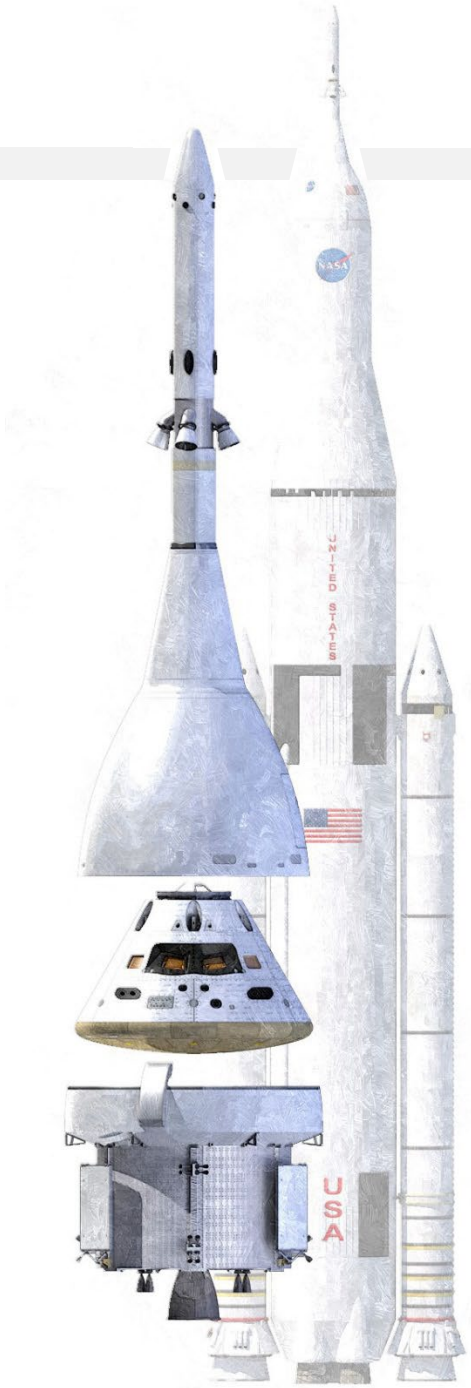


From Exploration Flight Test-1 to Artemis II–A NASA Langley's Orion Aerosciences Overview

Alireza Mazaheri

Langley Aerosciences Lead, NASA Langley Research Center

Karen L. Bibb

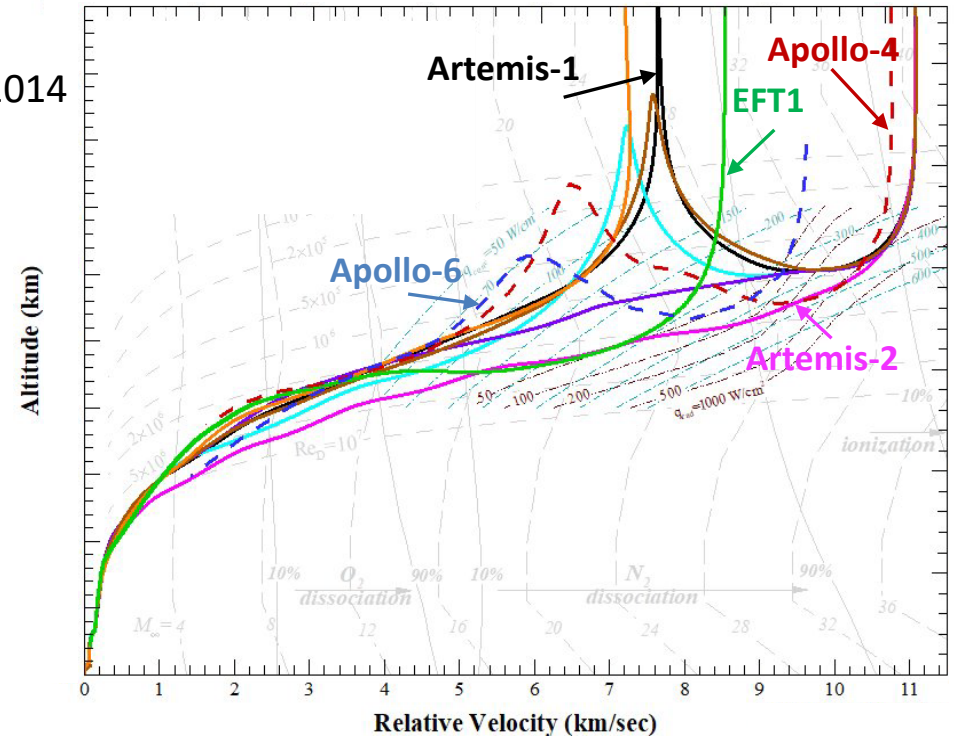
Aerodynamics Lead, NASA Langley Research Center

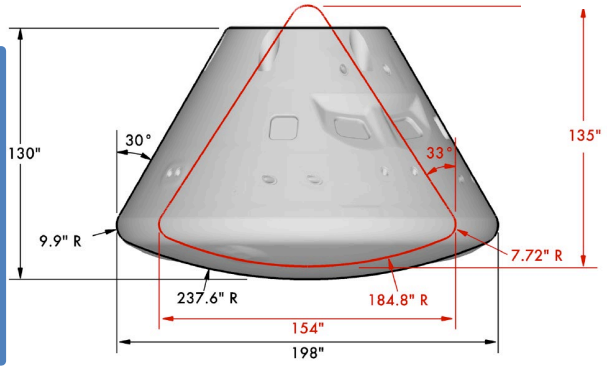
Victor R. Lessard

Langley Aerothermodynamics Lead, AMA Inc.

Background

- **The last Apollo (Apollo-17):** December 7, 1972
- **Exploration Flight Test (EFT) 1:** December 5, 2014
  Uncrewed, ~4hrs duration
  ~80% Lunar return velocity
- **Artemis-1:** November 16, 2022
  Uncrewed, 25-day mission
  Lunar return
- **Artemis-2:** April 1, 2026
  Crewed, 10-day mission
  Lunar return
- **Artemis-3:** mid 2027
  Crewed, TBD

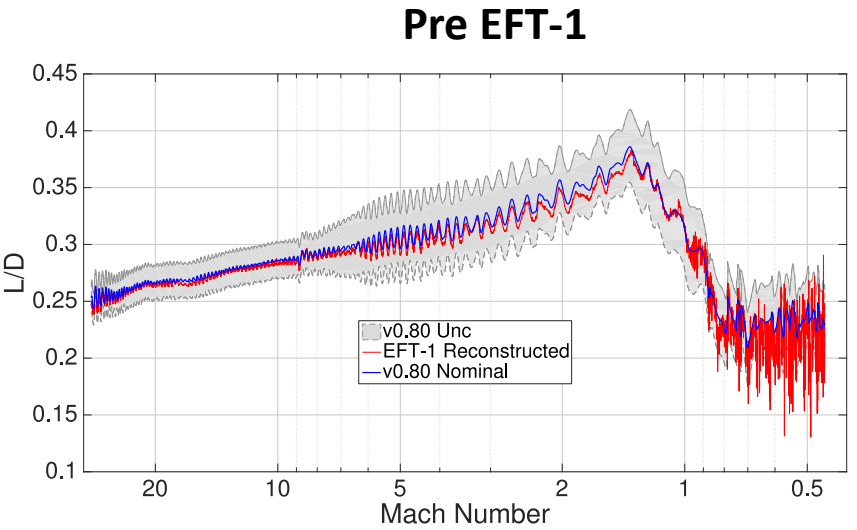


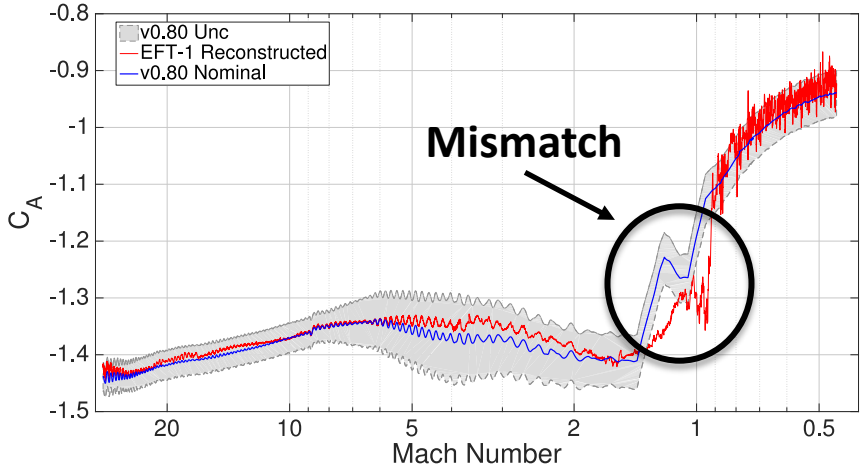


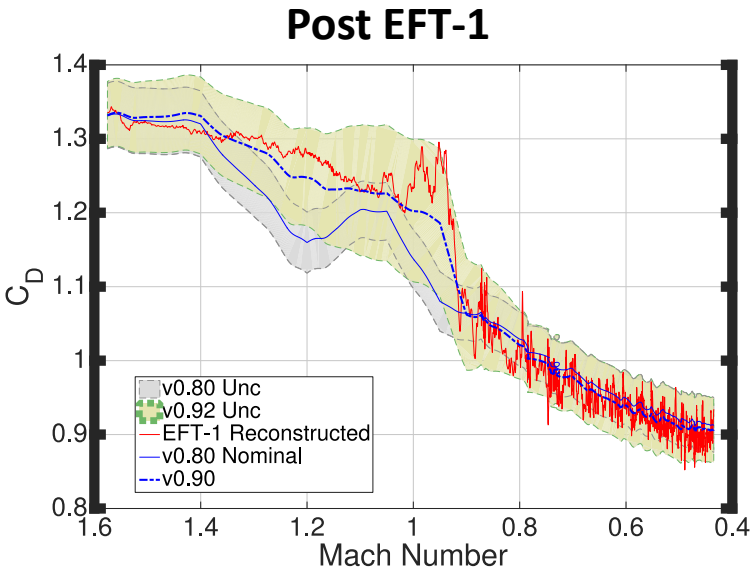
- **Size:** Orion > Apollo
- **Backshell:** Orion ≠ Apollo
- **TPS:** Apollo → Monolithic Honeycomb AVCOAT
  Orion Heatshield → AVCOAT tiles
  Orion Backshell → Shuttle tiles

EFT-1: Aerodynamic

- The aerodynamic database was proven to be very accurate.
- The flight data showed a mismatch in the transonic region & a need for additional data points in the database.

