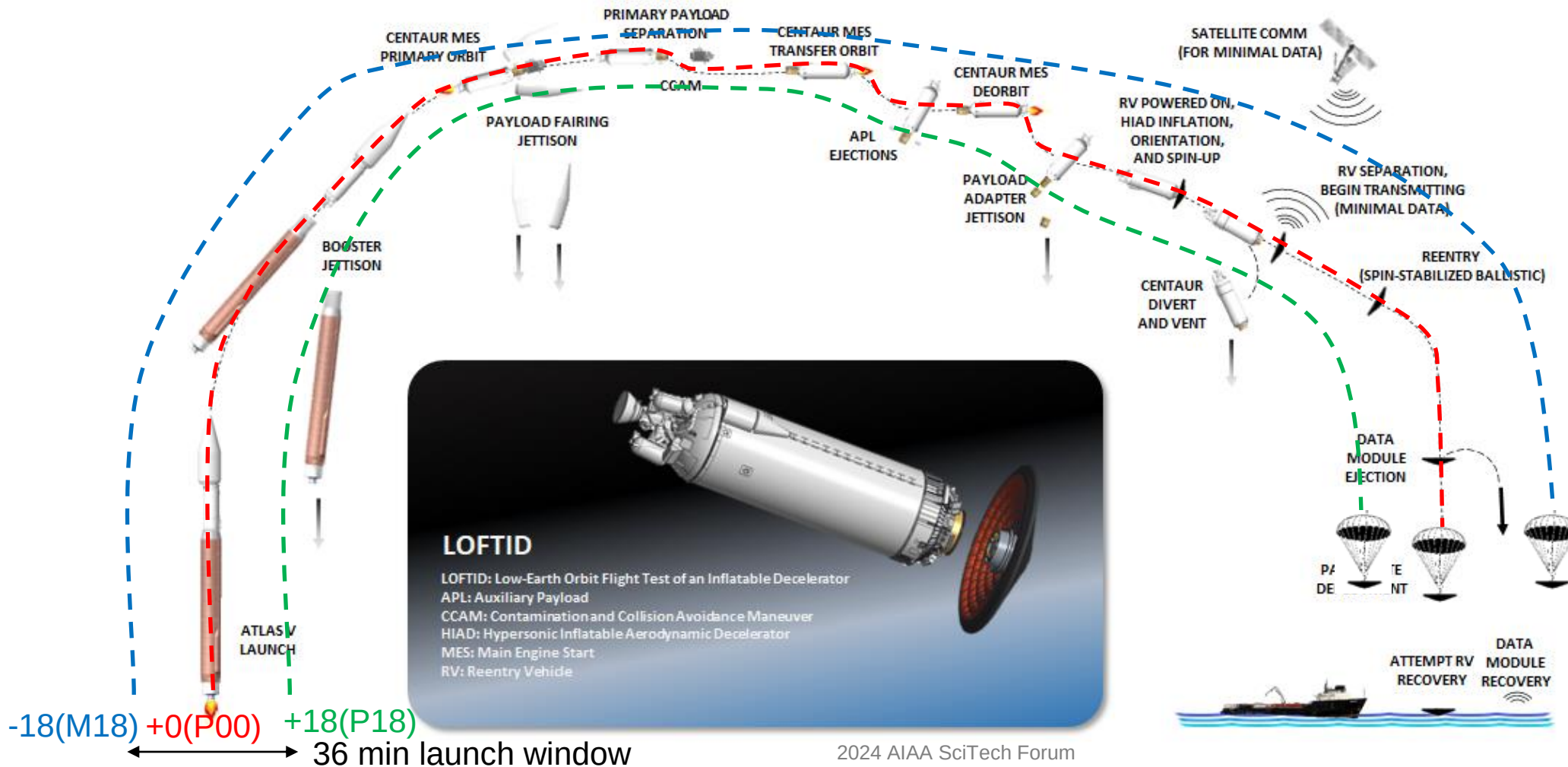
AIAA-2024-XXXX (Hollis)

AIAA-2024-XXXX (Tobin)



