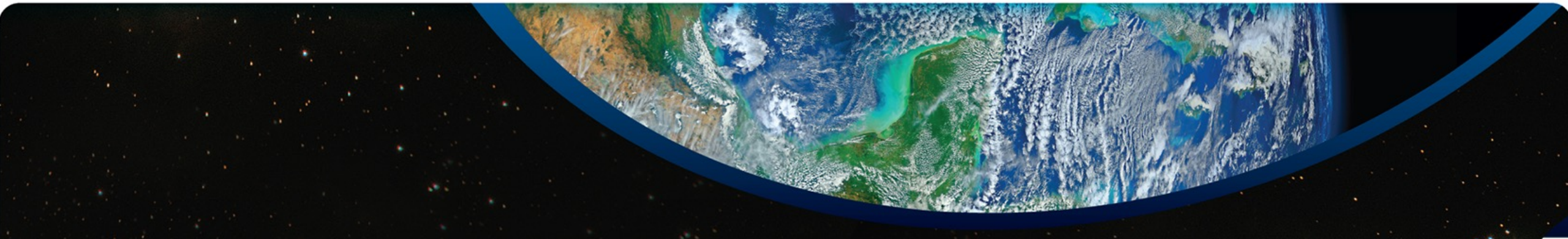


National Aeronautics and Space Administration

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OSIRIS-REx Flight Mechanics and Entry, Descent, and Landing Performance