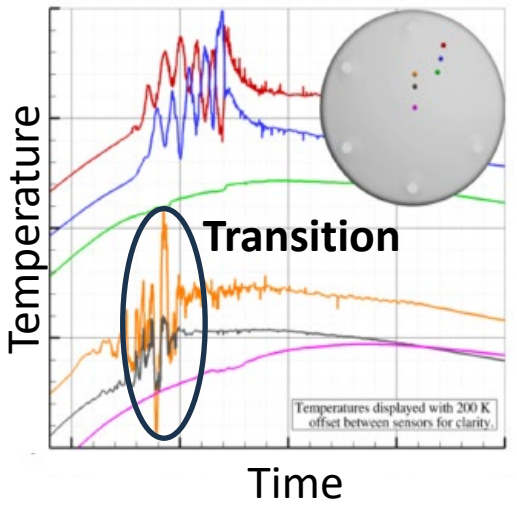


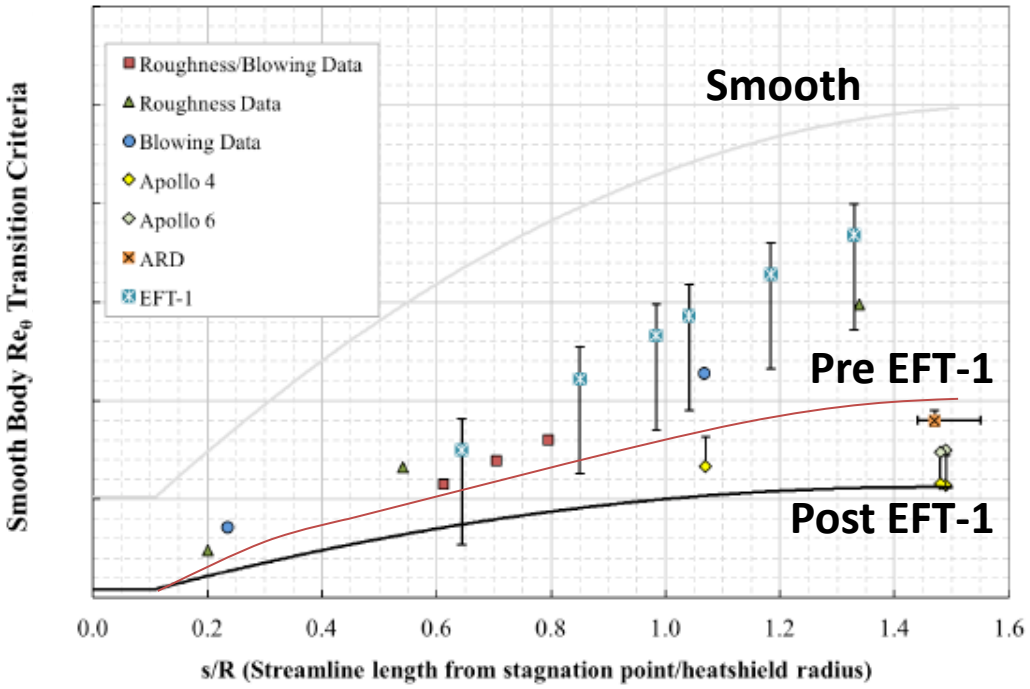




EFT-1: Heatshield

- Flight data and post flight heatshield images showed transition onset
- The aeroheating database did cover the EFT-1 transition
- The inclusion of Apollo data led to a new transition onset.

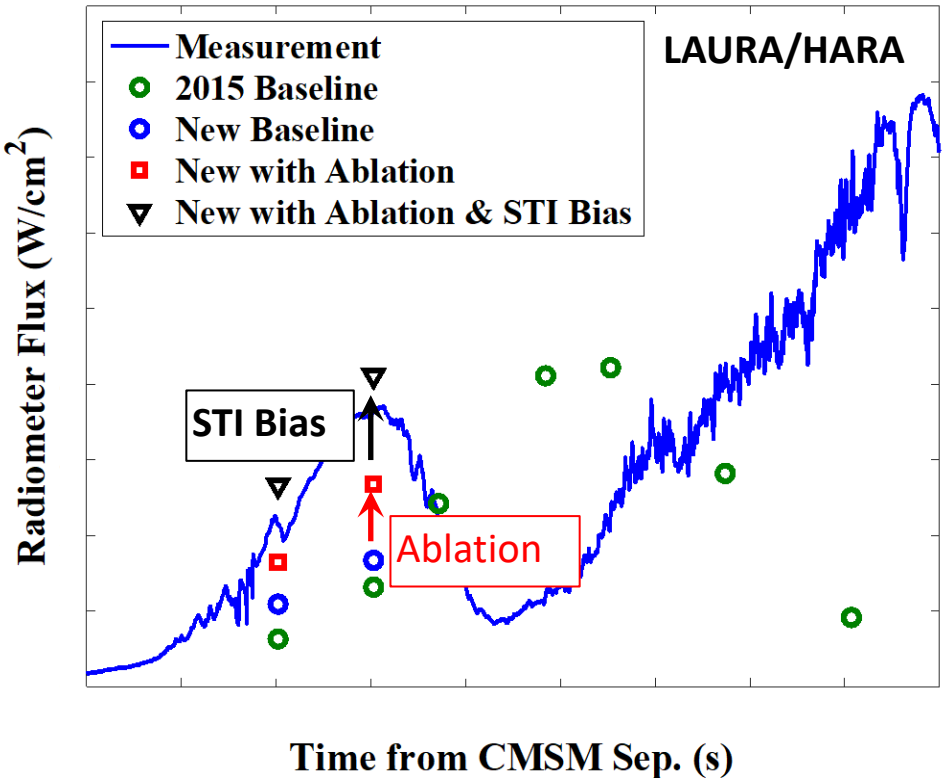




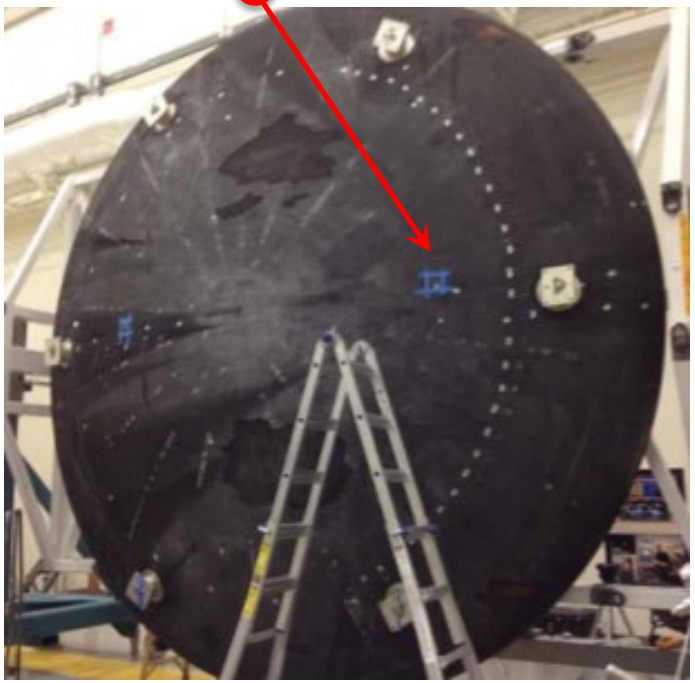
EFT1 Post-Flight

EFT-1: Radiation on Heatshield

- EFT1 radiometer data led to the development of a new radiation model for HCN by Chris Johnston, and an excellent agreement with the flight data.
- Measured data after the first pulse is considered useless.