Pre-Launch Trajectory Analysis

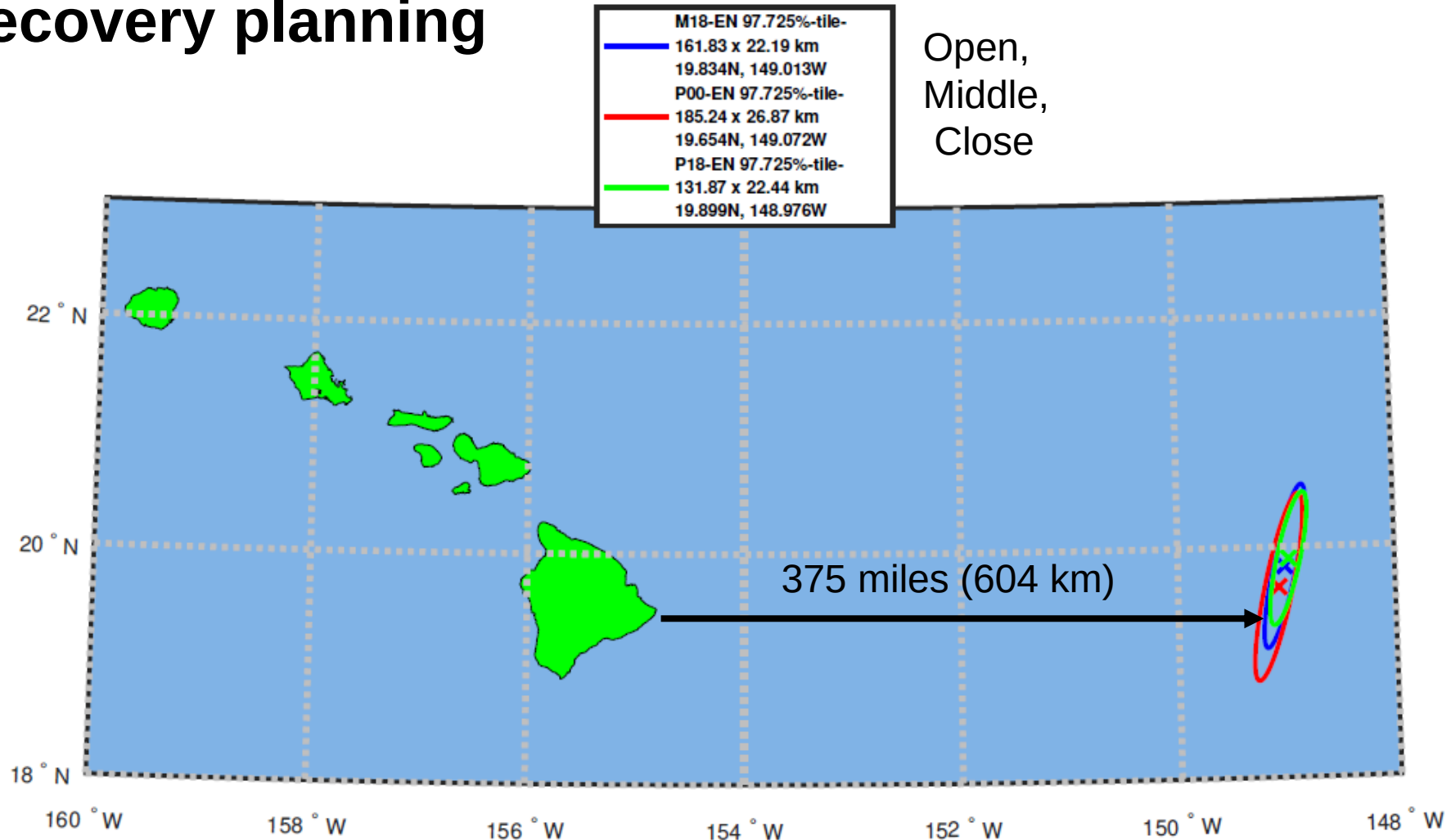
- Analyze potential trajectories over 36 minute launch window (**open**, **middle**, **close**)





Pre-Launch Trajectory Analysis

- **Splashdown ellipses provide landing prediction region that were used in recovery planning**





