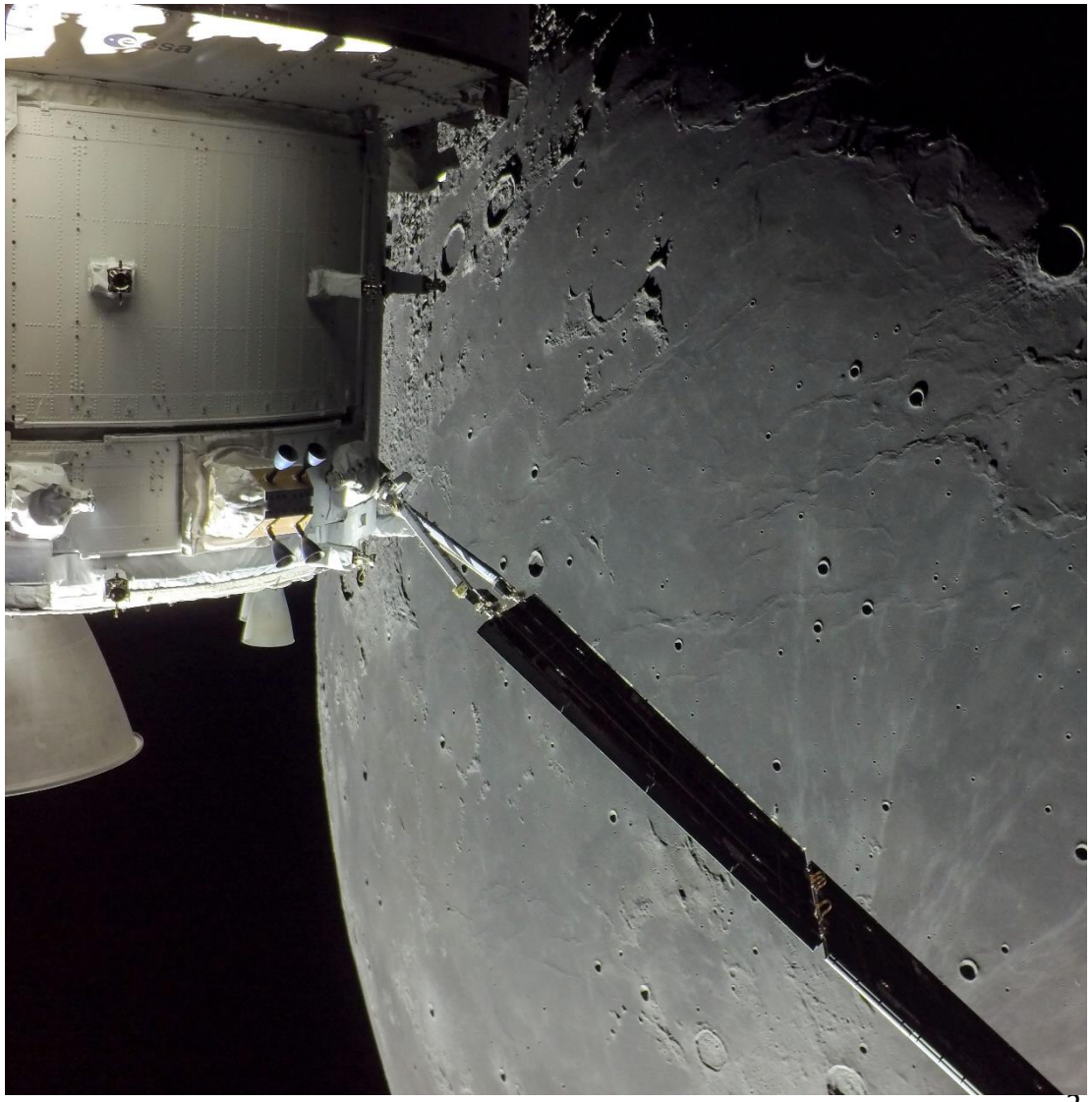
Power Generation Impacts of Spacecraft Albedo During the Artemis I Mission

Space Power Workshop
Torrance, CA
April 23, 2024

Spencer Furin
NASA Glenn Research Center
spencer.c.furin@nasa.gov

What is Spacecraft Albedo?

- **Albedo is diffusely reflected light**
  - Can have thermal, power generation impacts on spacecraft
- **Planetary albedo is light reflected by a planetary body**
  - Usually a concern for low altitudes
  - ISS designed to generate some power from Earth albedo
- **Spacecraft albedo refers to light diffusely reflecting off the spacecraft itself**
  - Similar to glint
  - But diffuse reflection instead of specular