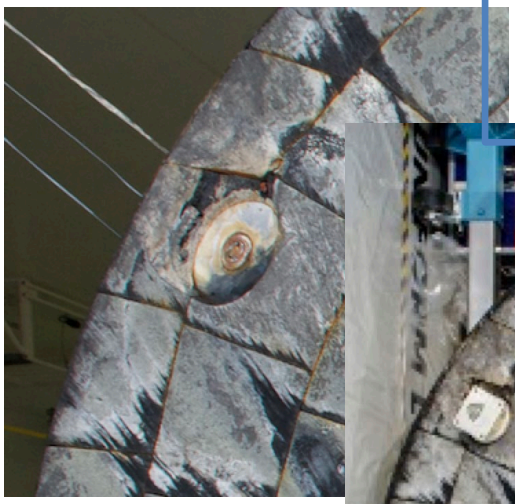


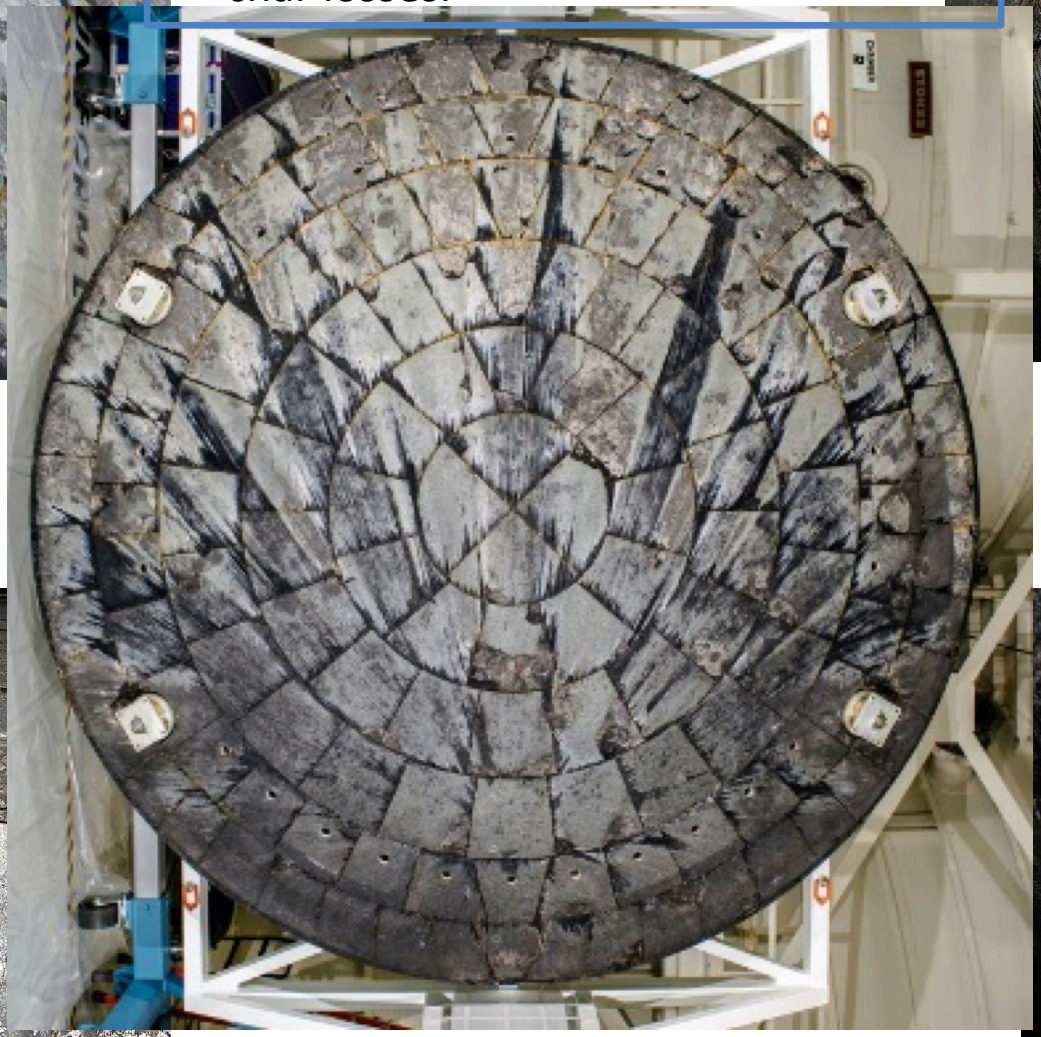
Stagnation Point Radiometer



Artemis 1 Post Flight Images

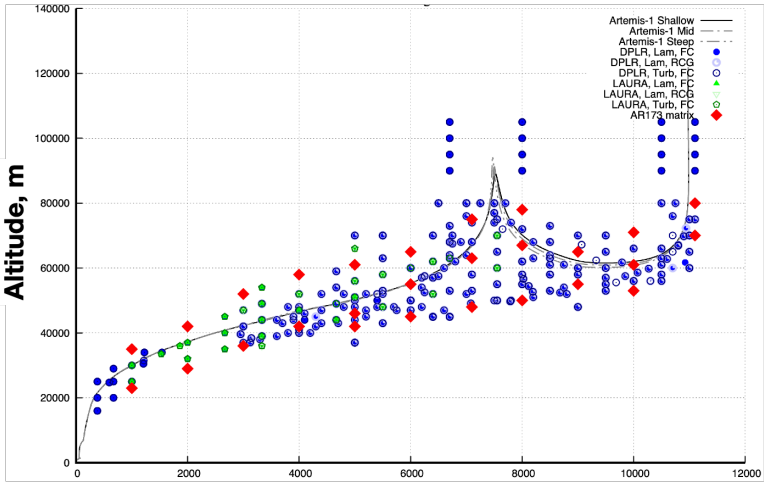
- Artemis-1 post-flight images show heatshield transition and significant char losses.

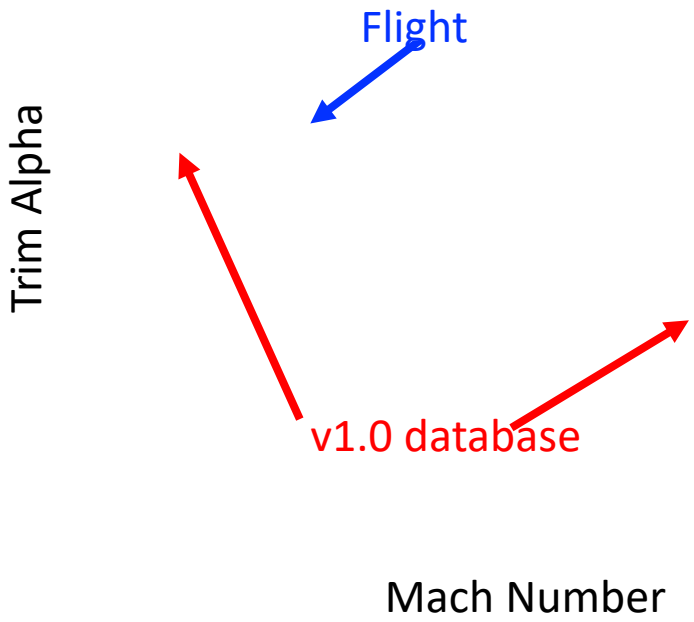


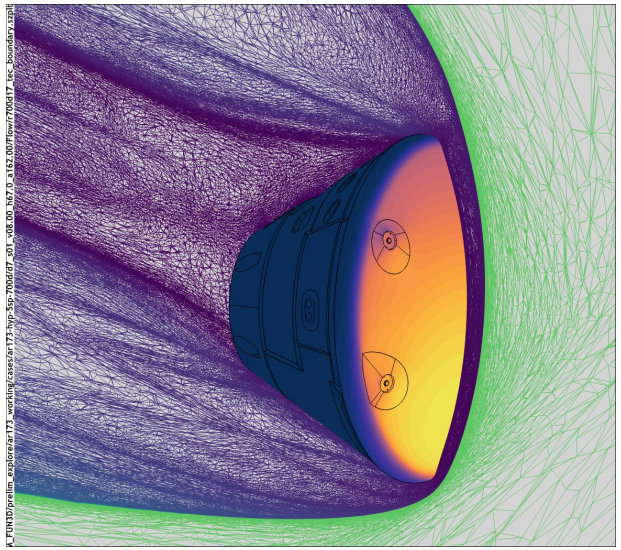


Artemis 1: Aerodynamics

- The Artemis-1 aerodynamic database captured the flight data within uncertainties.
- Char-loss didn't affect the aerodynamics significantly.