Pre-Launch Trajectory Analysis

Open Middle Close

Spin-up: 3 RPM

Entry Interface

Altitude: 125 km

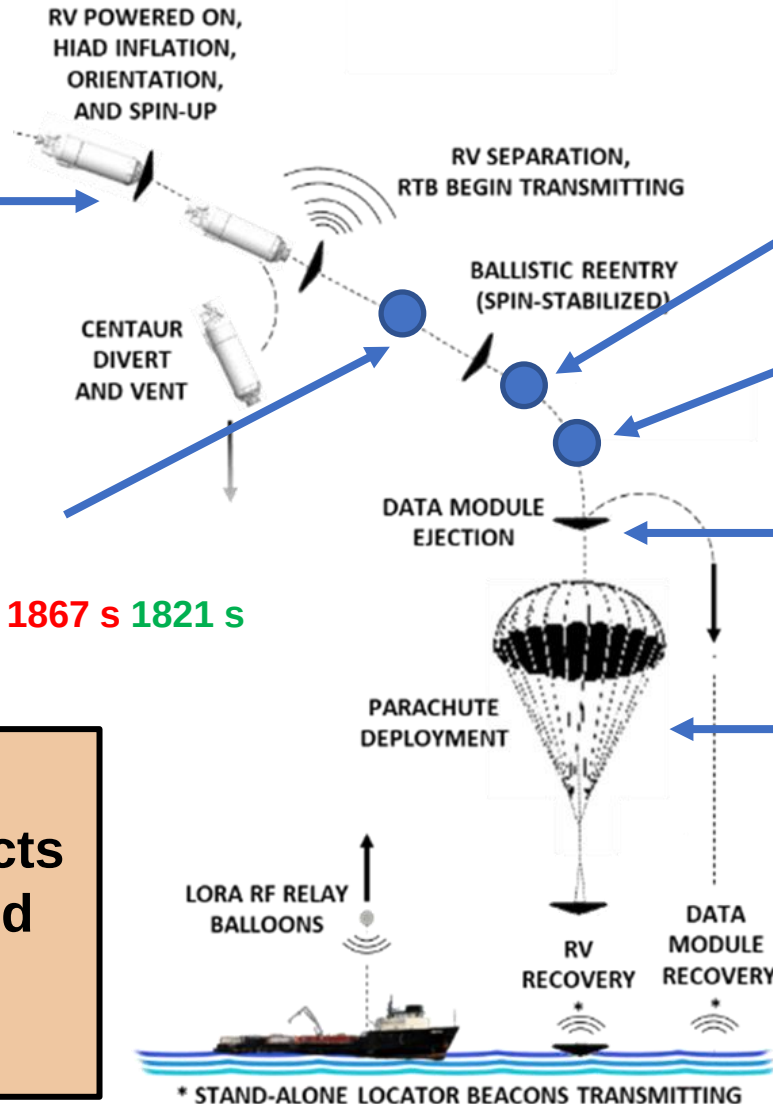
Velocity: 8.02 km/s

Flight Path Angle: -2.28 deg

Elapsed Time from RV Sep: 1818 s 1867 s 1821 s

Main Takeaway:

- Launch window affects mission timeline used during operations



See paper for full results from analysis

Peak Total Heat Flux @ Nose: 40.5 W/cm²

Peak Deceleration: 9.6 G's

Data Module Ejection: 2260 s since RV Sep

Altitude: 15.9 km 19.5 km 16.0 km

Mach: 0.23 0.32 0.24

Parachute Deploy: 2509 s since RV Sep

Altitude: 5.08 km 6.73 km 5.16 km

Total Angle of Attack: 4.73 deg 4.66 deg 4.74 deg

Splashdown:

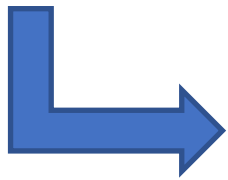
Elapsed Time from Entry: 1520 s 1724 s 1531 s

Vertical Velocity: 6.55 m/s



Operations Planning

- **Pre-launch trajectory analysis provided information needed for mission timeline and recovery preparation**
 - Completed 3 months prior to launch
- **Improvements to LOFTID flight mechanics tools**
 1. Integration of forecast atmosphere model
 2. Trajectory prediction automation