Anthony Williams, Eric Queen, Soumyo Dutta

Atmospheric Flight and Entry Systems Branch

Mark Johnson, Scott Francis

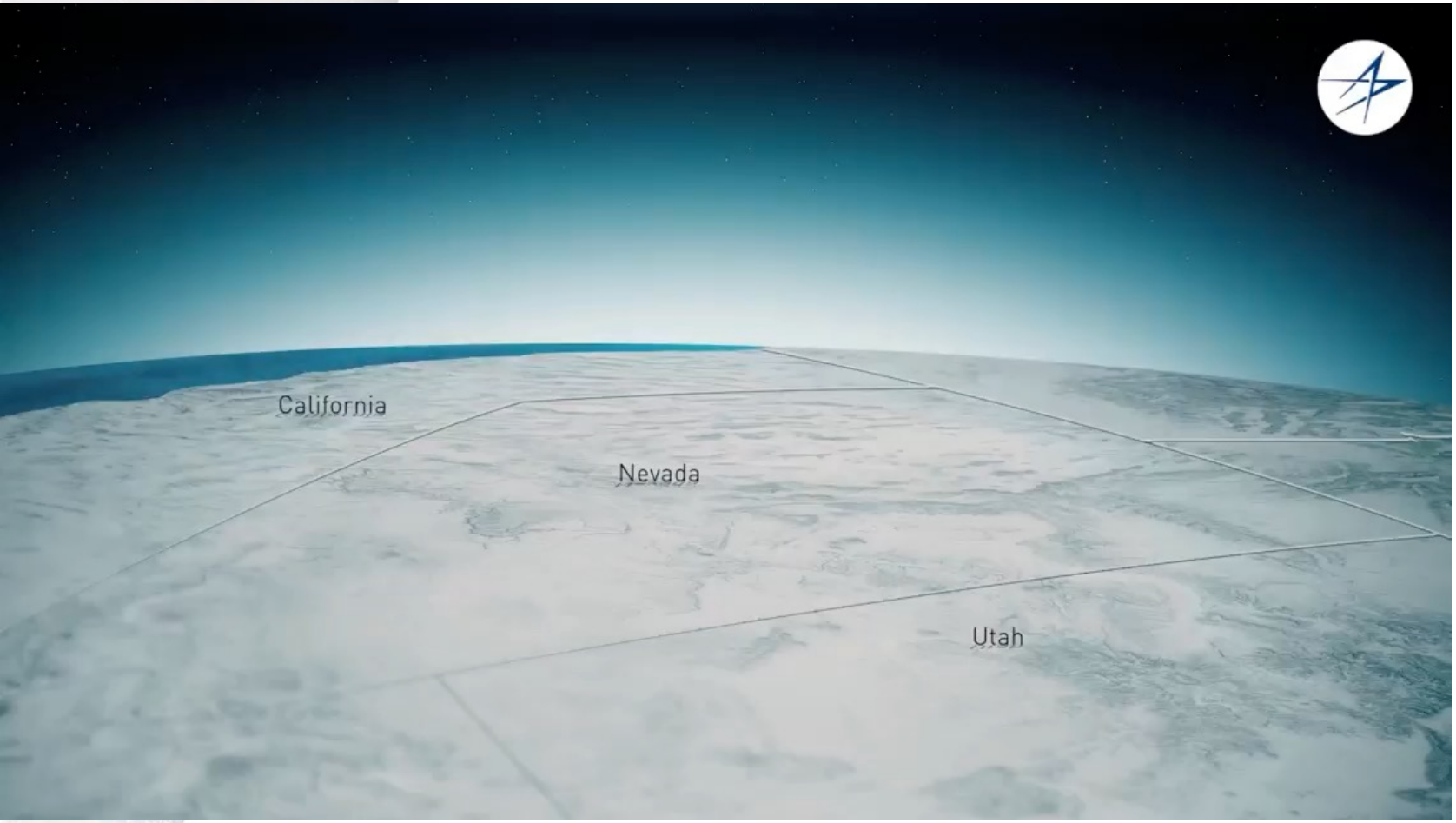
Lockheed Martin Space Corporation

21st International Planetary Probe Workshop, June 8th-14th, 2024
Williamsburg, VA, USA

Mission Overview

- **O**rigins, **S**pectral **I**nterpretation, **R**esource **I**dentification, **S**ecurity, **R**egolith **Ex**plorer (OSIRIS-REx) was the third mission in NASA's New Frontiers program
- Launched out of Cape Canaveral, FL on Sept 8, 2016 with science goal to return minimum of 60g of near-Earth asteroid Bennu's surface
- OSIRIS-REx departed surface of Bennu on May 10, 2021, and began its roughly 2.5 year flight back to Earth
- Sample Return Capsule (SRC) successfully completed the entry, descent, and landing (EDL) sequence and touched down at the Utah Test and Training Range (UTTR) on September 24, 2023

