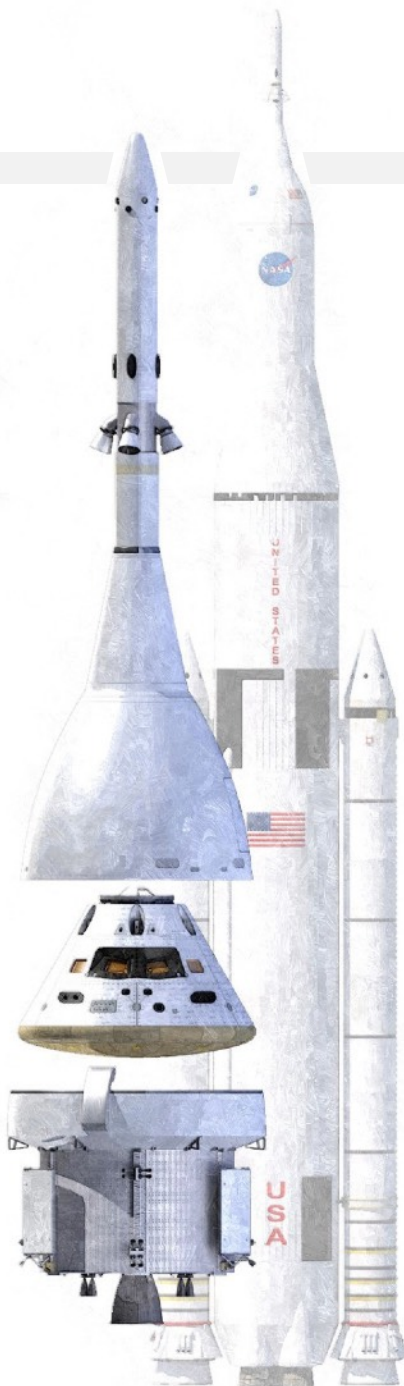




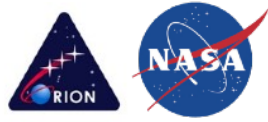
Boundary Layer Transition Challenges for the Orion Capsule