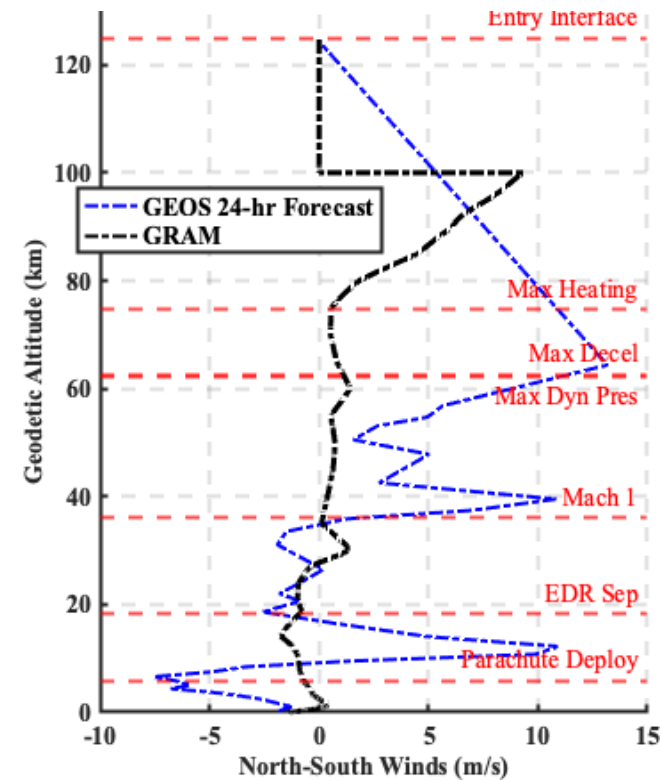
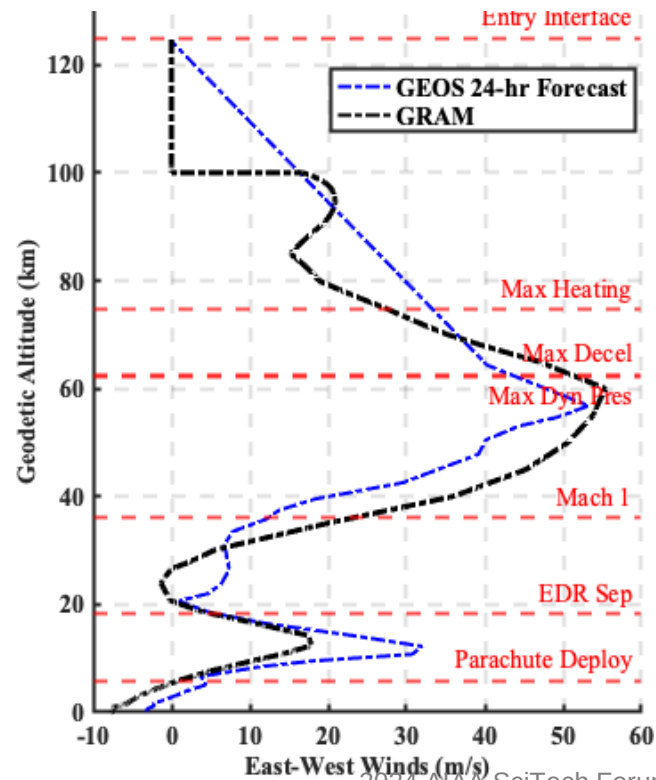
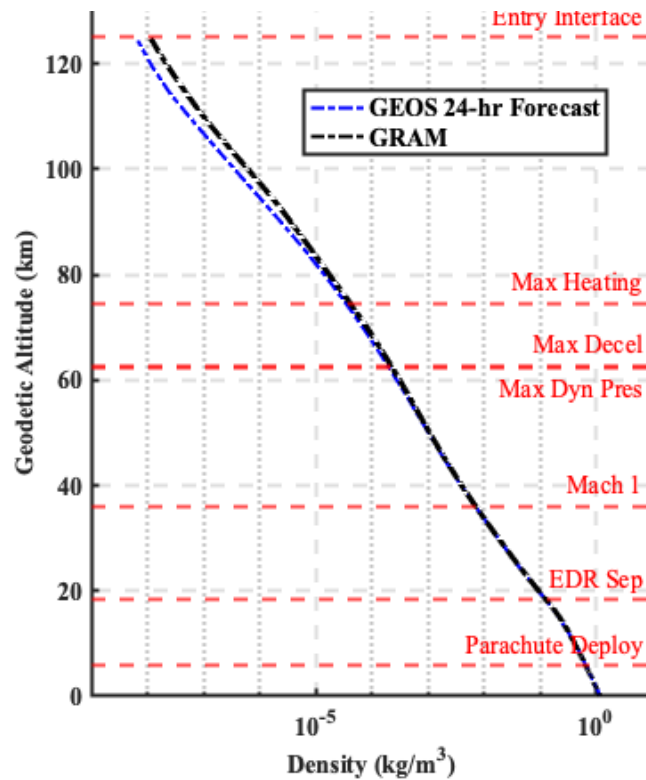


Improvements will allow for more accurate trajectory predictions and the ability to rapidly produce and send trajectory predictions to LOFTID launch support and recovery boat into place