Mission Overview – EDL Sequence



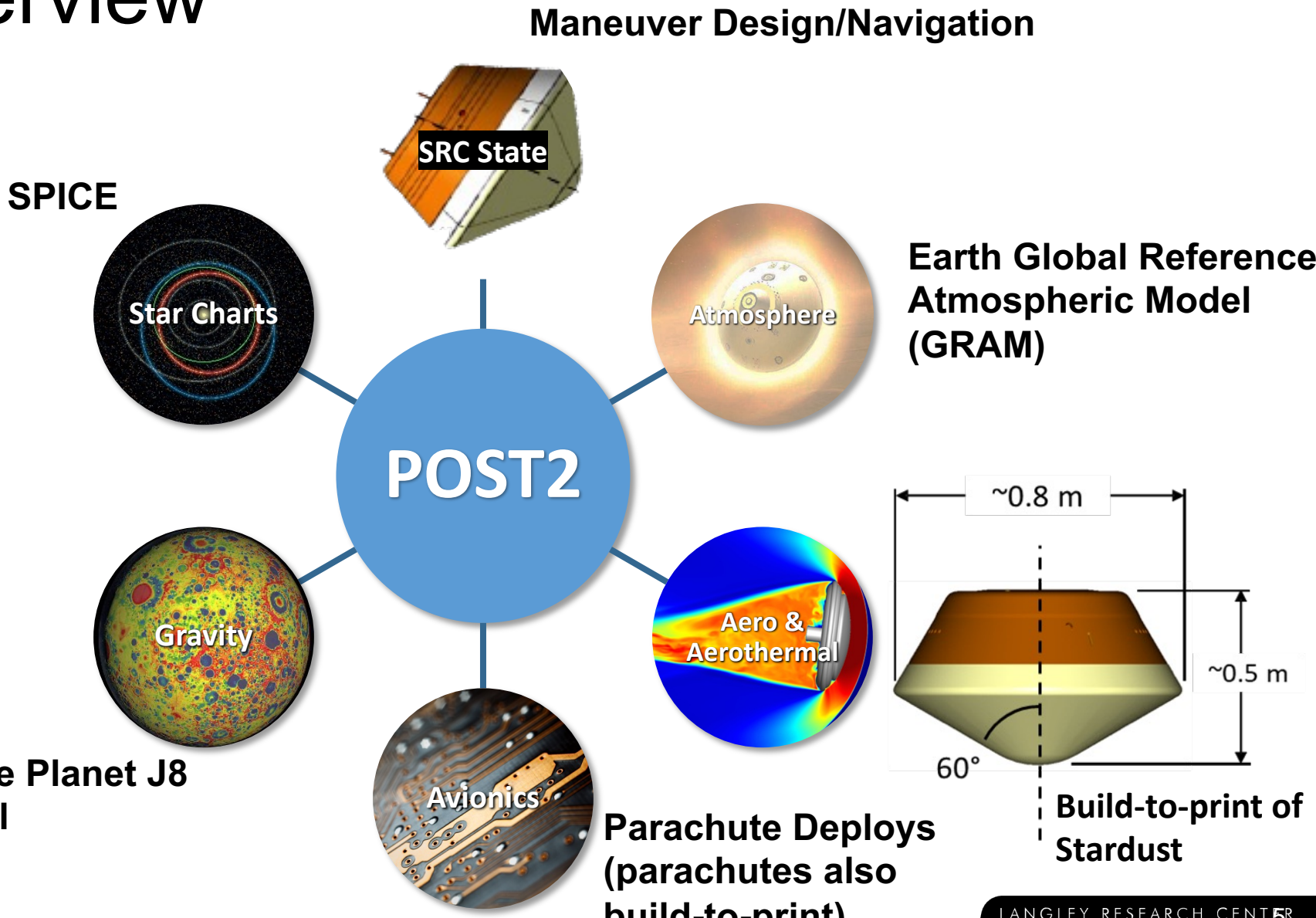
Credit: NASA GSFC/LM

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Modeling Overview

Program to Optimize Simulated Trajectories II (POST2) used for EDL simulations

- Ingests information from many external sources
- Propagates six degree-of-freedom equations of motion from 1 minute prior to atmospheric interface (6503.142 km radius) to touchdown at UTTR