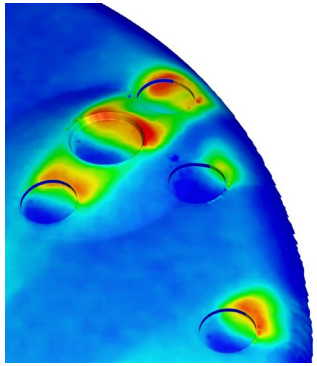


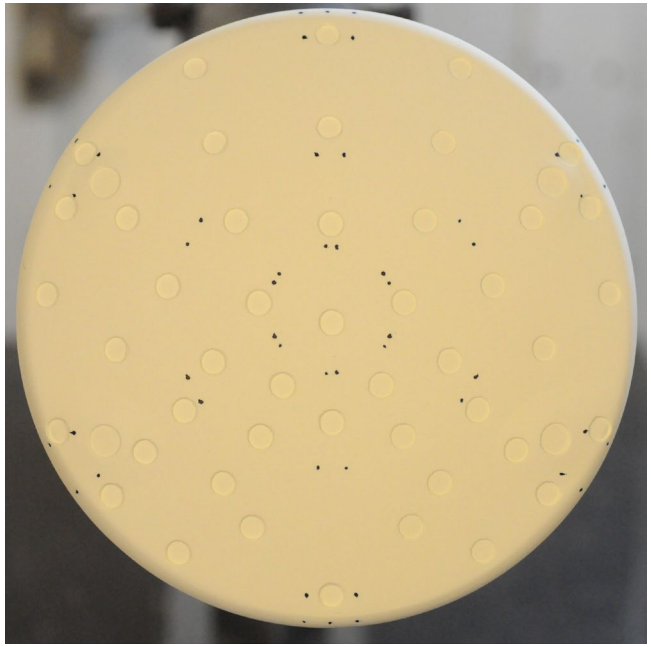


Artemis 1: Aeroheating

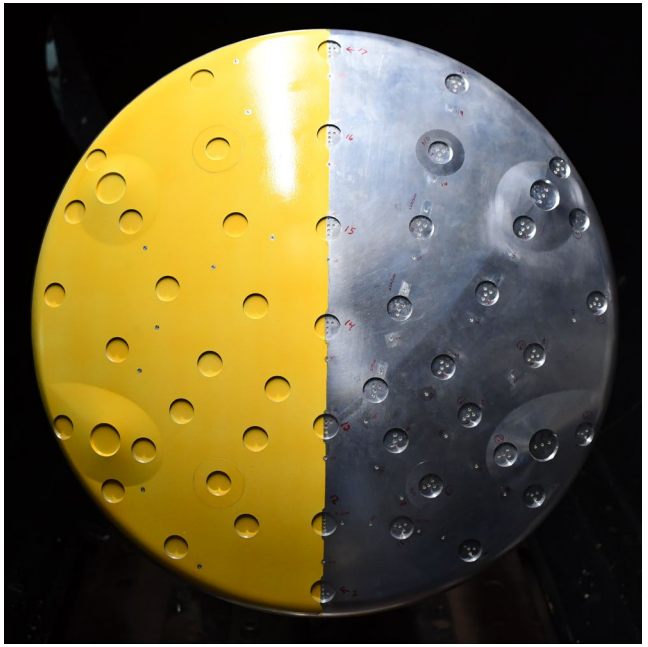
Langley 20-inch Mach 6

- 400+ runs
- 28 Configs
- 6” model

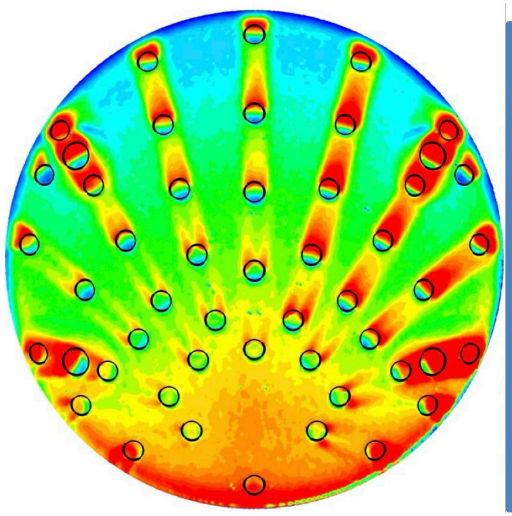




CUBRC Lens I



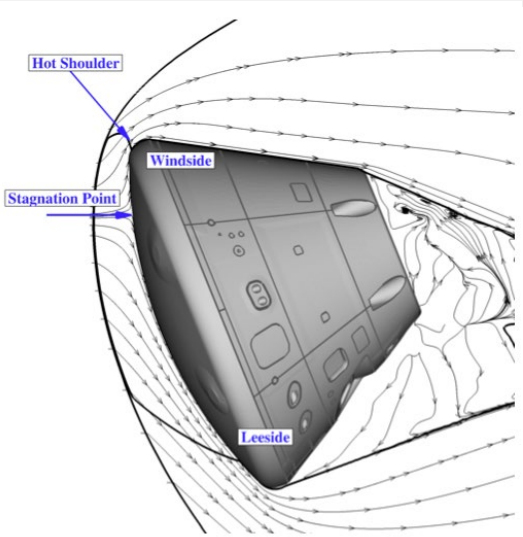
- Higher Re
- 179 runs
- 24” model

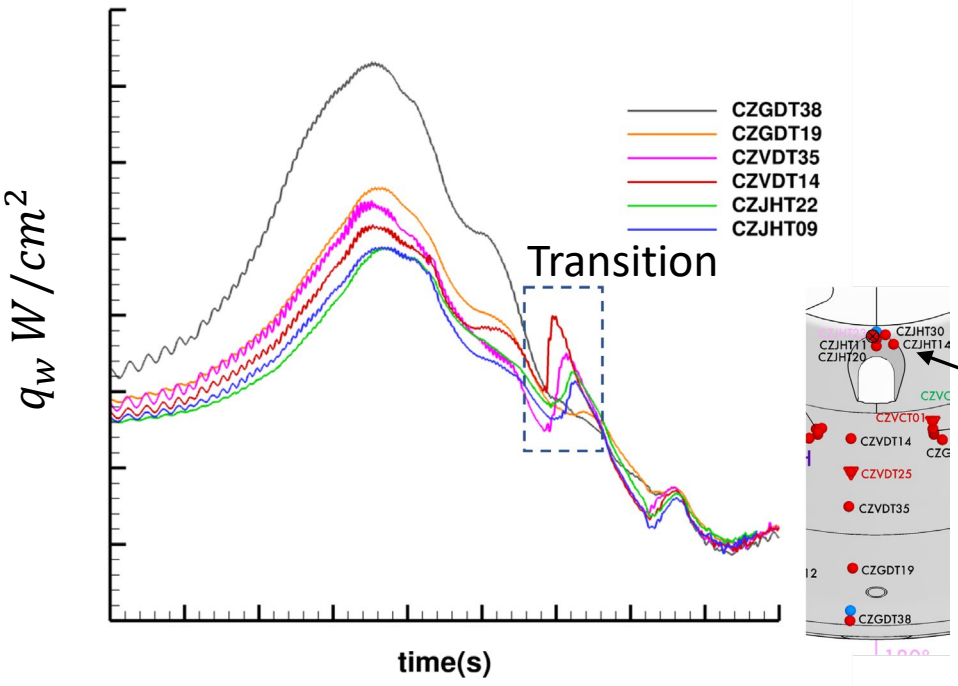


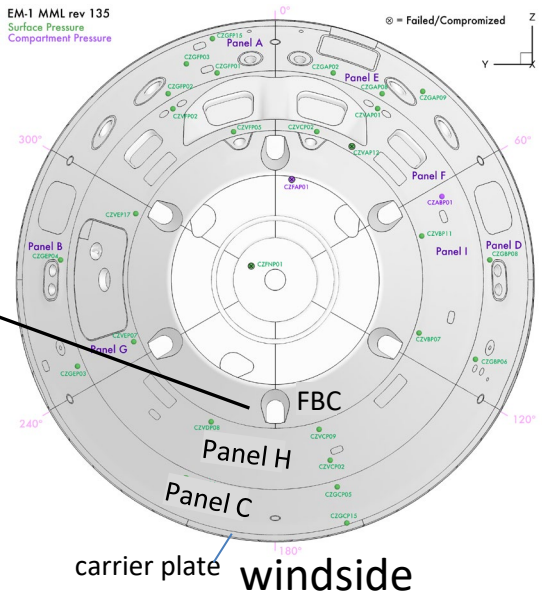
- A series of WT tests was conducted to understand the impact of the char loss on aeroheating environment.
- These WT data along with Artemis-I Flight data led to a development of a new transition model for Artemis-2.

Artemis 1: Aeroheating

- Flight data indicated earlier than expected transition onset on the backshell.
- The flight data and a series of new WT tests data led to development of a new transition onset for backshell.

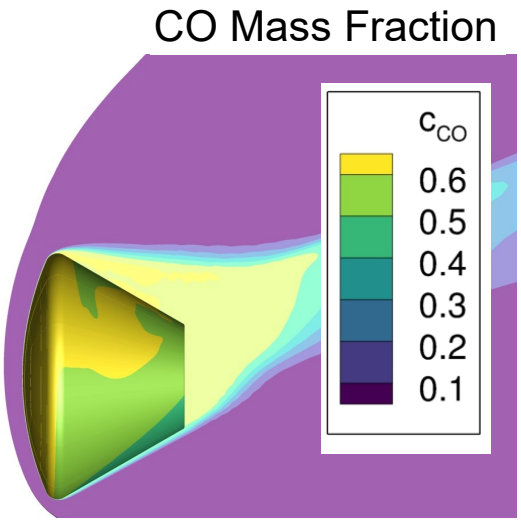


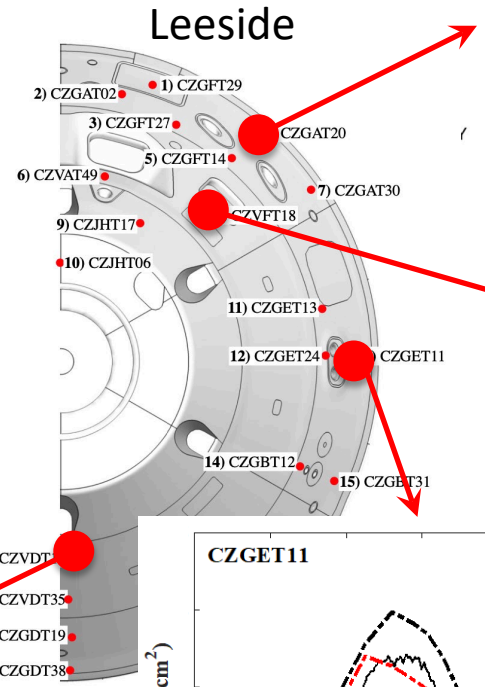


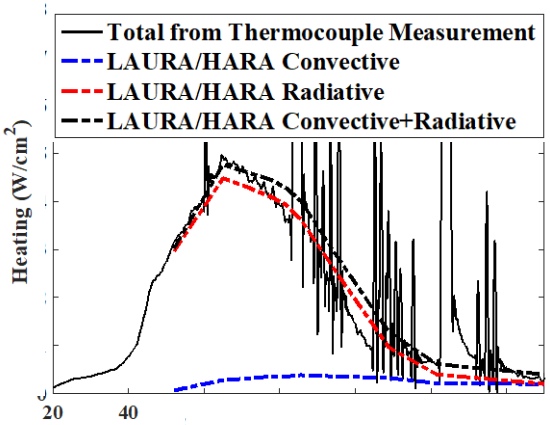


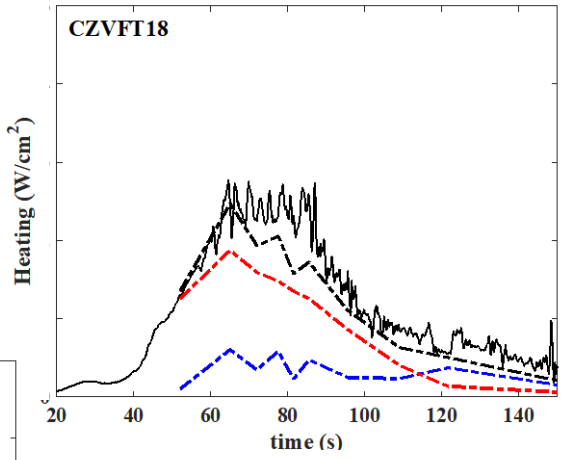
Artemis 1: Radiation Modeling

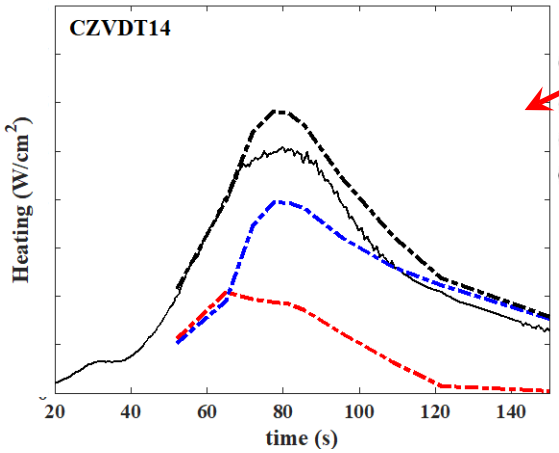
- Heating in the **separated** region was dominated by shock-layer radiation—as predicted by Chris Johnston's pre-flight simulations & verified by the post-flight data.