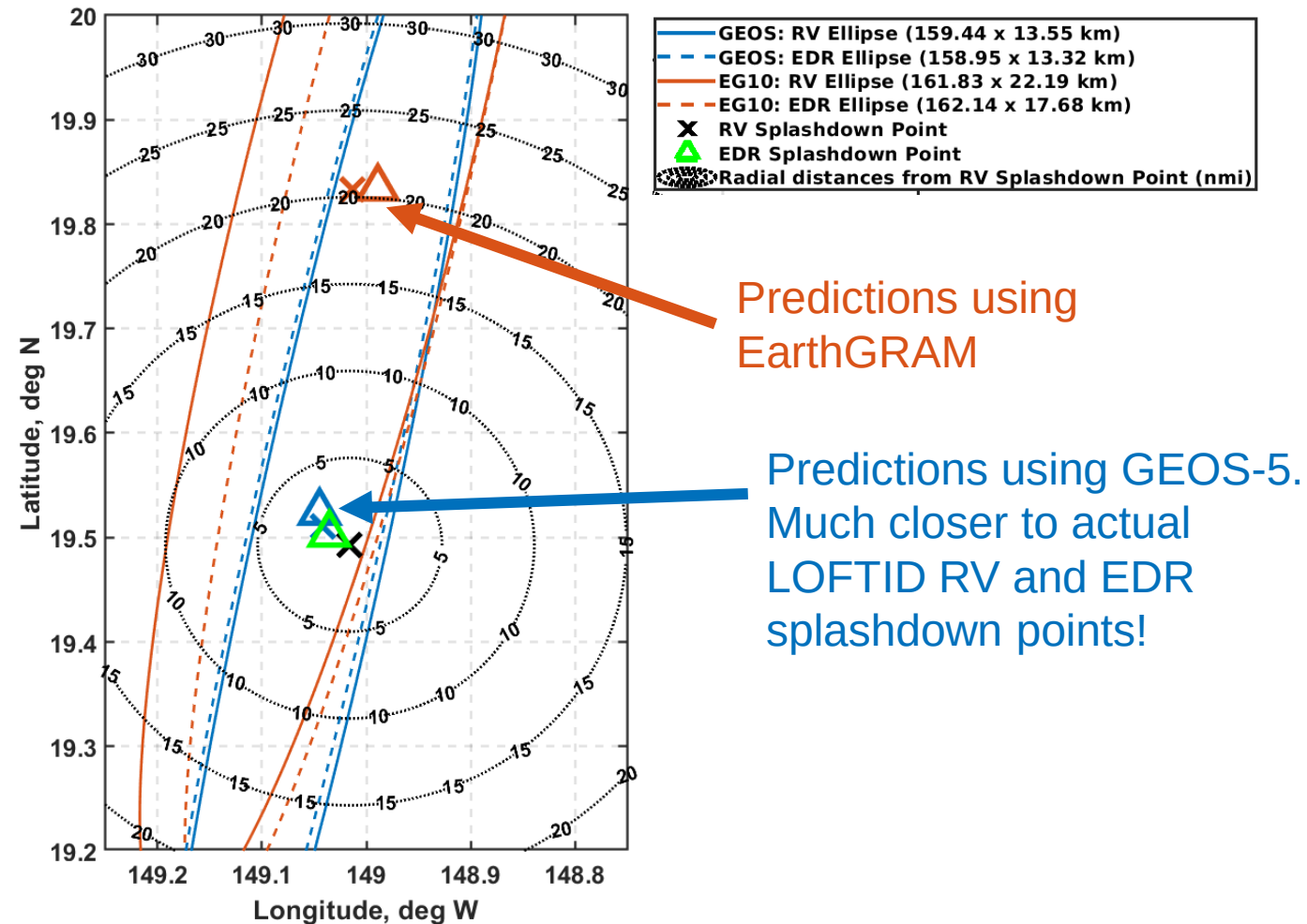
Atmosphere Forecasting

- EarthGRAM is an engineering atmosphere model sufficient for pre-launch analysis
- Goddard Earth Observing System (GEOS-5) provides weather forecast over splashdown region



Atmosphere Forecasting

➤ GEOS-5 model serves to improve prediction of splashdown points



Trajectory Automation

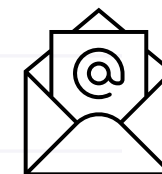
➤ Utilize Jenkins to script running of trajectory