19 OCT 2021

NATO STO AVT-346 Fall 2021 Meeting

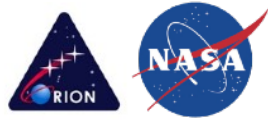
Lindsay Kirk
NASA Johnson Space Center

Primary BLT Contributions for Orion

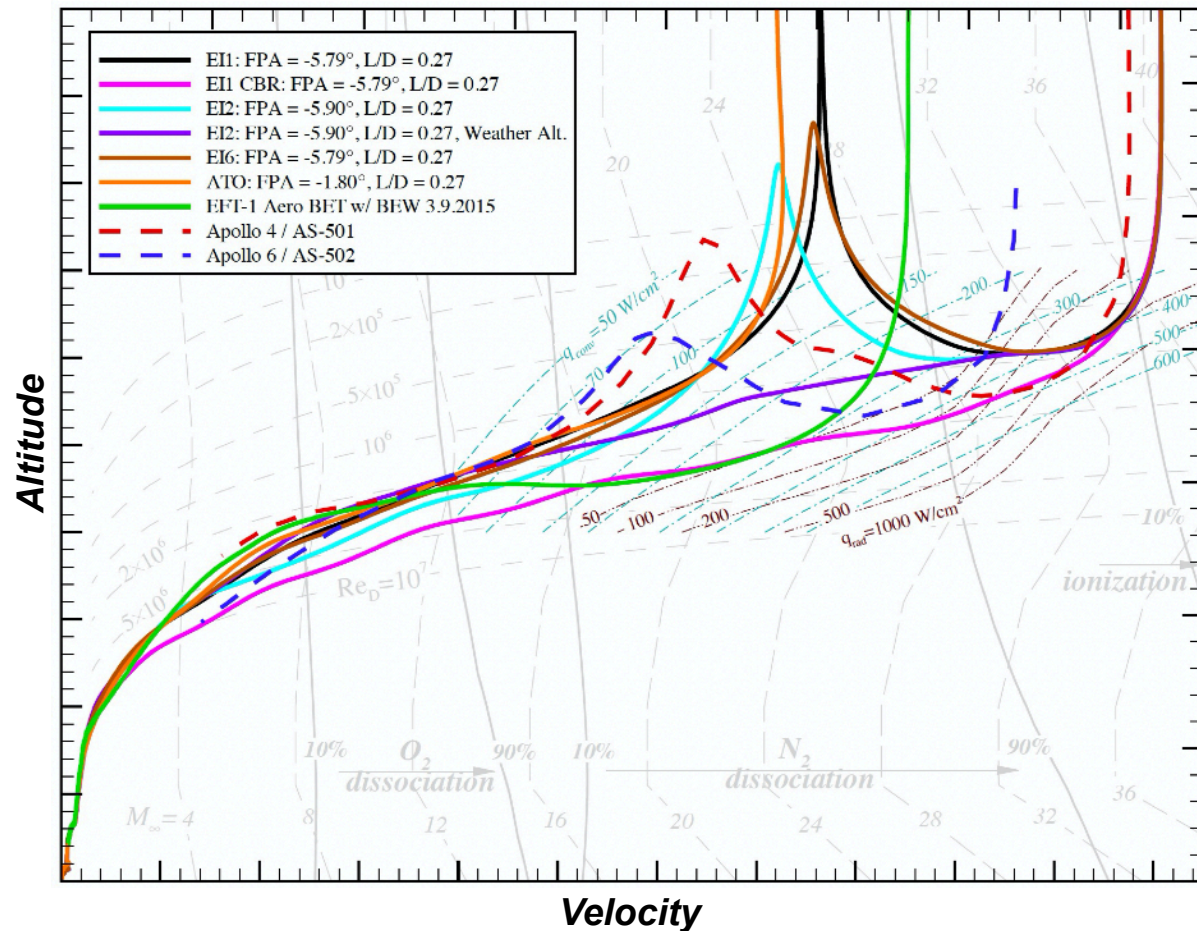


- **Heatshield (subsonic BL edge)**
 - Acreage transition on an ablative surface (rough, blowing) with chemical reactions
 - Discrete roughness transition due to fences/gaps between TPS blocks, instrumentation plugs, TPS block mismatch, and compression pads
- **Backshell (supersonic BL edge)**
 - Acreage transition with ramps (compression and expansion) between panels
 - Transition due to mismatch at tile interfaces and thermal barriers
 - Chemical reactions due to deposition of heatshield ablation products
- **Additional considerations:**
 - Ground-to-flight traceability of transition data
 - Discrete transition due to TPS damage resulting from MMOD impact
 - Relaminarization due to skip entry trajectories

Reentry Trajectory BLT Considerations

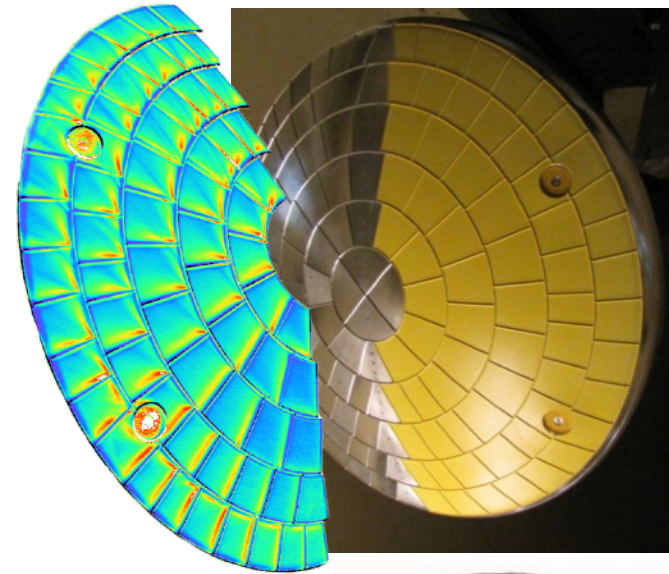


- Orion designed to enter faster than and fly further than Apollo
- Lunar return environments are much more extreme than LEO return making chemistry and radiation much larger contributors to overall environment
 - Convective heating scales with V^3 and radiation heating scales with V^8
 - Mars return is even more challenging at 14 km/sec!
- Strong chemistry effects make ground-to-flight traceability of BLT data challenging
- Orion lunar return trajectories utilize skip guidance, so BL relaminarization must also be accounted for