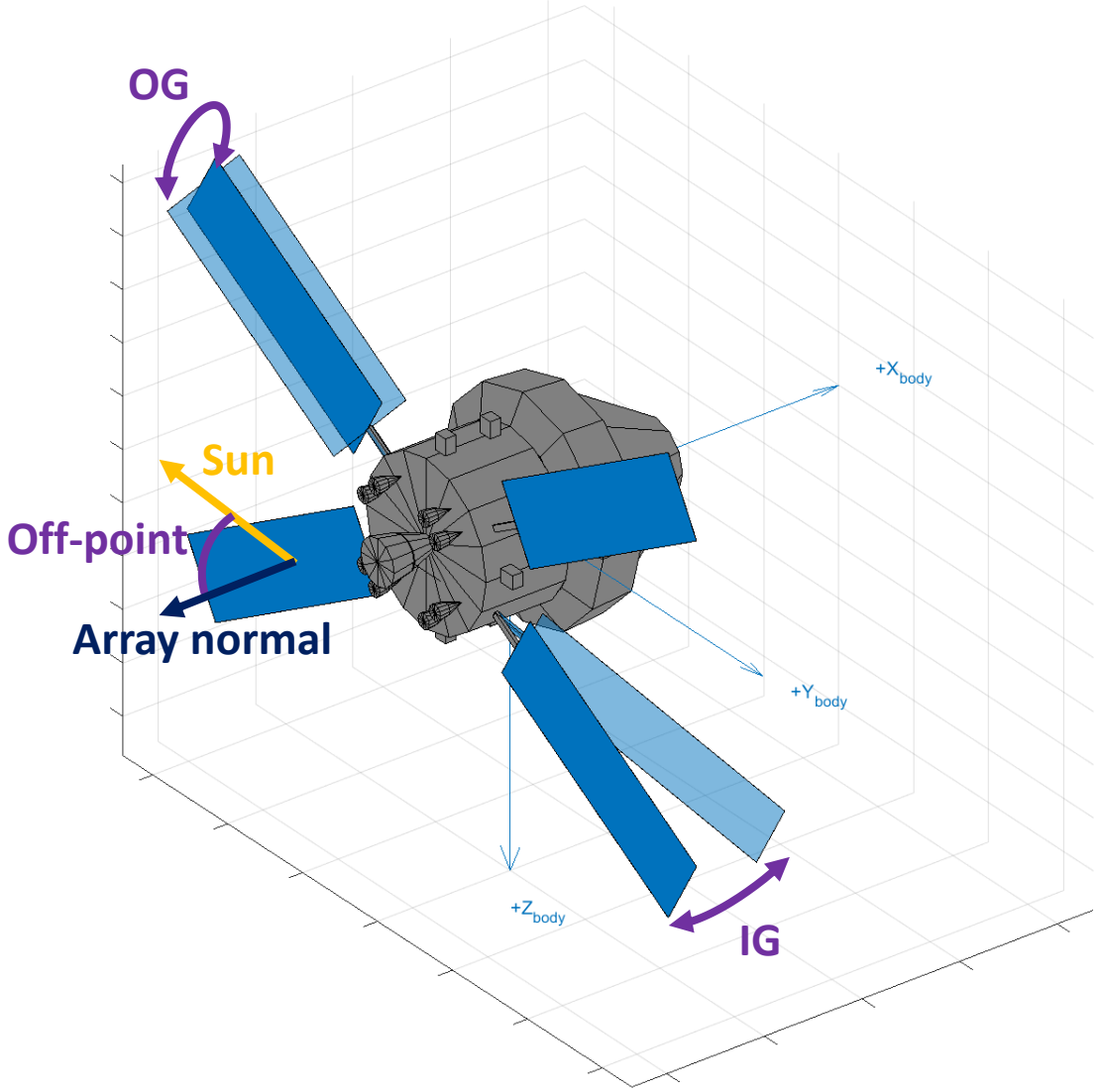


Why study Spacecraft Albedo?