Decisional Analyses

- Prior to each major trajectory event, such as a trajectory correction maneuver (TCM), predicted EDL performance was assessed to determine Go/No-Go

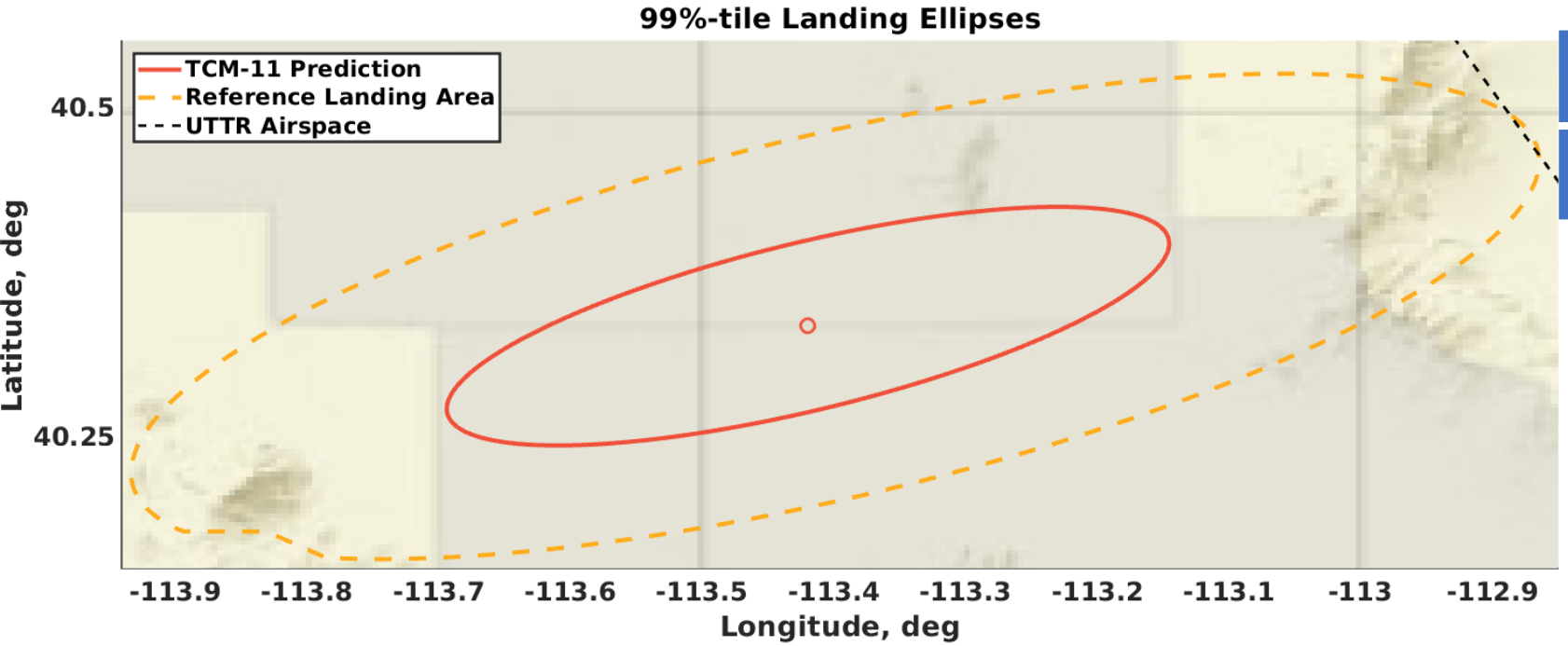
- Key metrics consisted of:
  - Survivability of SRC
    - Peak heat rate, heat load
    - Peak deceleration
  - Landing Accuracy
    - % cases landing within agreed upon reference landing area (RLA) at UTTR (95km x 30km)