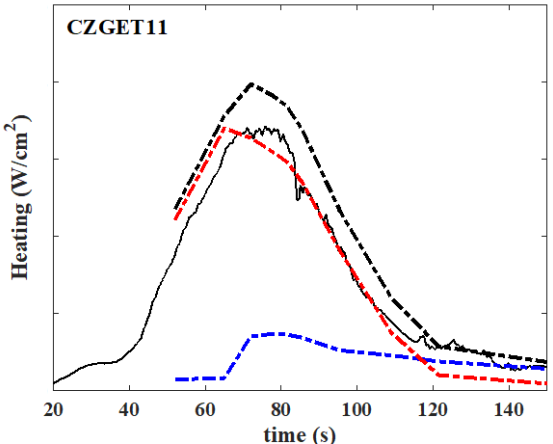




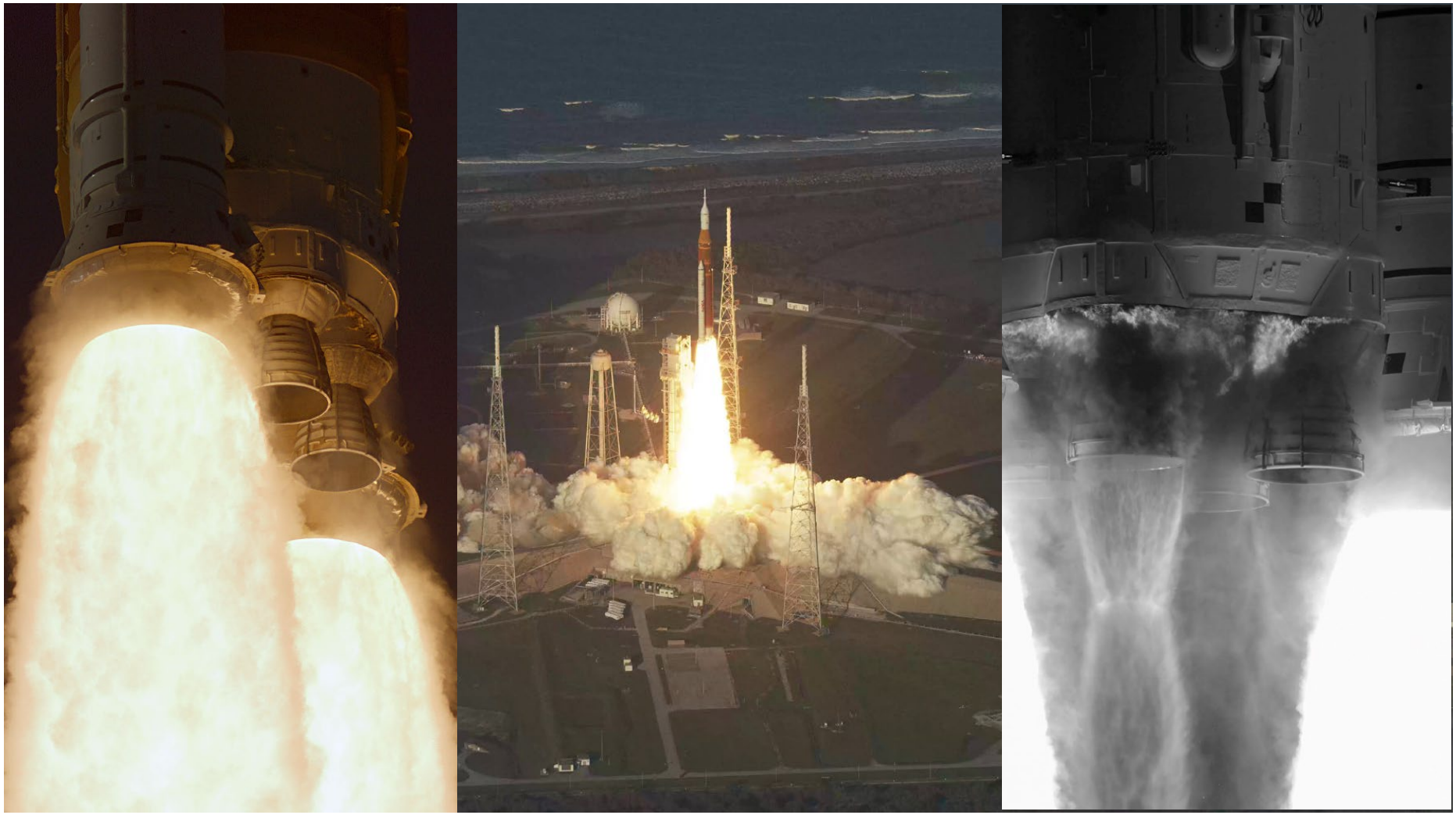




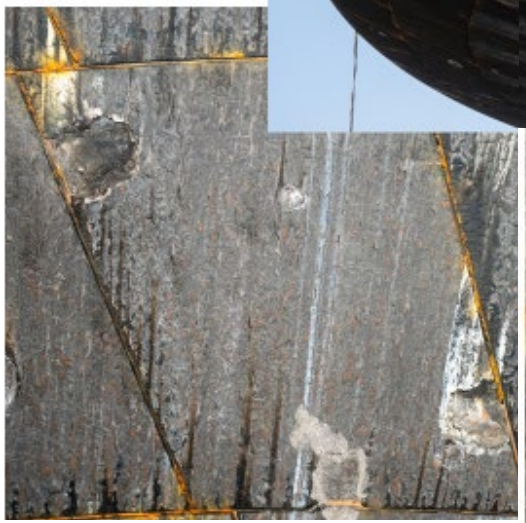




Artemis-II Flight



Artemis 2: Post-Flight Images



- Minimal heatshield damages.
- No evidence of transition onset.
- Limited entry flight data, including FADS.

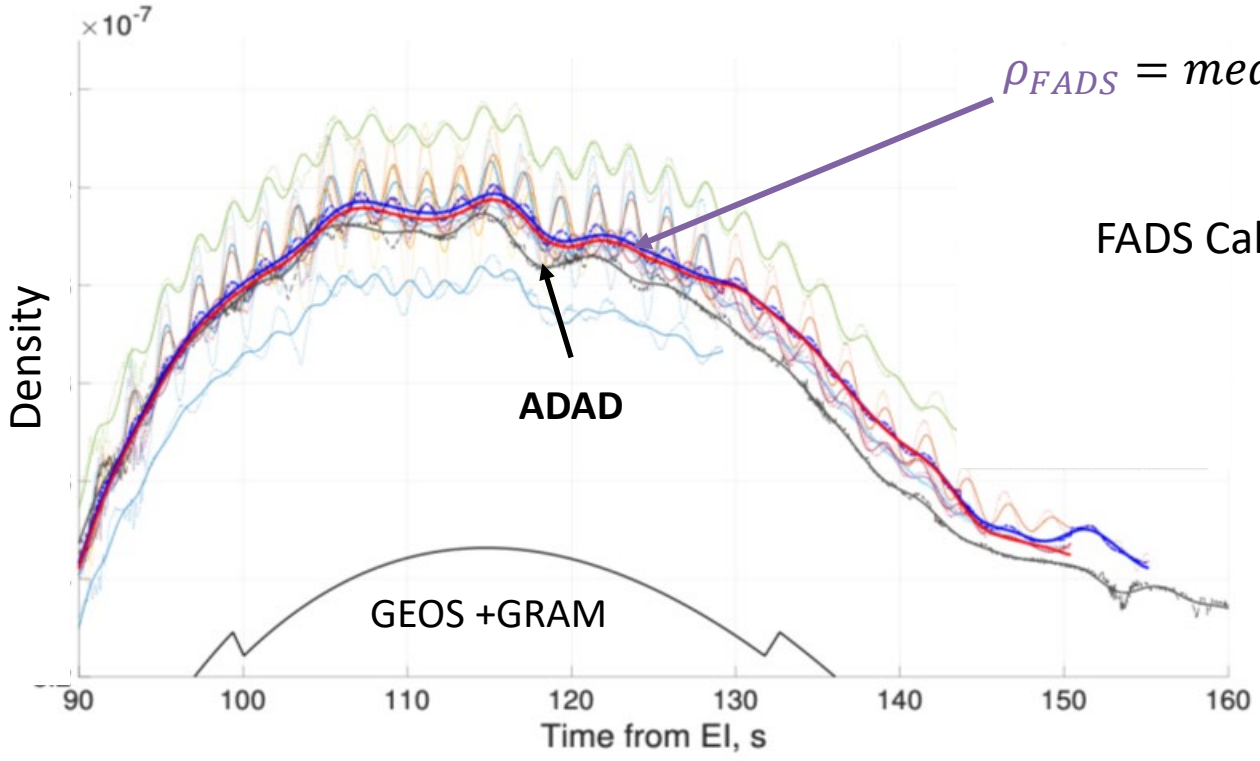
Artemis 2 : Post-flight Density Reconstruction

- FADS are often used to back out density. We've got limited FADS data.
- Density derived from GEOS + GRAM are not accurate for aeroheating analysis.
- Aerodatabase Derived Atmosphere Data (ADAD) is shown to be accurate enough in the absence of FADS data.