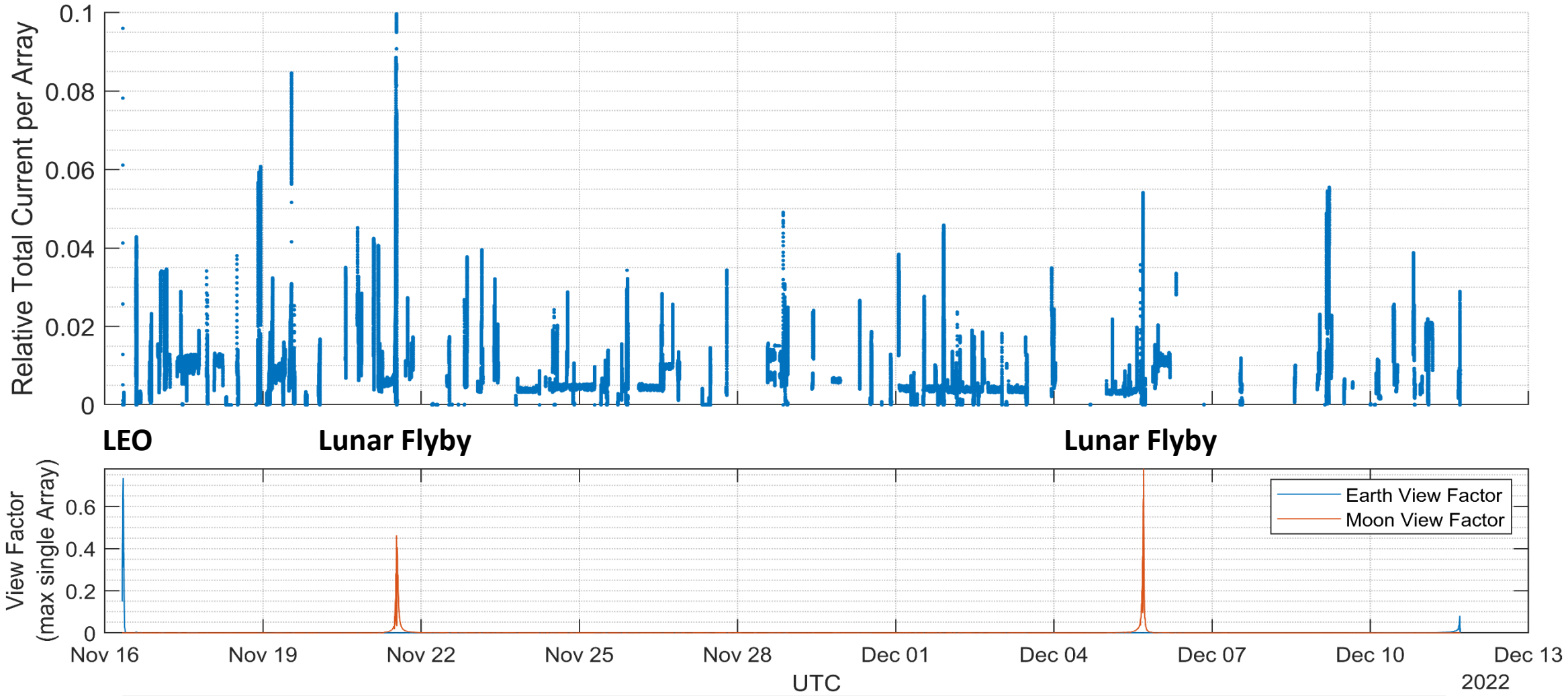
- **Spacecraft albedo can cause photovoltaic cells to generate current**
  - Small, but measurable
  - Noticed in real-time telemetry on Artemis I
- **Account for this generation in power analysis**
  - Orion has array pointing constraints that limit power generation during certain mission events
    - Often pinch-points for the power system
    - Potentially improve launch availability
  - Could potentially drive current generation higher than anticipated – similar to glint
- **Need to avoid albedo in order to "turn off" an array**
  - Power cycle hardware fed directly by the array
  - Battery reconditioning/capacity measurement

Spacecraft Albedo on Artemis I

- **Definitions**
  - Off-point angle: angle between sun vector and array normal
  - IG: inner gimbal
    - Positive position is canted towards nose
  - OG: outer gimbal position
    - 0° is cells facing nose, 180° is cells facing tail
- **No planned, specific event to measure albedo impacts**
  - Used data from across entire mission sampled at 1 Hz
- **Filtered to points where array was off-pointed ≥90°**
  - From edge-on to pointed fully away from sun
  - Treated each array as a separate data point
  - Data may contain trace amounts of glint as well