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Decisional Analyses

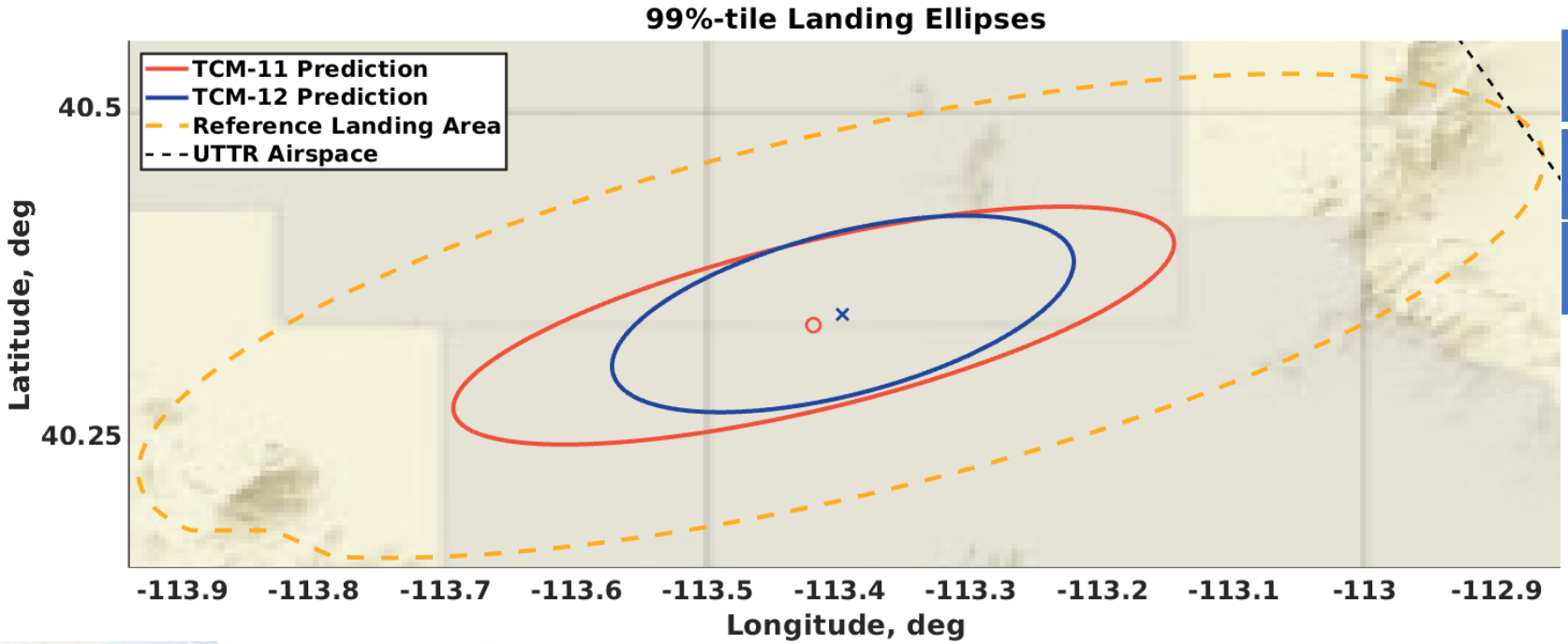


Event	Event Time	Executed	Ellipse Size
TCM-11*	E-14 days	Yes	48.7km x 13.9km

* First TCM to target Earth entry trajectory

Reference Landing Area (RLA): 95km x 30km

Decisional Analyses

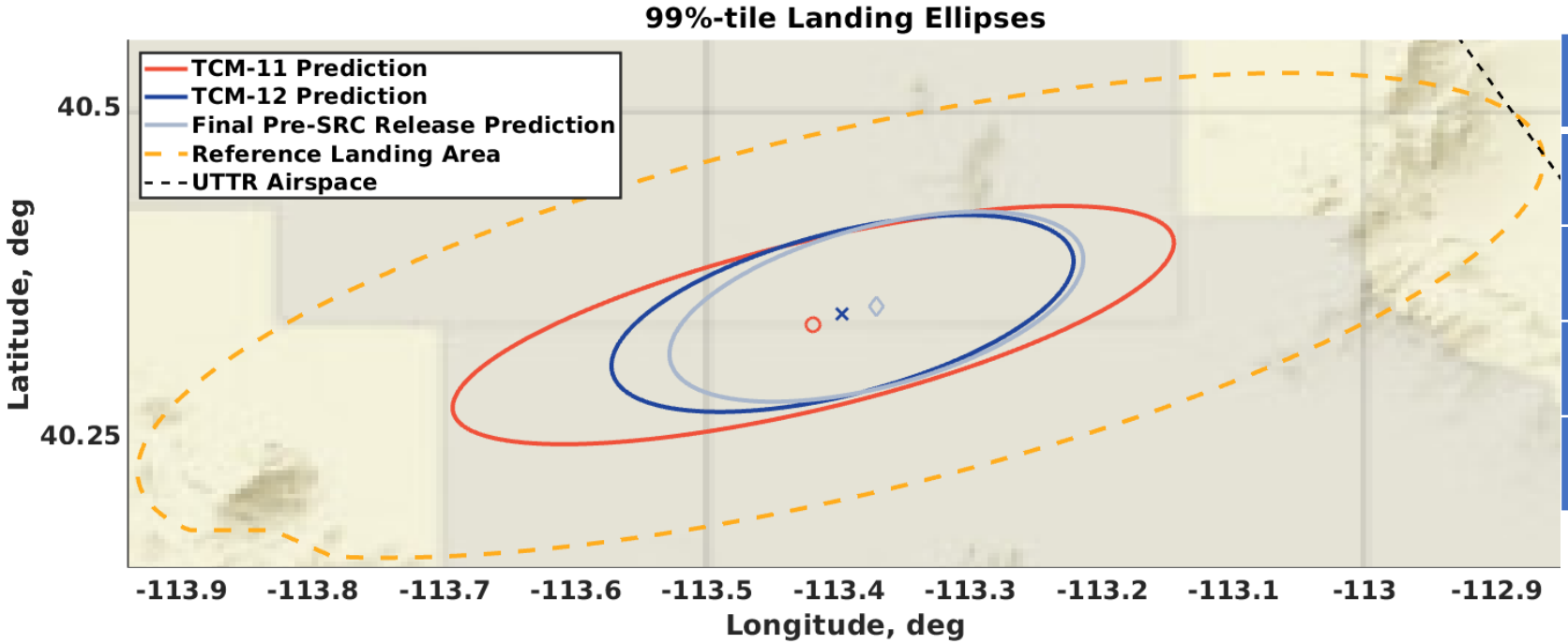


Event	Event Time	Executed	Ellipse Size
TCM-11*	E-14 days	Yes	48.7km x 13.9km
TCM-12	E-7 days	Yes	32km x 13.6km