Pressure data

$$\rho_{FADS} = mean\left(\frac{2P_i}{V^2 C_{p,i}}\right)$$

FADS Calibration model



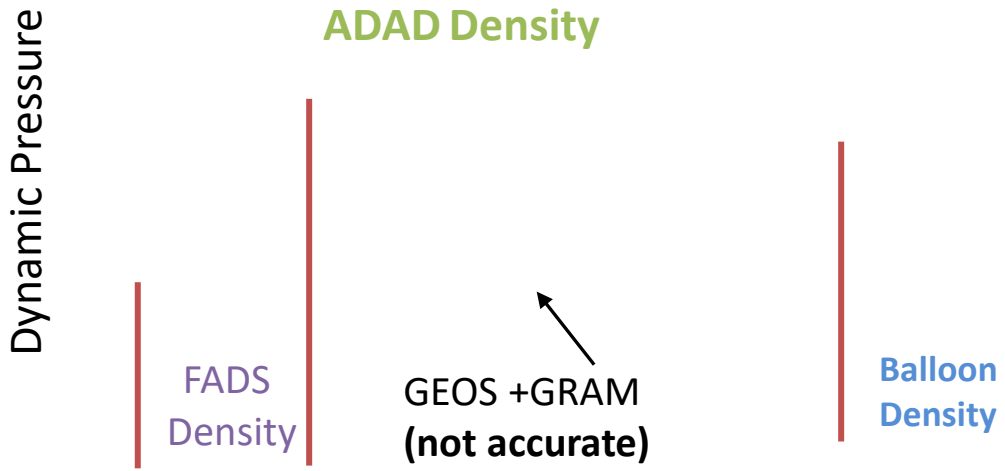
Artemis 2: Best Estimated Trajectory

- Limited FADS data
- Aerodatabase Derived Atmosphere Data (ADAD) is used to cover between the FADS data and Balloon region.

From Database

$$C_x = \frac{2ma_x}{\rho V^2 S_{ref}} \rightarrow \rho$$

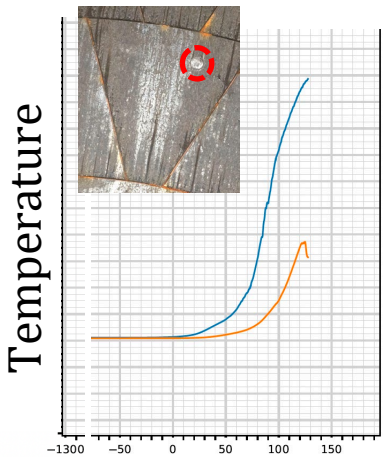
From Inertial Measurement Unit (IMU) flight data

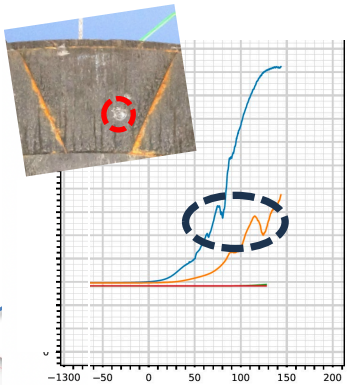


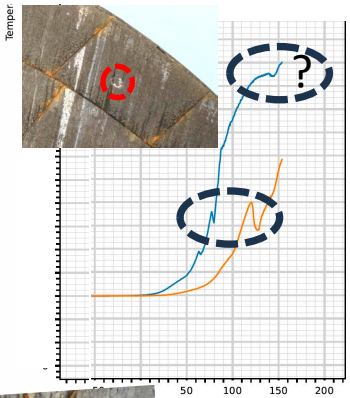
Artemis-2 Thermocouple Traces

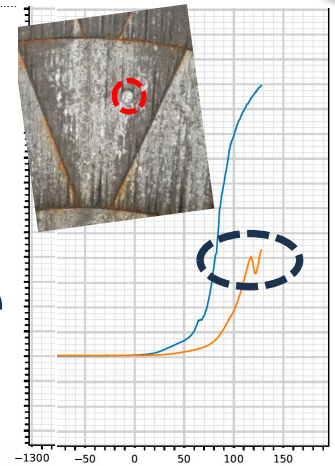
near surface 0.1”

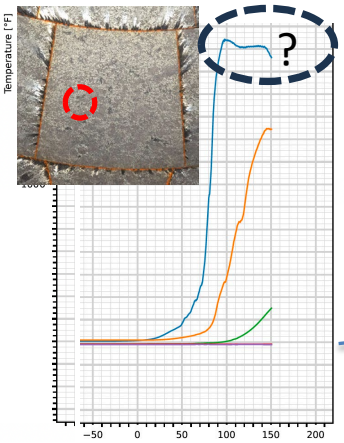
- We’ve got a limited set of DFI data.
- Some of these data are yet to be fully understood.

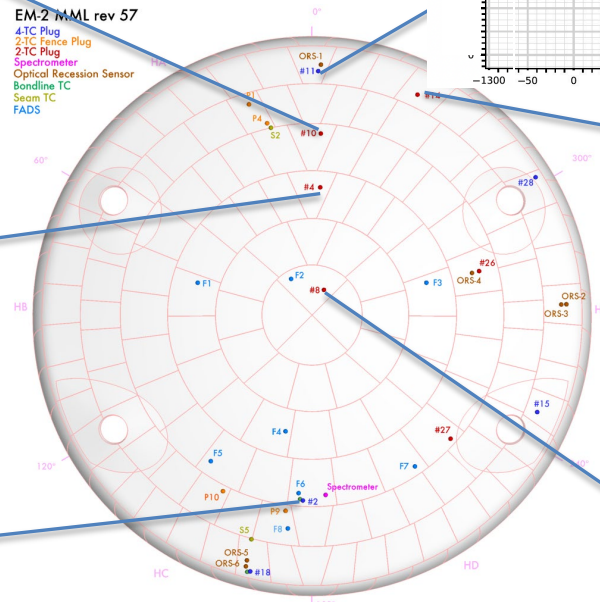


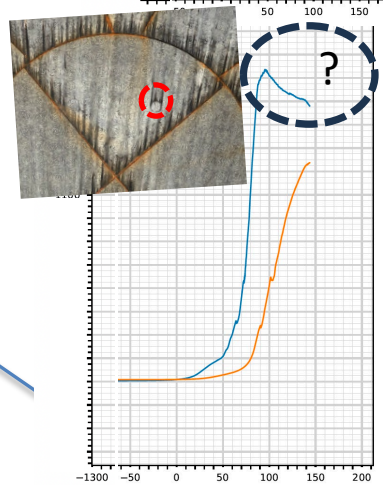






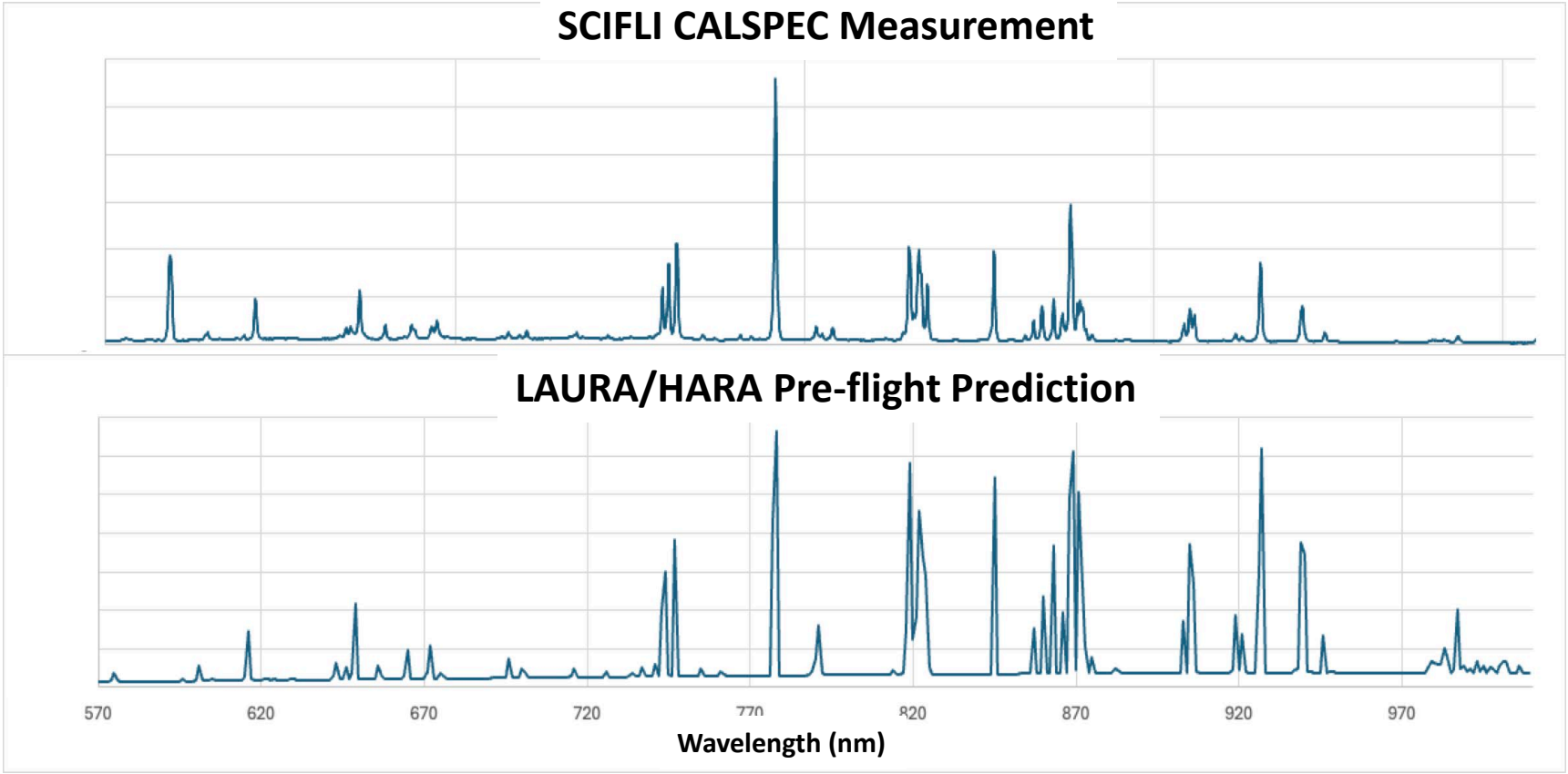






Artemis-2 Spectral Observation (SCIFLI)

- **Preliminary** analysis shows an excellent agreement between the measured spectral signature and the pre-flight predictions.