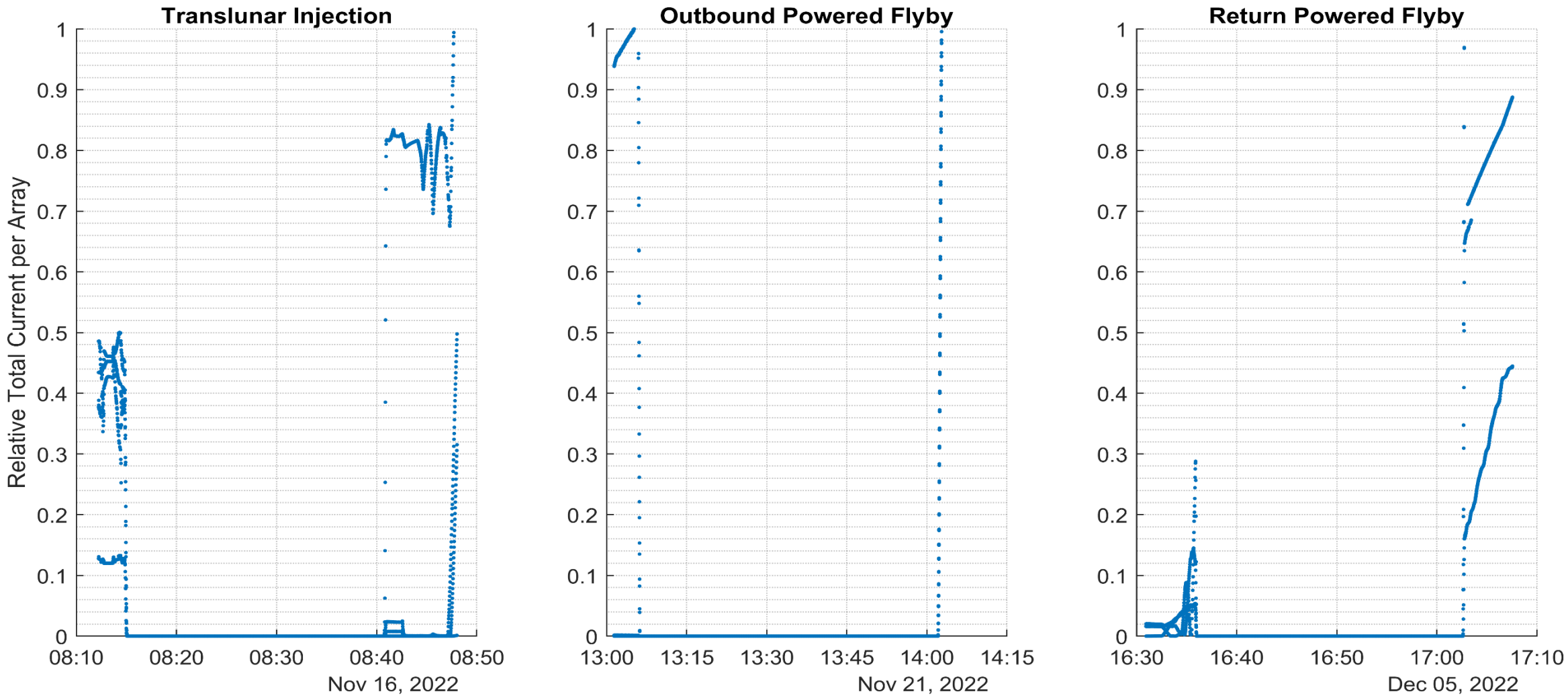


Mission Data Overview



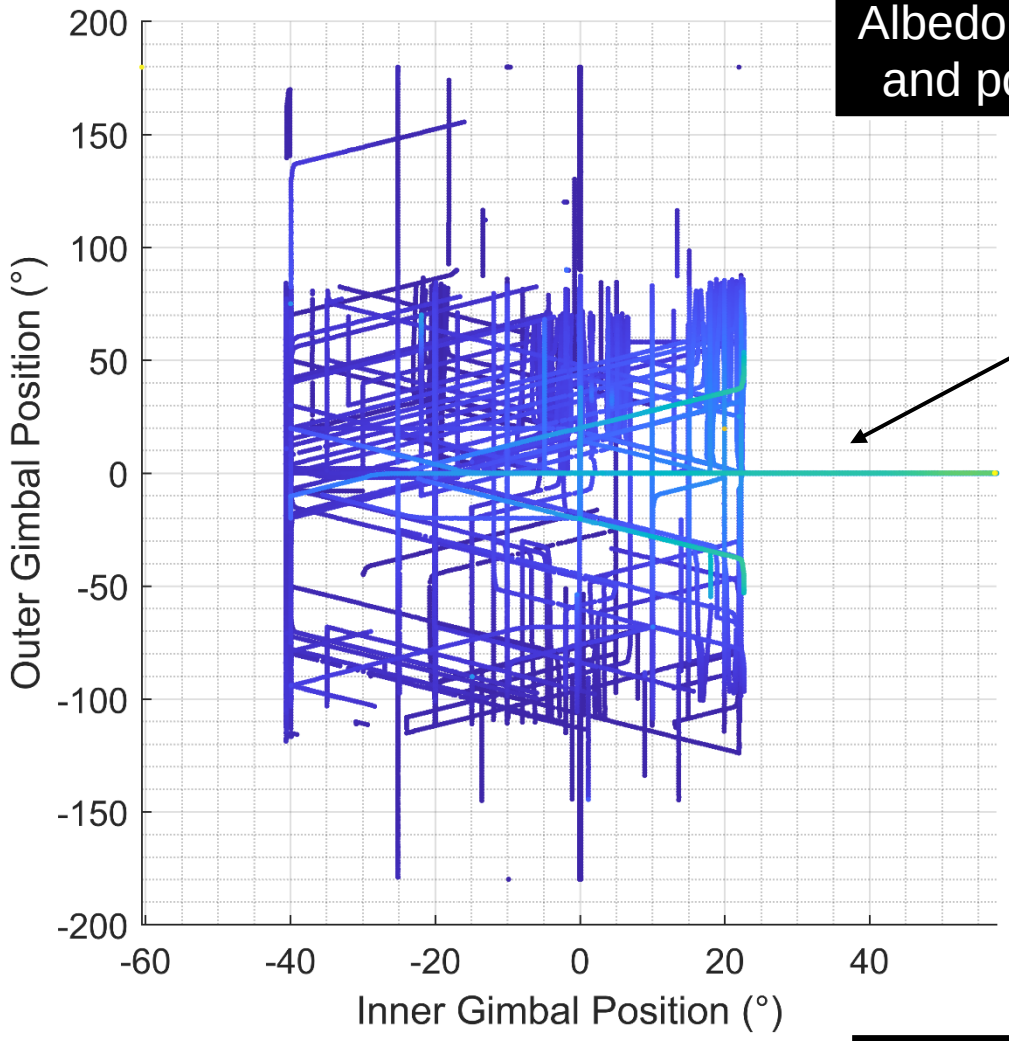
Significant amount of measurable current from an off-pointed array throughout the mission
Only a few, short durations where planetary albedo could have been a contributor