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Decisional Analyses



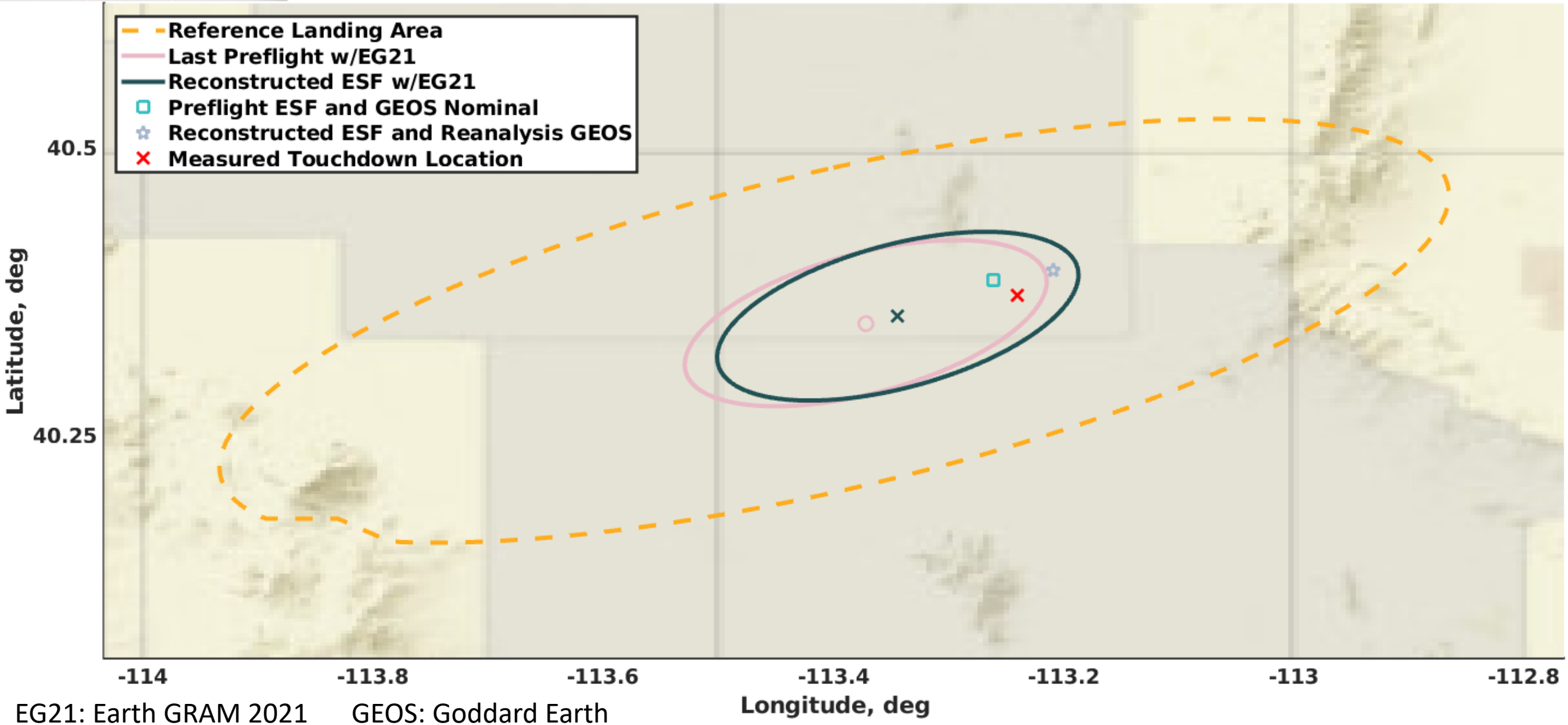
Event	Event Time	Executed	Ellipse Size
TCM-11*	E-14 days	Yes	48.7km x 13.9km
TCM-12	E-7 days	Yes	32km x 13.6km
TCM-13 **	E-31 hours	No	N/A
SRC Release	E-4 hours	Yes!	28.2km x 13.2 km