Summary

- An incredible group of talented and dedicated individuals across the center and the agency made these missions possible.

- We're progressively getting better with our environment predictions and continue upgrading our tools as we obtain more data.

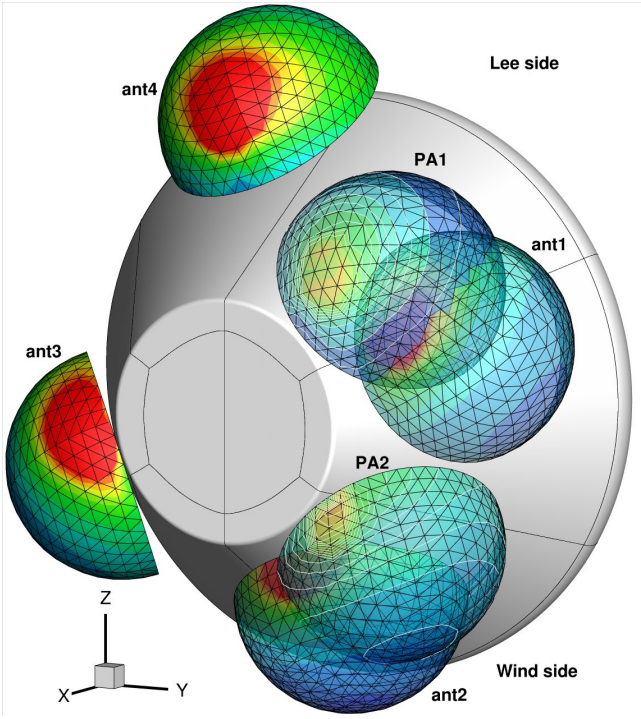
- We've just begun analyzing post Artemis-2 flight data, including the amazing SCIFLI observations.

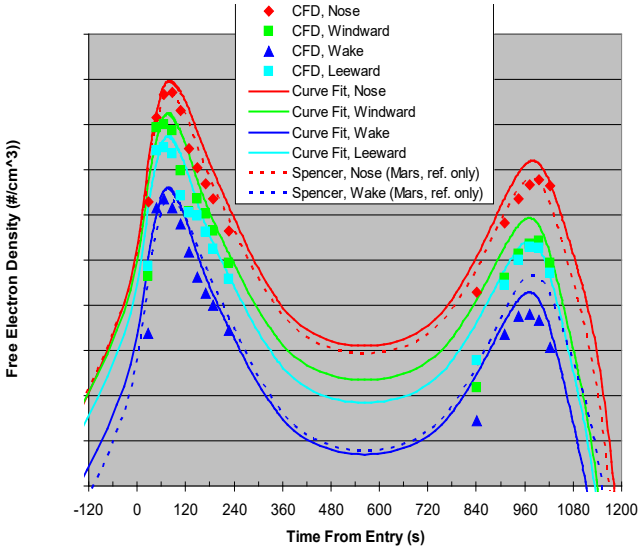
- Artemis 3 mission–mid 2027!

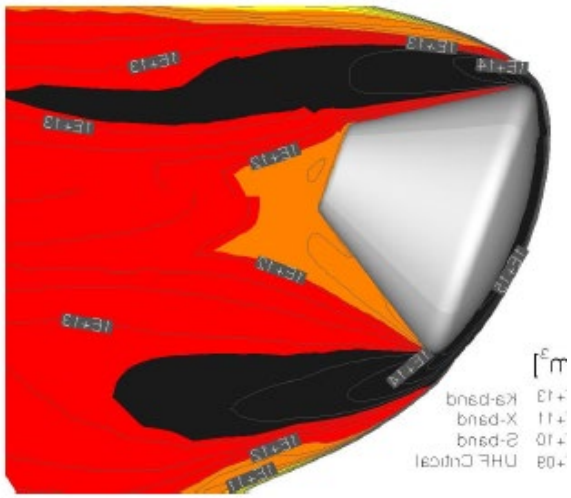
Backups

EFT-1: Blackout Analysis

Implemented blackout surfaces for phased array antennas.

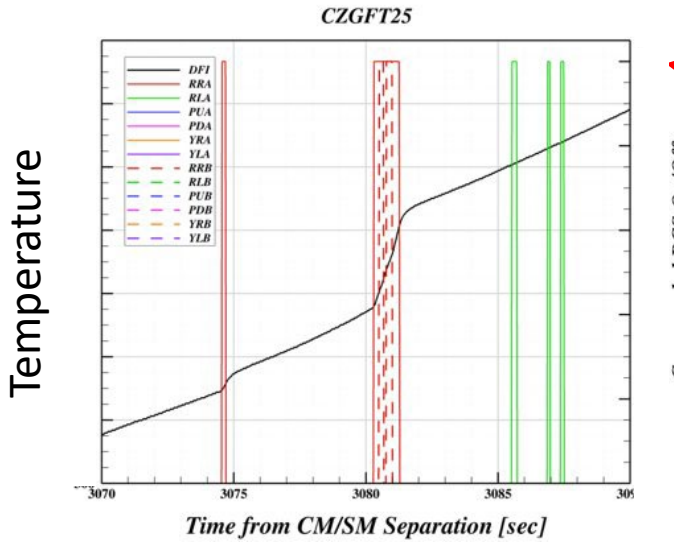


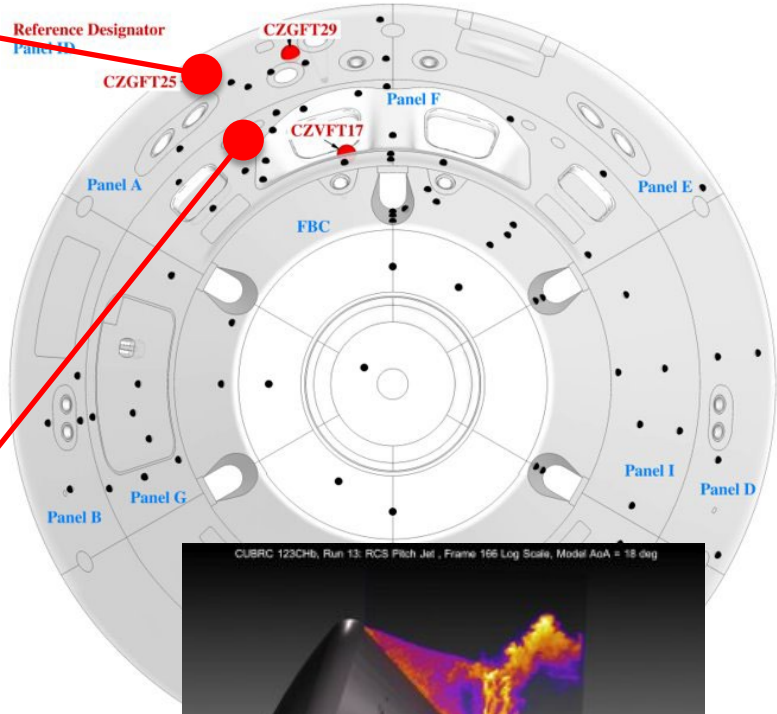


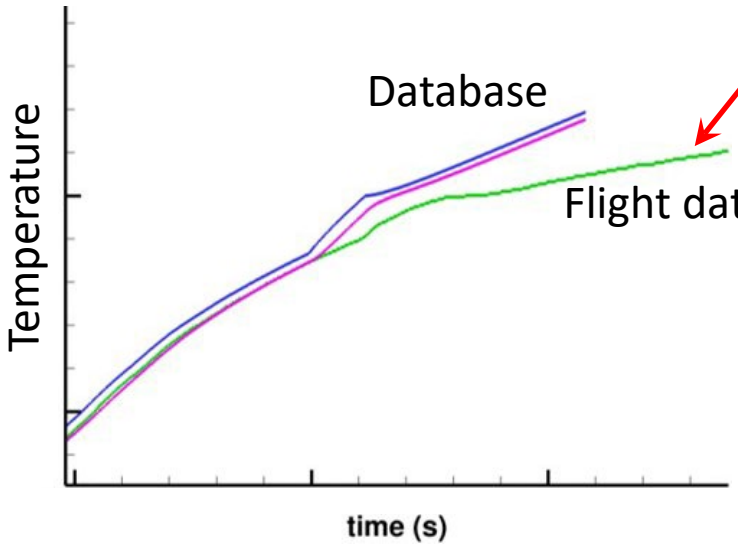


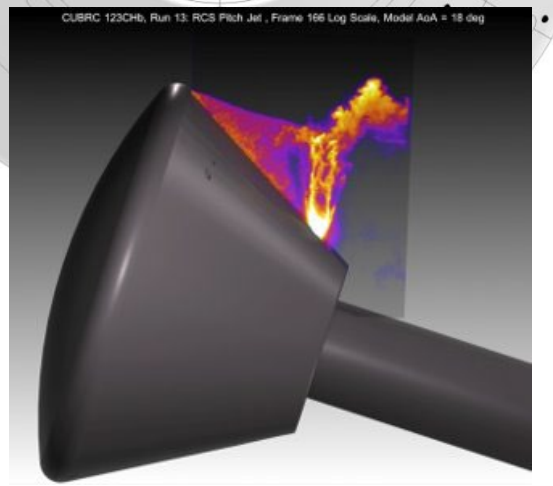
EFT-1: RCS Impacts on Heating

Flight data confirmed the database Augmentation Factor for RCS is adequate.