- Automate daily checkout/runs of GEOS forecasts
- Automate day-of-launch trajectory predications

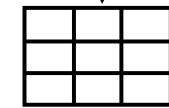
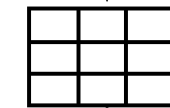
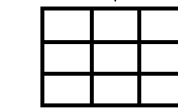


W	Name ↓	Last Success	Last Failure	Last Duration
🌞				sec
🌞				
🌞				
🌞				
🌞				
🌞	6_Generate_Monte_Carlo_Products	11 mo #658	1 yr 4 mo #238	11 min

Jenkins Dashboard



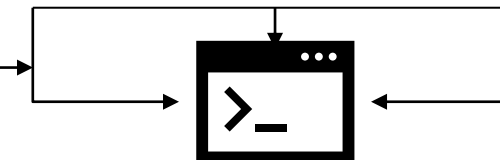
Receive Orbital
Parameter
Message



Tables



Terminal



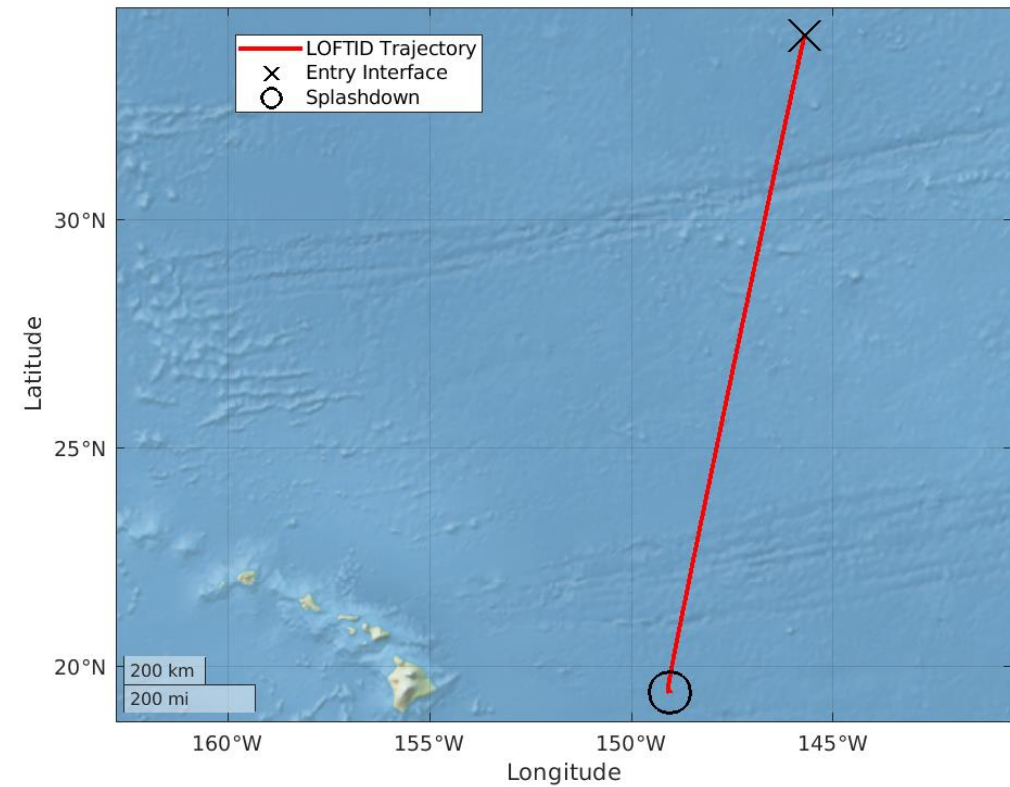
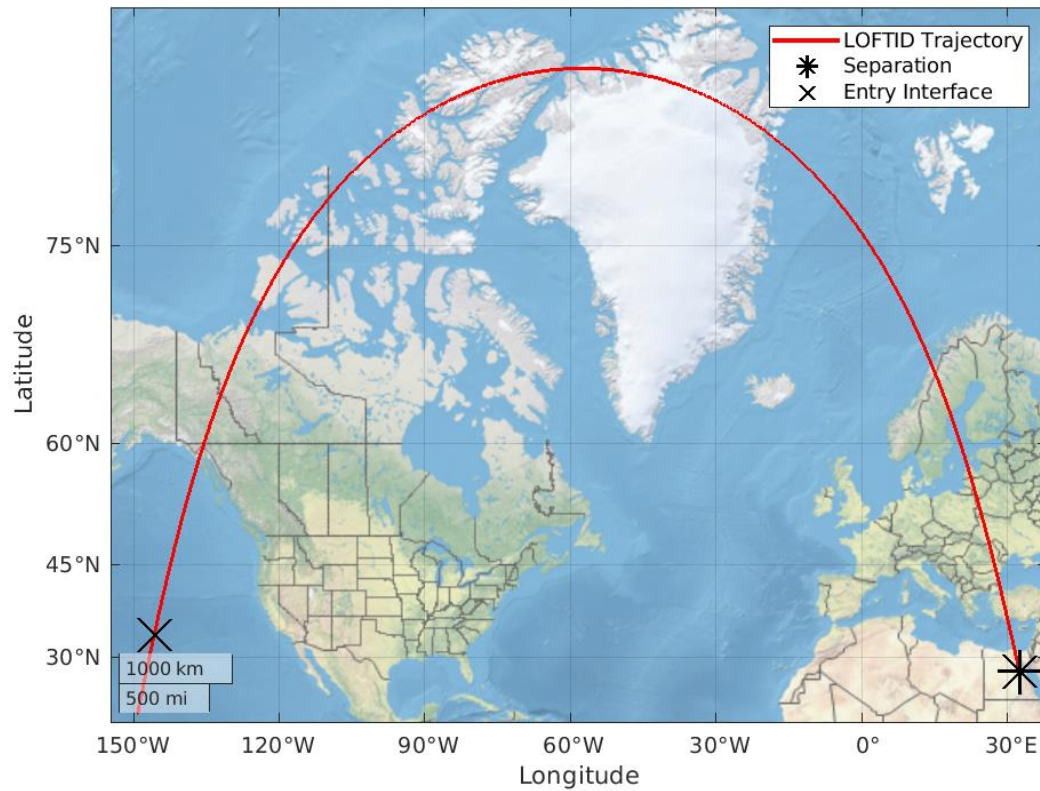
Run Sim