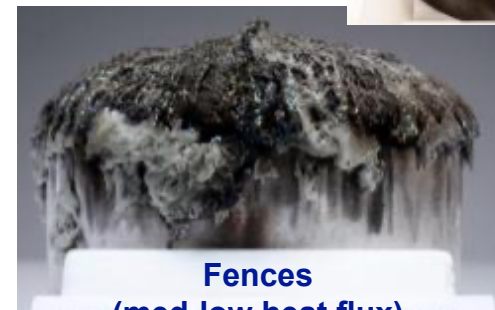


Heatshield BLT Considerations

- **Block heatshield TPS configuration**
 - Mismatch between blocks at interfaces (due to manufacturing or differential recession) can introduce instabilities
 - Gaps (high heat flux) or fences (medium-low heat flux) between block interfaces can be present throughout different portions of the reentry
- **Many opportunities for discrete bypass transition: compression pads, instrumentation plugs, discrete roughness, etc.**
- **Ablative TPS produces rough surface and gas-surface interactions that disrupt the boundary layer and introduce instabilities**



Gaps
(high heat flux)

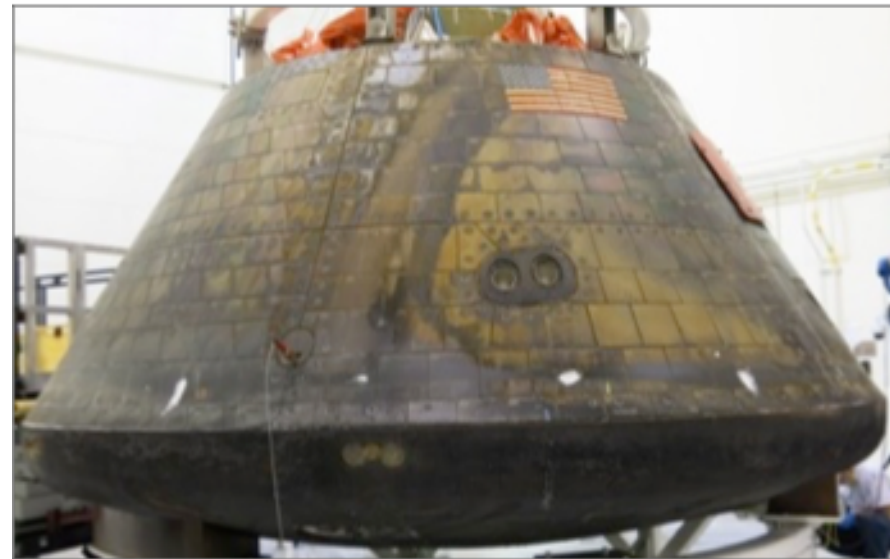


Fences
(med-low heat flux)

