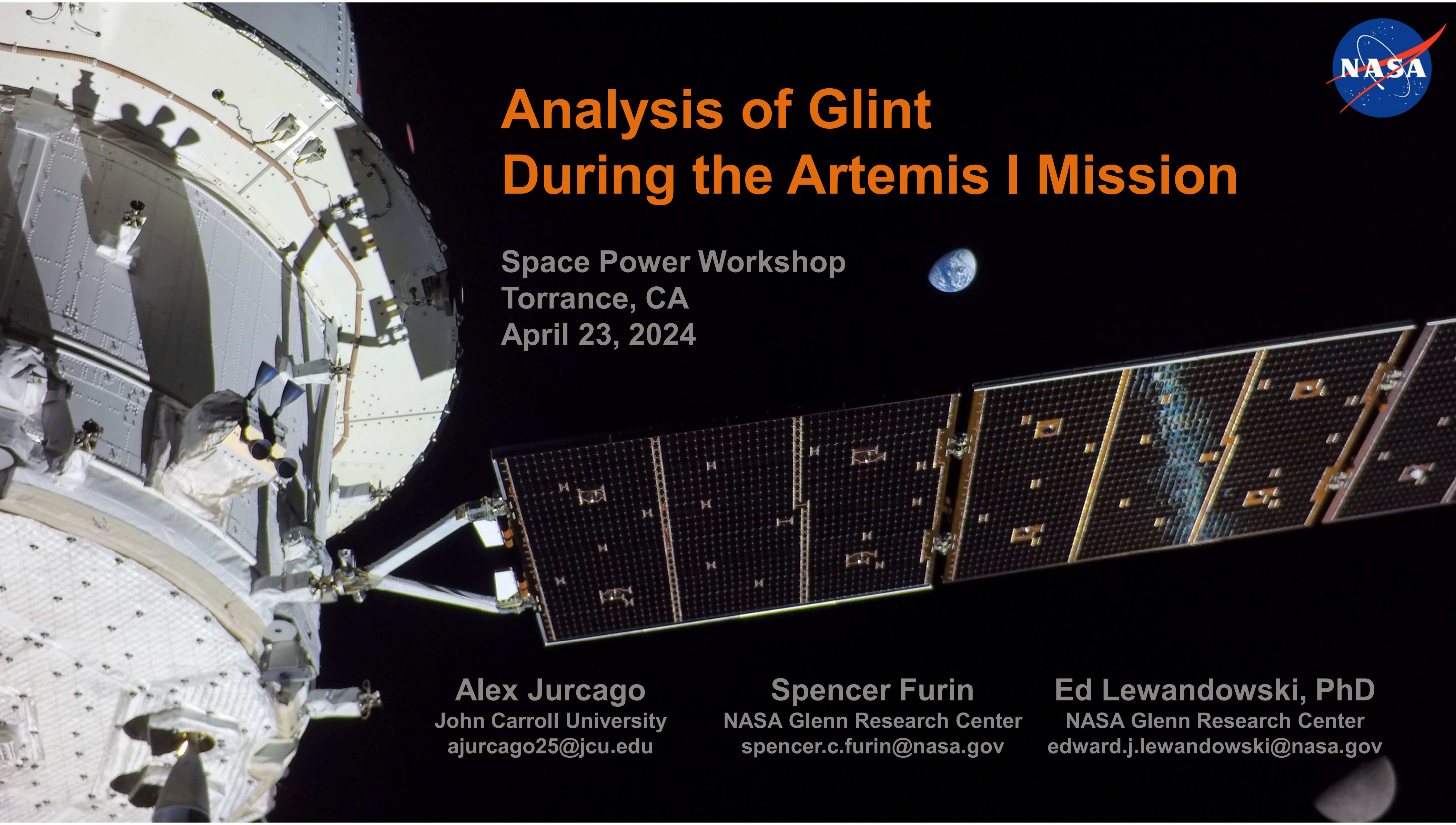

Analysis of Glint During the Artemis I Mission

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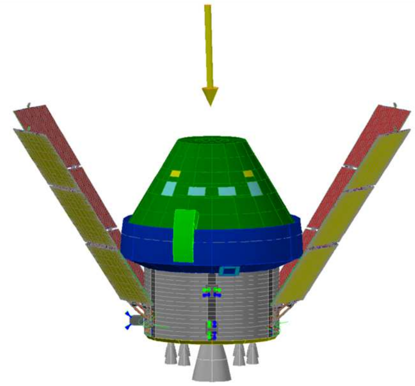
What is Glint?