Generate
Results Package



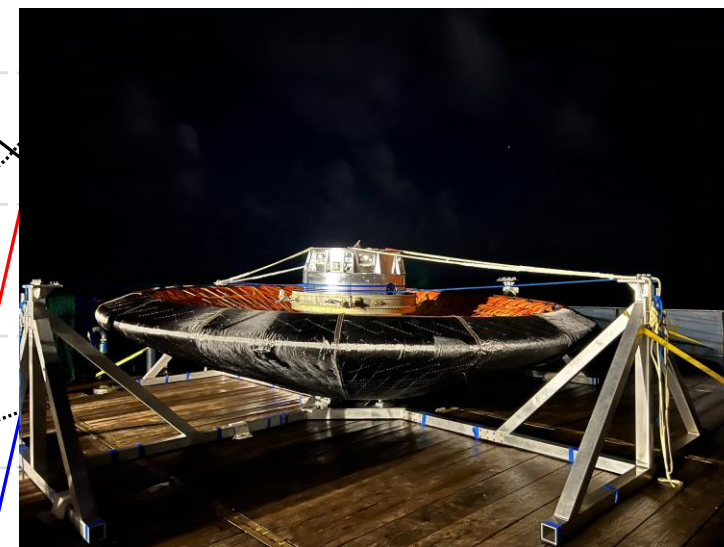
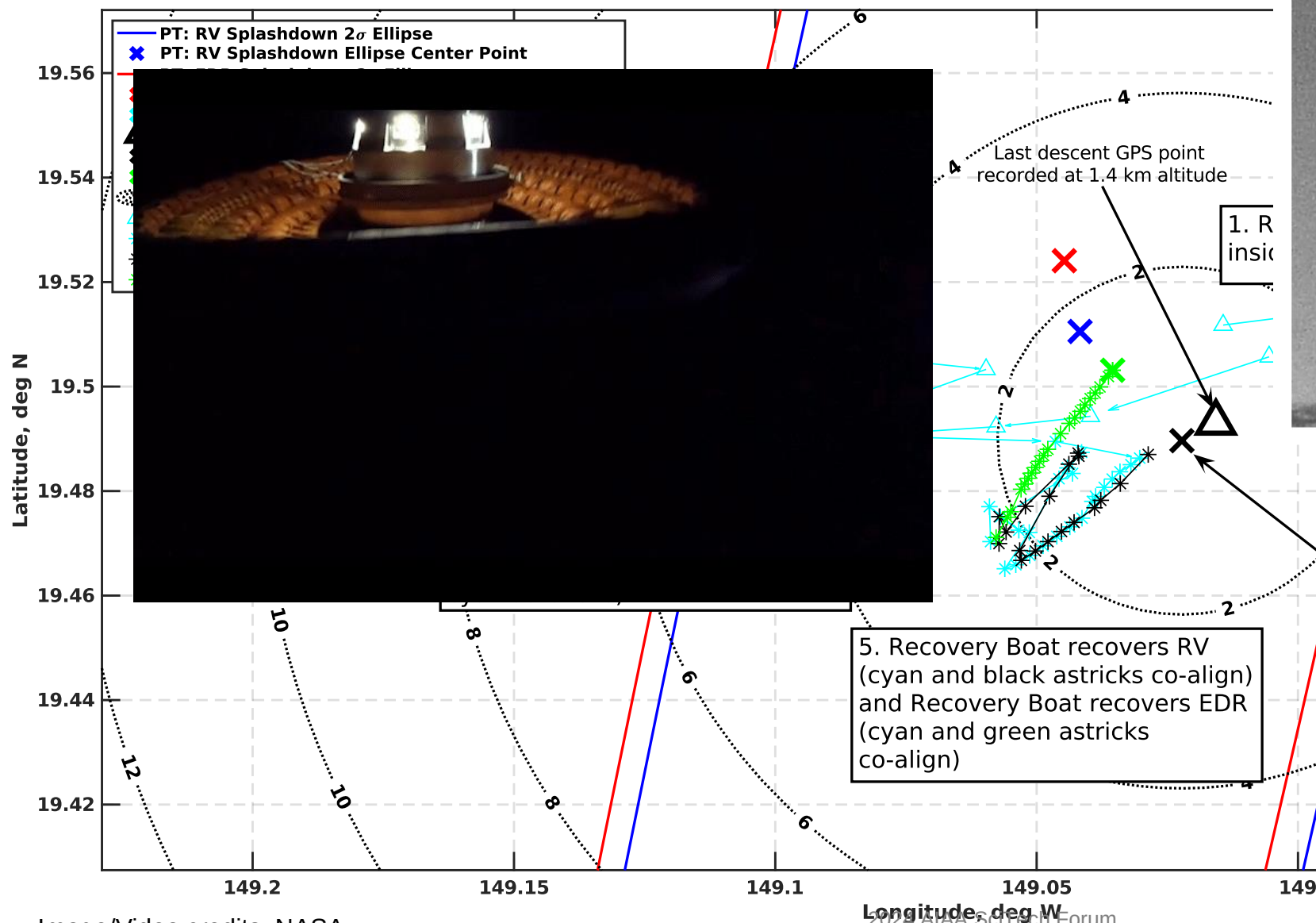
Day-of-Launch Performance

➤ LOFTID trajectory ground track





Day-of-Launch Performance



Summary

- **LOFTID mission was a success safely surviving re-entry and meeting mission requirements**
- **Pre-launch trajectory analysis facilitated launch operation mission planning and recovery**
- **Integration of atmosphere forecasting allowed for more accurate day-of-flight trajectory predictions**
- **Integration of automation allowed for more flexibility in mission operations support**
- **Next talk will discuss LOFTID post-flight trajectory reconstruction**



Image credit: Greg Swanson (NASA)



Backup





Trajectory Simulation Modeling

➤ Flight Mechanics modeling using Program to Optimize Simulated Trajectories II (POST2)

Ask Raf to generate
POST2 graphics for
this chart

Ejectable Data Module
(LaRC)

Parachute System
(Airborne Systems)

Aerothermodynamics
(LaRC)

Initial State & Uncertainty
(KSC LSP)

Separation Attitude
(ULA)

Orbital Parameter Message
(ULA)

LOFTID Aerodynamics
(LaRC)

Mass Properties
(LaRC)

Atmosphere
(MSFC, GSFC)

Flight Mechanics Simulation Tool

Program to Optimize
Simulated Trajectories II
(POST2)

AIAA-2024-XXXX (Korzun)

AIAA-2024-XXXX (Hollis)

AIAA-2024-XXXX (Tobin)

GSFC: NASA Goddard Space Flight Center
KSC LSP: NASA Kennedy Space Center Launch Service Provider
LaRC: NASA Langley Research Center
MSFC: NASA Marshall Space Flight Center
ULA: United Launch Alliance