* First TCM to target Earth entry trajectory
** Not necessary

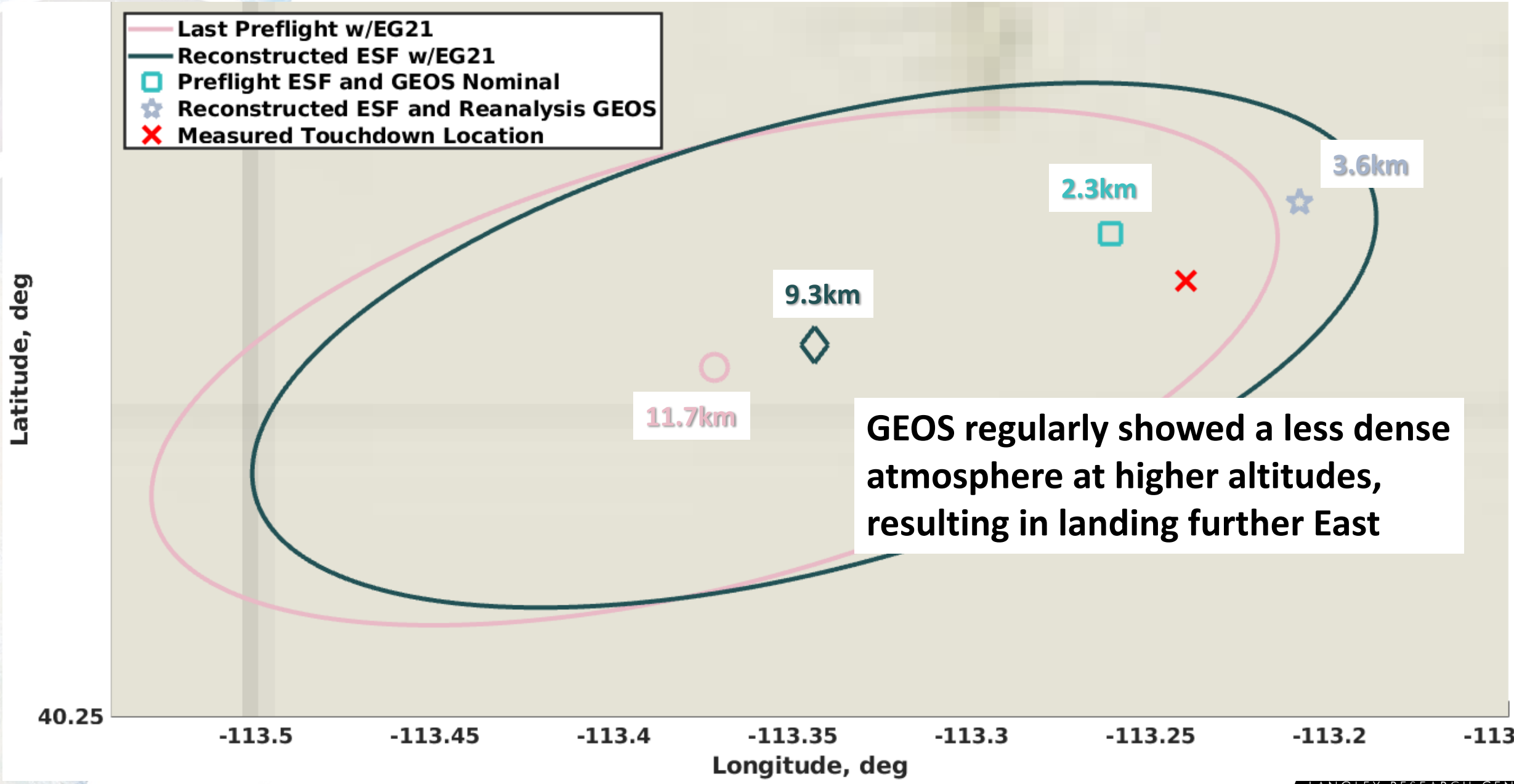
Reference Landing Area (RLA): 95km x 30km

Most of cross track uncertainty is due to winds

Pre- and Post-Flight Comparisons



EG21: Earth GRAM 2021
ESF: Entry State File
GEOS: Goddard Earth Observing System


Last Preflight w/EG21
Reconstructed ESF w/EG21
Preflight ESF and GEOS Nominal
Reconstructed ESF and Reanalysis GEOS
Measured Touchdown Location
3.6km
2.3km
9.3km
11.7km
GEOS regularly showed a less dense atmosphere at higher altitudes, resulting in landing further East
Latitude, deg
40.25
-113.5
-113.45
-113.4
-113.35
-113.3
-113.25
-113.2
-113.15
Longitude, deg