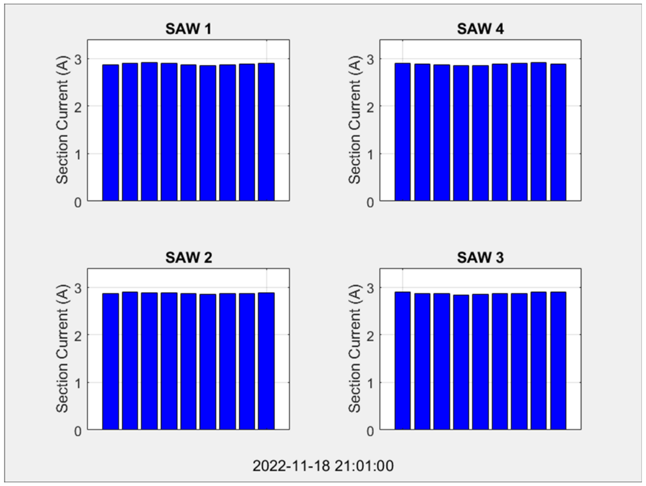
- **Reflection of light off a specular surface**
  - Shiny/mirror-like
- **Glint in the context of spacecraft**
  - Glint visible to external observers
  - Glint back onto itself or another spacecraft
- **Potential consequences**
  - Increased current and heat
  - Interfering with crew's view
  - Interfering with star tracking or other components
- **Orion spacecraft is susceptible to glint**
  - Reflective aluminized tape covering crew module

Glint Test on Artemis I

- **Concern that glint could cause excessive solar array current generation**
  - Cleared with analysis years before flight
- **Flight test added to study glint during Artemis I**
  - Goal of anchoring models with flight data
  - Model predicted that attitude/array positions already planned for visual inspection procedure would produce measurable glint without exceeding hardware limits
  - Performed during both outbound and return legs
- **Glint effects clearly visible in current telemetry**
  - Localized flux led to significant increase in current on one to two circuits compared to neighboring circuits
  - Location of glint moved along wing during maneuver

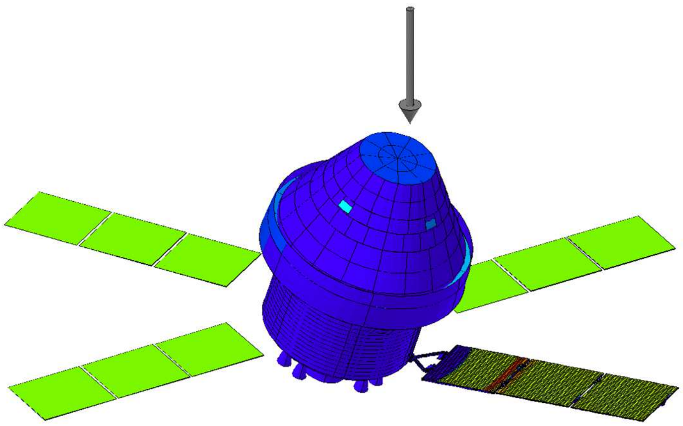


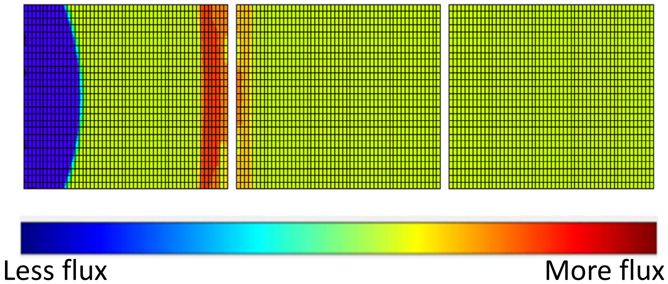
Vehicle attitude during DFTO



Analysis Method

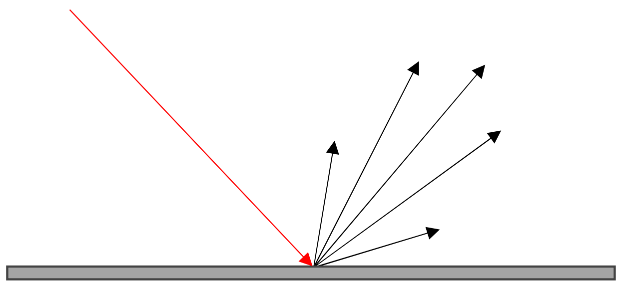
- **Inputs taken from telemetry**
  - Sun vector, sun-spacecraft distance, solar array gimbal positions → thermal model
  - Operating voltage, section shunt status→ electrical model
- **Monte-Carlo ray tracing for radiation performed by RadCAD**
  - Optical properties of each node on model defined for solar spectrum
  - Calculates incident flux per solar cell, passed to electrical model
- **Solar array model**
  - Based on spacecraft power system model developed and used at NASA Glenn Research Center
  - Generates IV curve for each cell, composites into strings and circuits
  - Current extracted from composite circuit curve based on operating voltage