Telemetry Accuracy

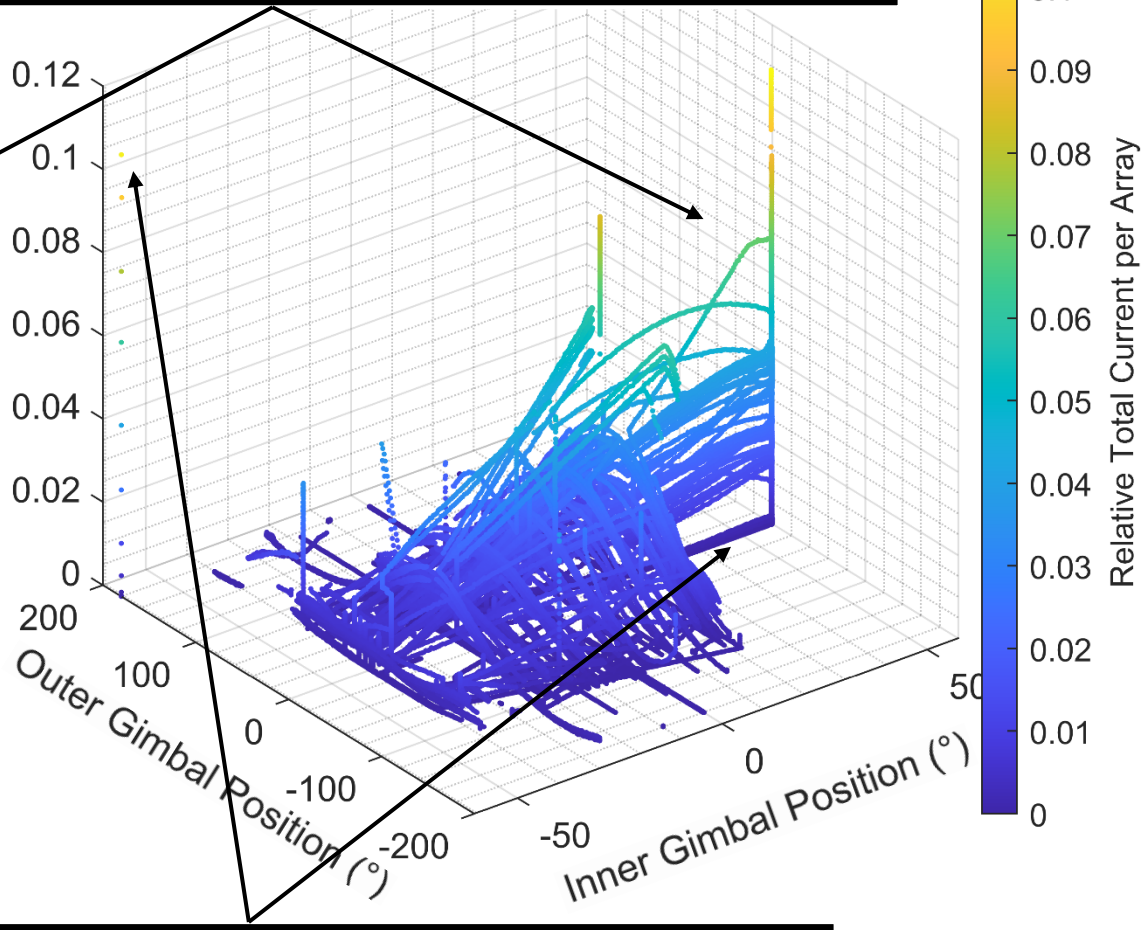


Data from eclipses shows that sensors can and did accurately measure periods of zero current