Drogue diameter: ~0.8m
Main diameter: ~7.3m

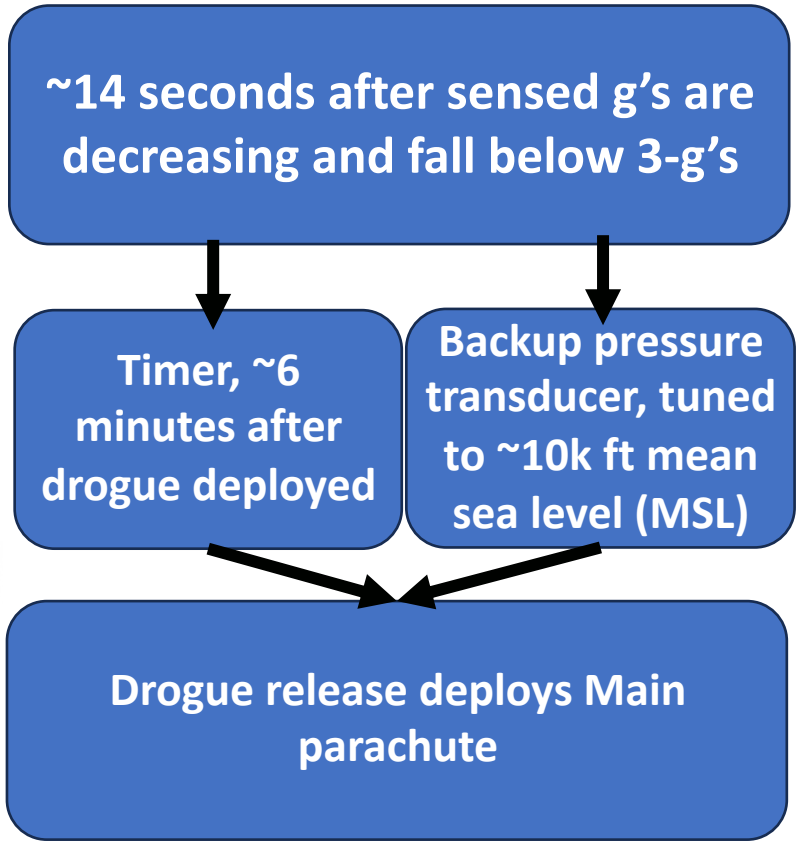
Parachute Anomaly

Nominal conops for drogue and main parachutes:

Drogue Parachute Deployed, *Mortar Fire*
~32km altitude

Drogue released from SRC

***Main* Parachute Deployed**
~3000m altitude

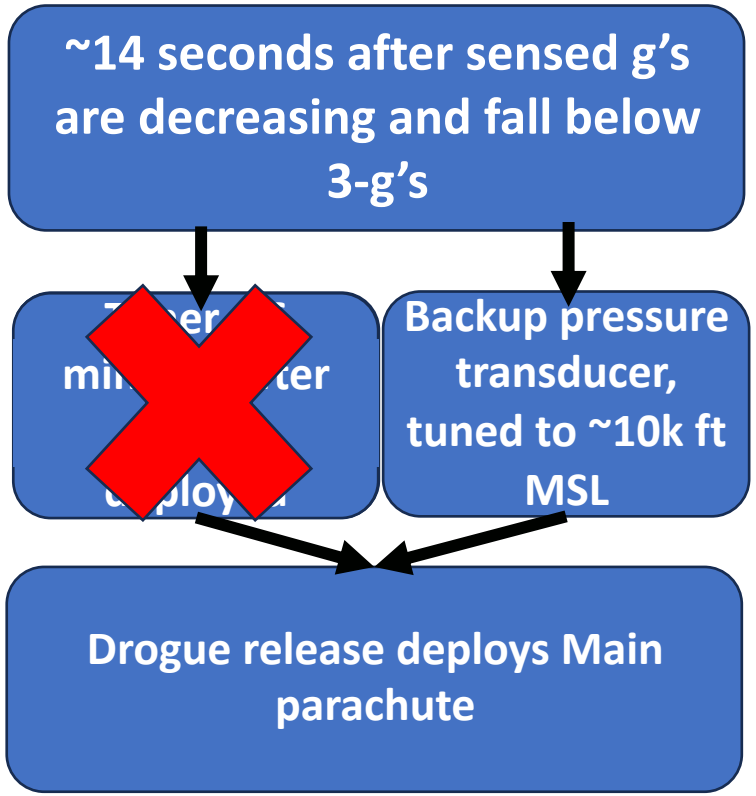


Actual sequence of events:

Drogue released from SRC, *Main*

Drogue Parachute Deployed, *Mortar Fire*

Drogue and Main Deployment nearly coincident
~2700m altitude



Trajectory Reconstruction

- Radar tracking was planned to occur by UTTR
- Due to differences in actual trajectory from predicted nominal, tracking data was not able to be collected
- Current reconstruction efforts are relying on data from aircraft observations, and have limited overlap throughout the trajectory

Summary

- OSIRIS-REx returned a sample from the surface of the near-Earth asteroid Bennu, touching down safely at UTTR on September 24, 2023
- Measured landing location was within the preflight predicted 99% landing ellipse
- Due to less-dense atmosphere and drogue parachute deployment anomaly, touchdown location was ~11.7km from preflight predicted mean landing location
- Reconstruction and reconciliation efforts are ongoing



Credit: NASA GSFC

Backup