Backshell BLT Considerations



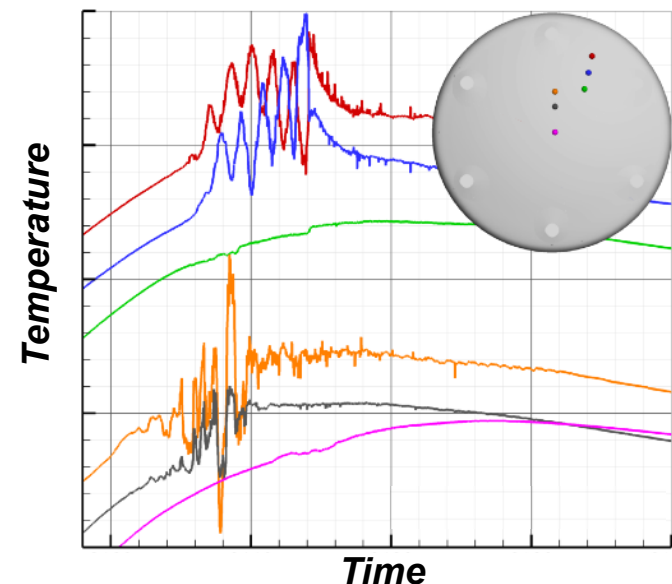
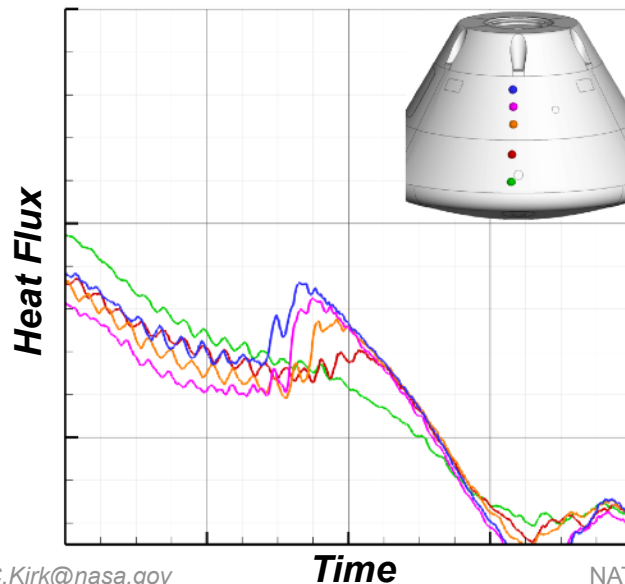
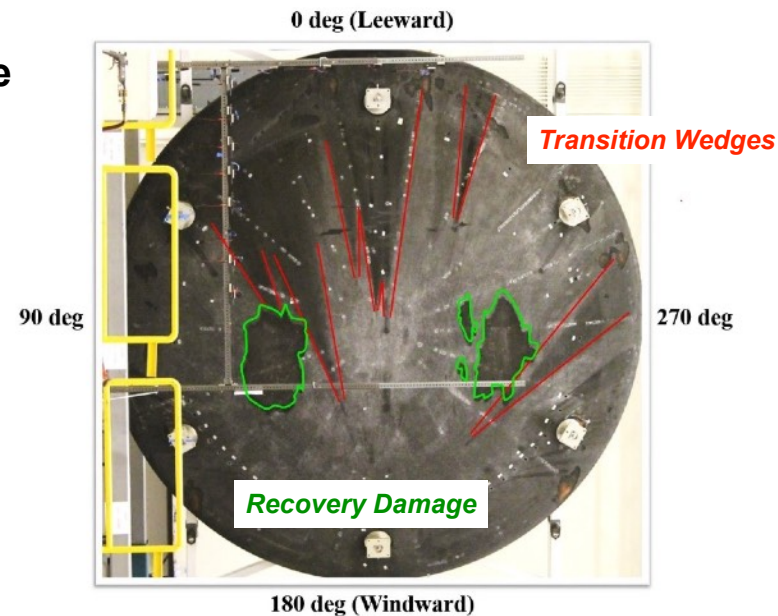
- **TPS panel and tile interfaces**
 - Panel interfaces contain both compression and expansion ramps that will introduce instabilities into the supersonic backshell boundary layer
 - Any mismatch at tile interfaces and/or thermal barriers can introduce steps and gaps leading to bypass transition
- **Changes in surface and boundary layer chemistry due to deposition of heatshield ablation products will affect boundary layer receptivity and stability characteristics**



EFT-1 Flight Transition Observations

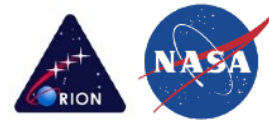


- Post-flight TPS observations showed heatshield transition wedges, some due to natural transition, some due to discrete roughness such as instrumentation plugs.
- Transition indications observed in near-surface temperature measurements
 - Progression from leeward towards windward, but stopping near heatshield geometric center
 - Observed first in centerline measurement locations, followed by off-centerline measurement locations
- Reconstruction of backshell heat flux environments from temperature measurements show transition along the windside centerline.