Generation vs Gimbal Positions

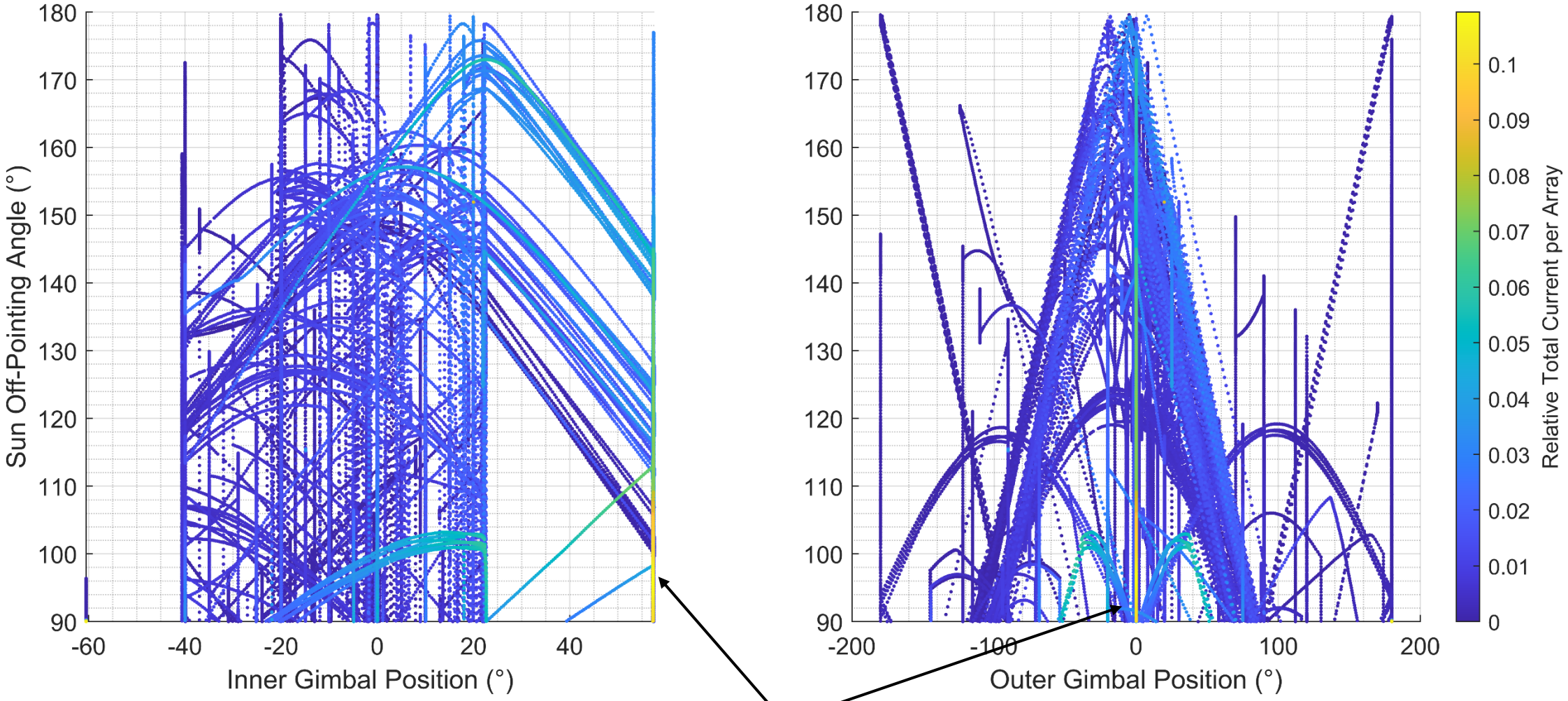


Albedo current typically associated with small OG angles and positive IG angles (cells forward, arrays canted in)



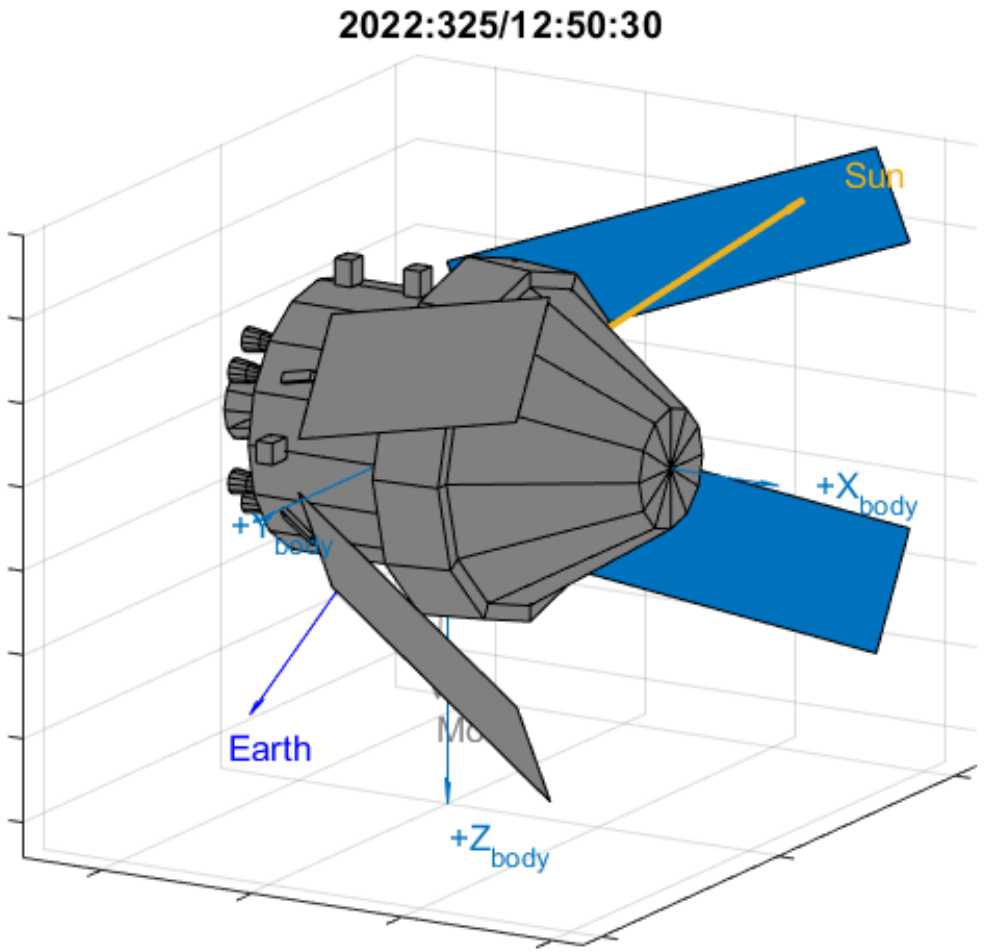
But not always – points with zero current recorded for same gimbal positions + one significant outlier event