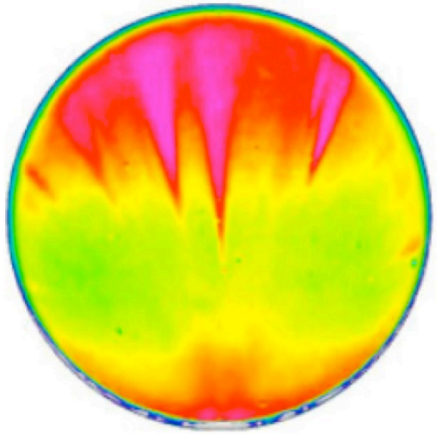


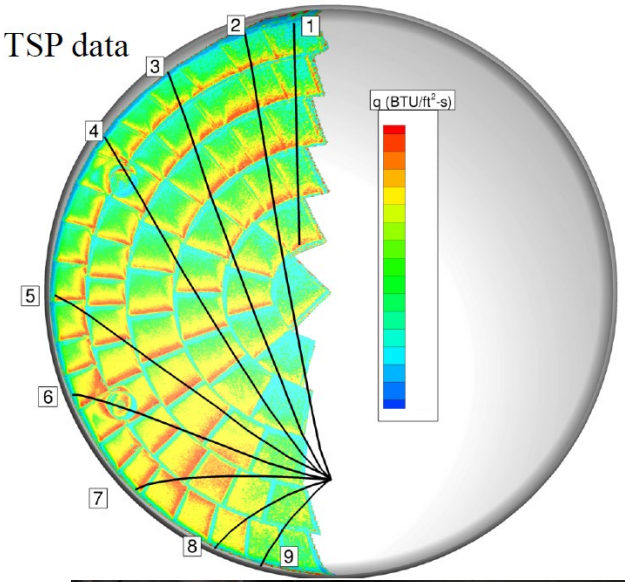


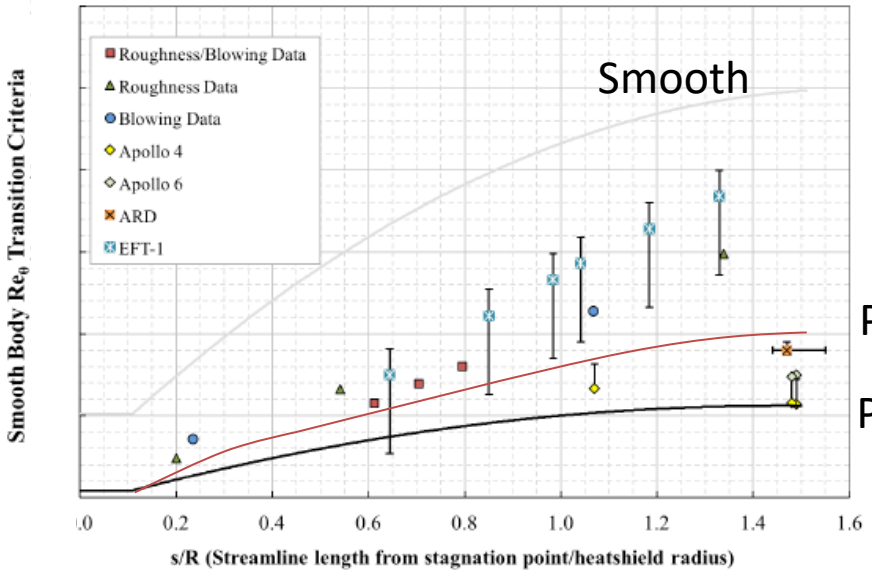


EFT1 – Post Flight Images

Mach 6 Wind-Tunnel

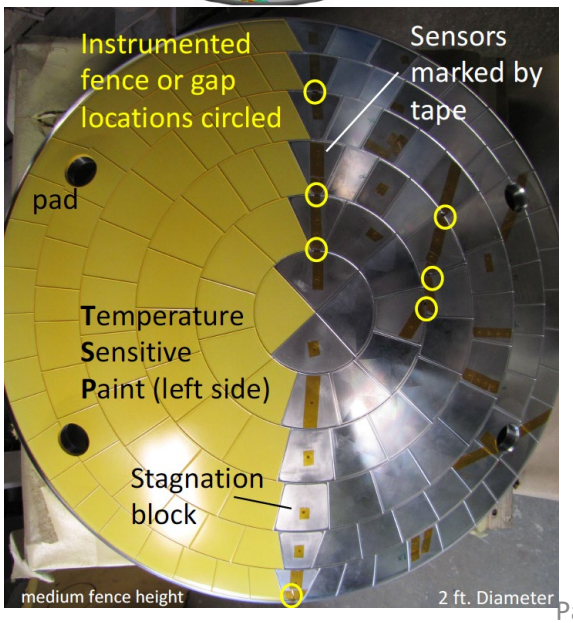


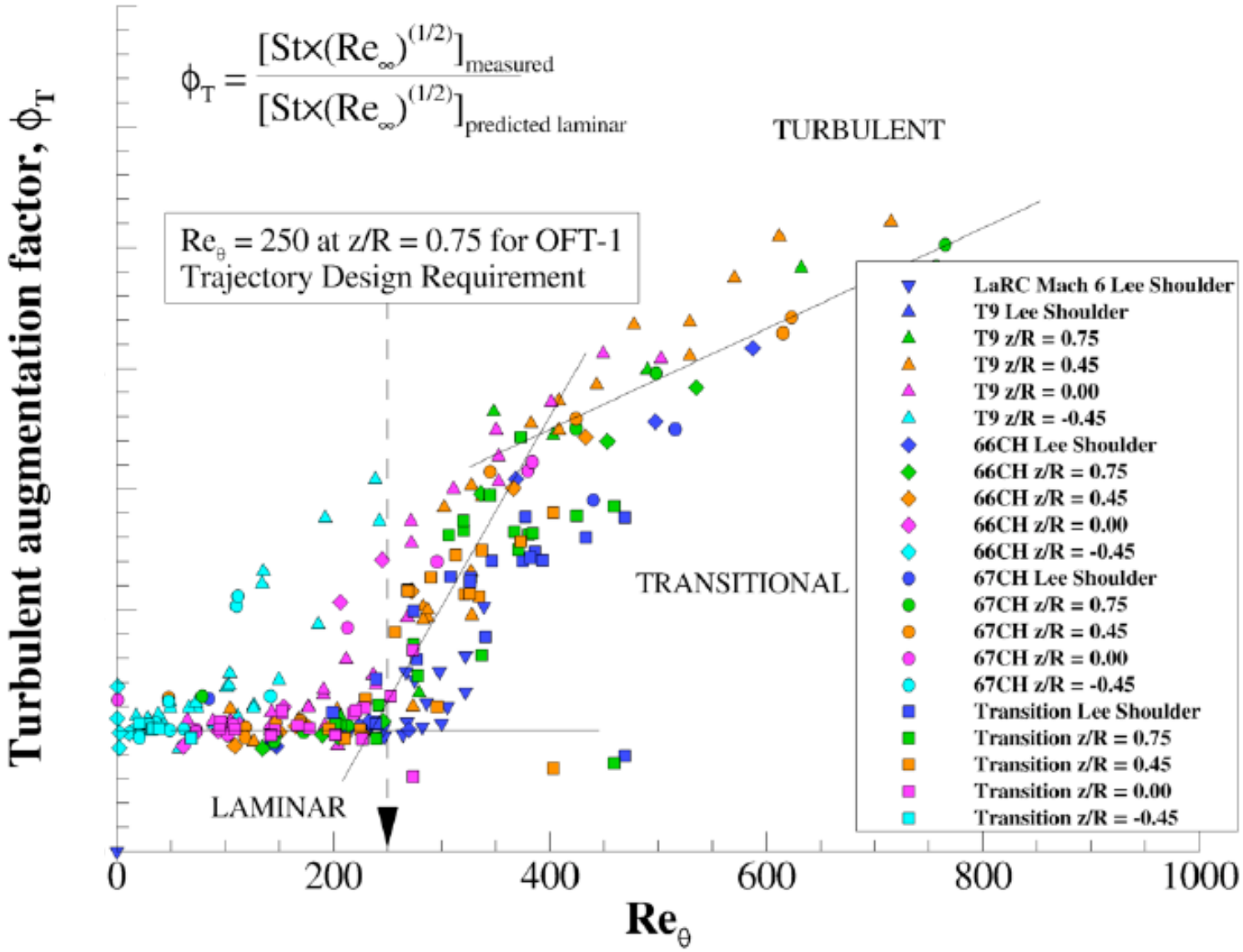




Pre EFT-1

Post EFT-1




$\phi_T = \frac{[St \times (Re_\infty)^{(1/2)}]_{measured}}{[St \times (Re_\infty)^{(1/2)}]_{predicted\ laminar}}$
TURBULENT
Re_θ = 250 at z/R = 0.75 for OFT-1
Trajectory Design Requirement
TRANSITIONAL
LAMINAR
Turbulent augmentation factor, ϕ_T
0
200
400
600
800
1000
Re_θ
LaRC Mach 6 Lee Shoulder
T9 Lee Shoulder
T9 z/R = 0.75
T9 z/R = 0.45
T9 z/R = 0.00
T9 z/R = -0.45
66CH Lee Shoulder
66CH z/R = 0.75
66CH z/R = 0.45
66CH z/R = 0.00
66CH z/R = -0.45
67CH Lee Shoulder
67CH z/R = 0.75
67CH z/R = 0.45
67CH z/R = 0.00
67CH z/R = -0.45
Transition Lee Shoulder
Transition z/R = 0.75
Transition z/R = 0.45
Transition z/R = 0.00
Transition z/R = -0.45