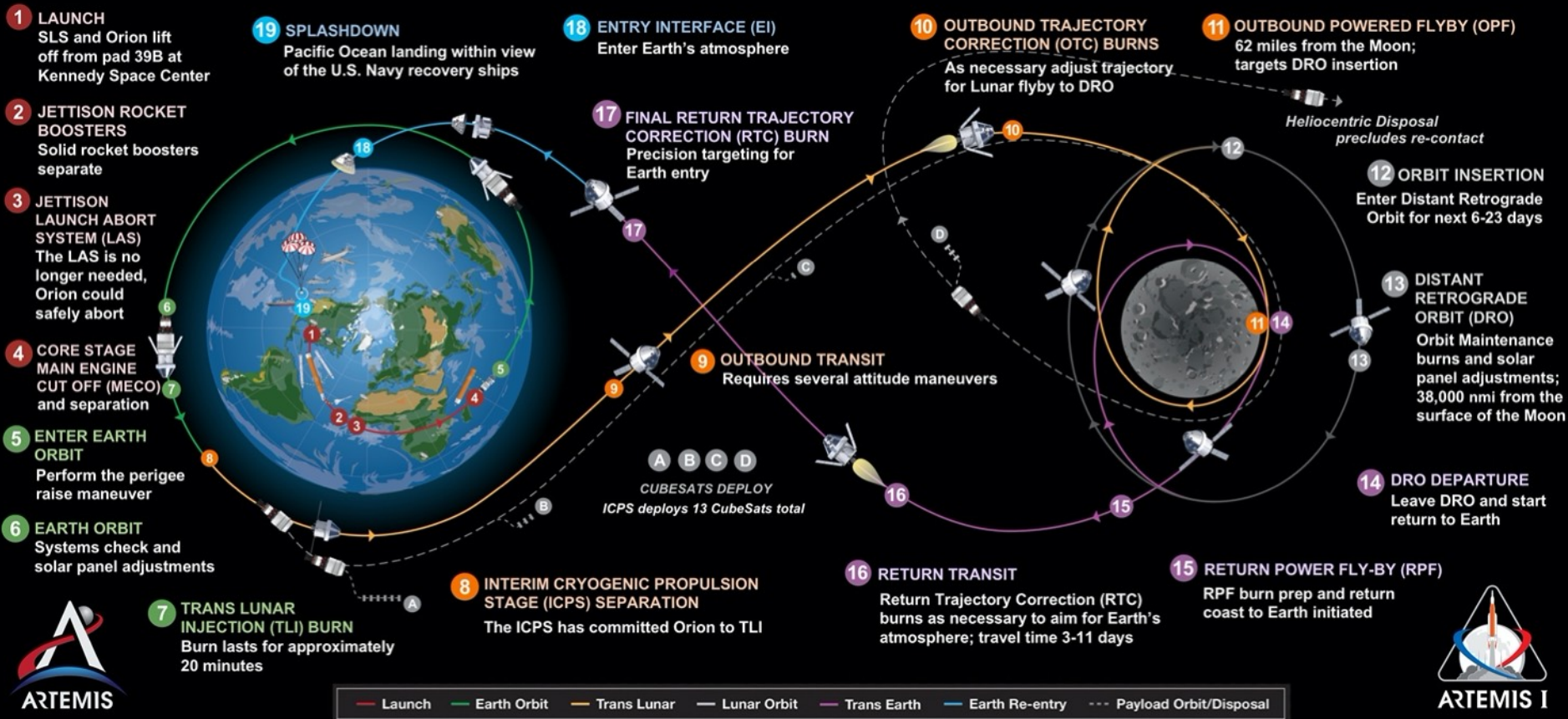
BACKUP

Artemis I Mission Overview



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