Generation vs Off-Point Angle

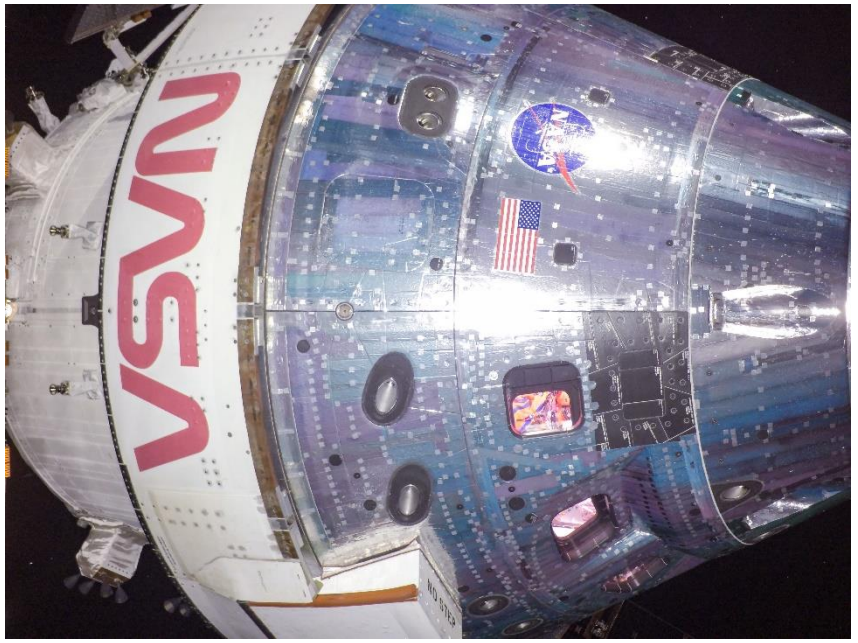


Significant albedo events consistently associated with low off-pointing angles

Specific Condition: Lunar Flybys

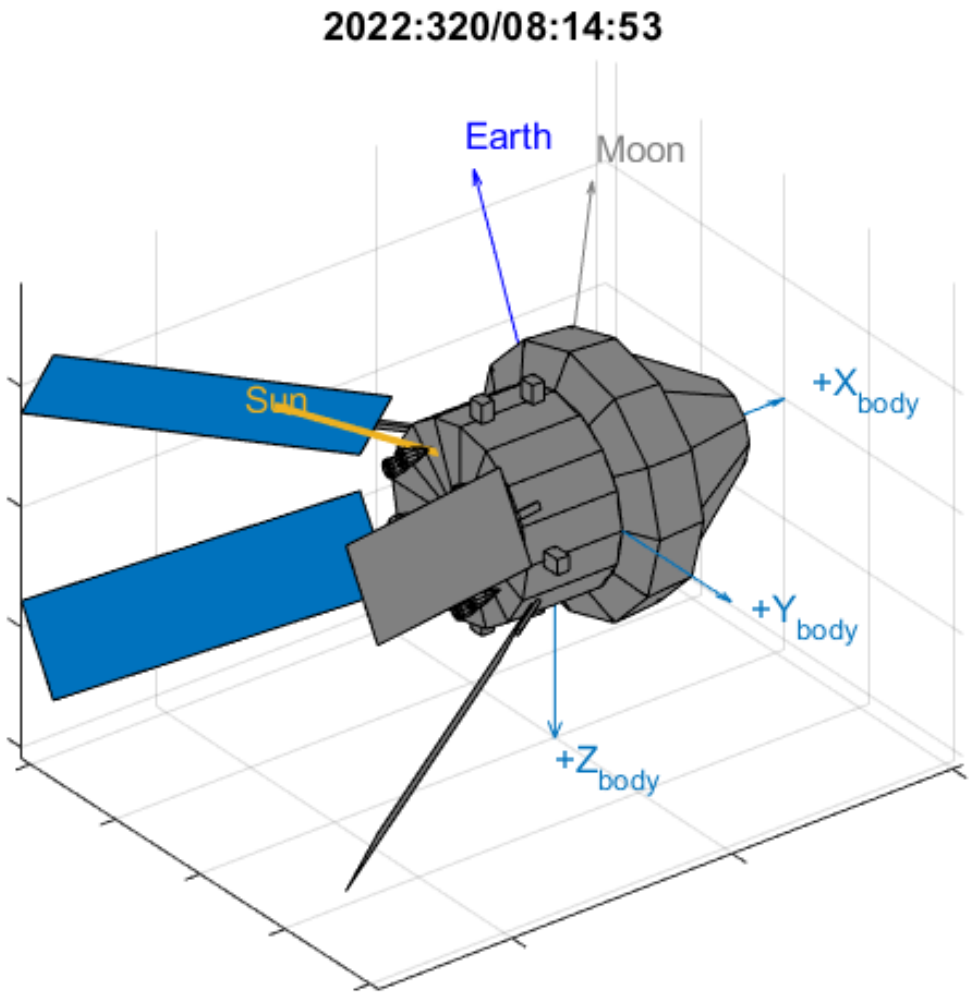


- **Arrays canted forward**
  - Protects arrays during propulsive burn
- **Follows primary trend identified on earlier slides**
  - Cells (blue side) facing in, array canted forward
  - Large view factor of sun-facing side of vehicle
    - Comparison of arrays suggests little influence from lunar albedo
  - Highest albedo generation recorded during mission



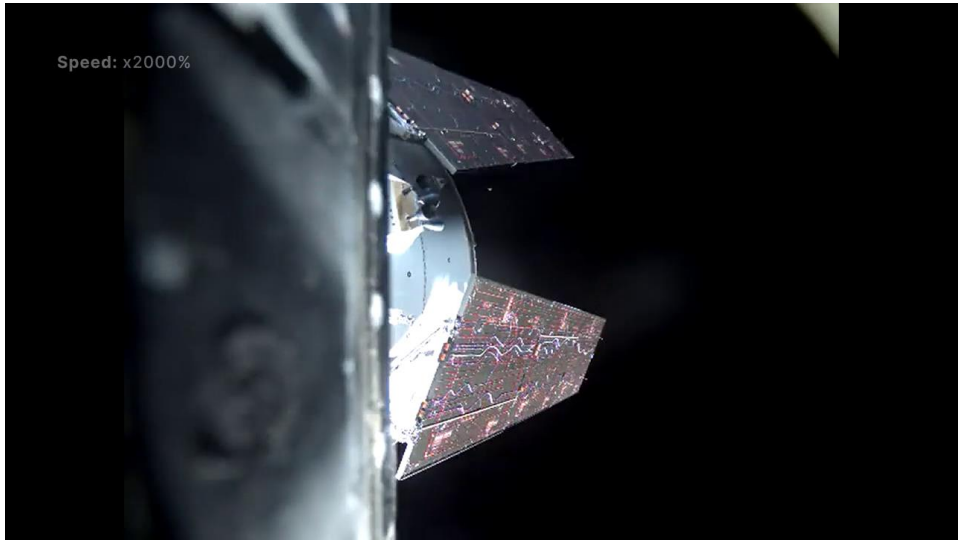
View from array tip camera

Specific Condition: Translunar Injection



Upper stage not shown in model

- **Arrays canted aft**
  - Protects arrays during propulsive burn by upper stage
- **Outlier event noted on earlier slide**
  - For most of mission, this position would have views mostly of space
  - First few hours of mission, this position provides almost full view of the upper stage



View from crew module adapter camera

Results Discussion

- **Two main factors influence Orion's arrays' response to spacecraft albedo throughout mission**
  - Array's position relative to the vehicle
    - Determined by gimbal positions
  - Sun's position relative to the vehicle
    - Determined by attitude
  - Neither is sufficient to cause power generation from albedo on its own
    - Both must be controlled if trying to induce or avoid albedo-generated current
- **Greatest response is seen when arrays are canted significantly and are close to edge-on to sun**
  - Canting ensures array has a significant view of the rest of the spacecraft
  - Low off-pointing angle allows sun to illuminate the spacecraft structure while avoiding shadows from the array itself

Conclusion

- **Orion is uniquely susceptible to power generation impacts from spacecraft albedo**
  - White paint, aluminized tape on exterior surfaces
  - Mission profile featuring frequent solar array repositioning, attitude maneuvers
  - Makes it an excellent platform to characterize solar array response
- **While results shown here are specific to Orion, fundamental principles are applicable more generally**
  - Albedo generation increases when solar arrays are pointed towards the vehicle
  - Albedo generation increases when the sun illuminates the vehicle from the side, avoiding the array's own shadow
- **May be worth analyzing preflight for certain mission profiles**
  - Power stressing events driven by solar array positioning rather than eclipses

Questions?

Spencer Furin