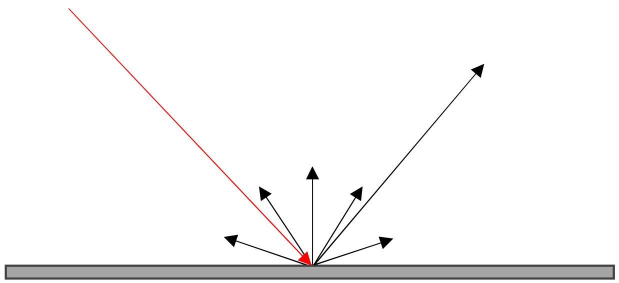


Glint Model Sensitivity Testing

- **Importance of understanding model sensitivity**
  - Glint is a multi-disciplinary problem
  - Need to understand what factors are/are not important when applying to new spacecraft models
- **Multiple contributing factors were studied**
  - Case matrix established to test these variables
- **Parameters of the system**
  - Model geometry
  - Sun vector
    - Off-point angle: angle between longitudinal axis and sun vector
    - Roll angle: azimuth of sun vector around longitudinal axis
  - Solar array inner gimbal angles
  - Crew module optical properties
    - Specularity – the probability of a light ray to directly reflect off a node
      - If light ray is not absorbed or reflected specularly, it reflects diffusely in a random direction
    - Absorptivity – the probability of a light ray to be absorbed by a node



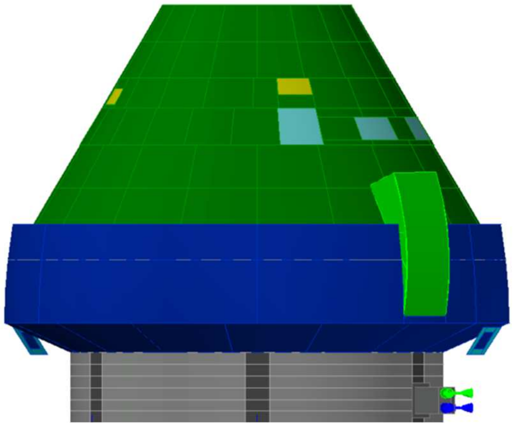
Reality

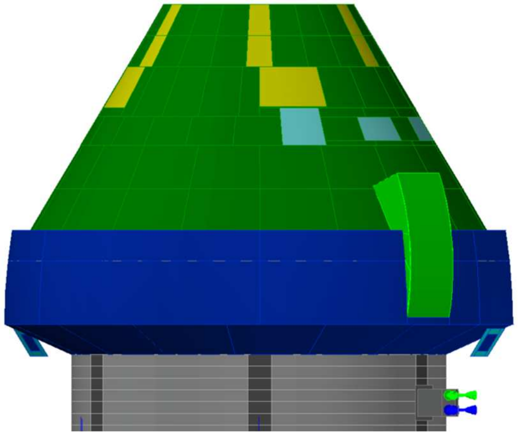


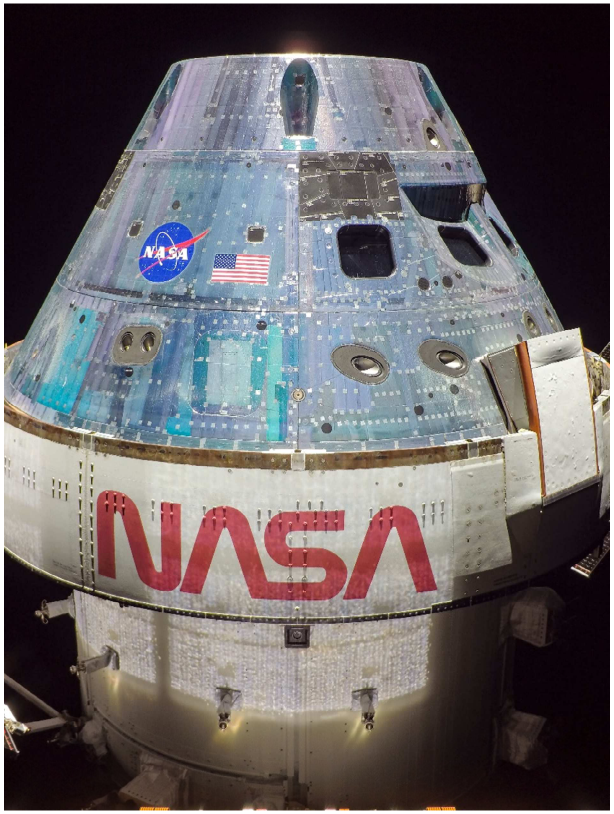
RadCAD reflection method

Geometry Sensitivity

- **Model changes had to be made for simulated data to match in-flight glint pattern**
  - Added detail to the crew module surface nodes to account for large untaped areas
  - Slightly shifted some geometric features

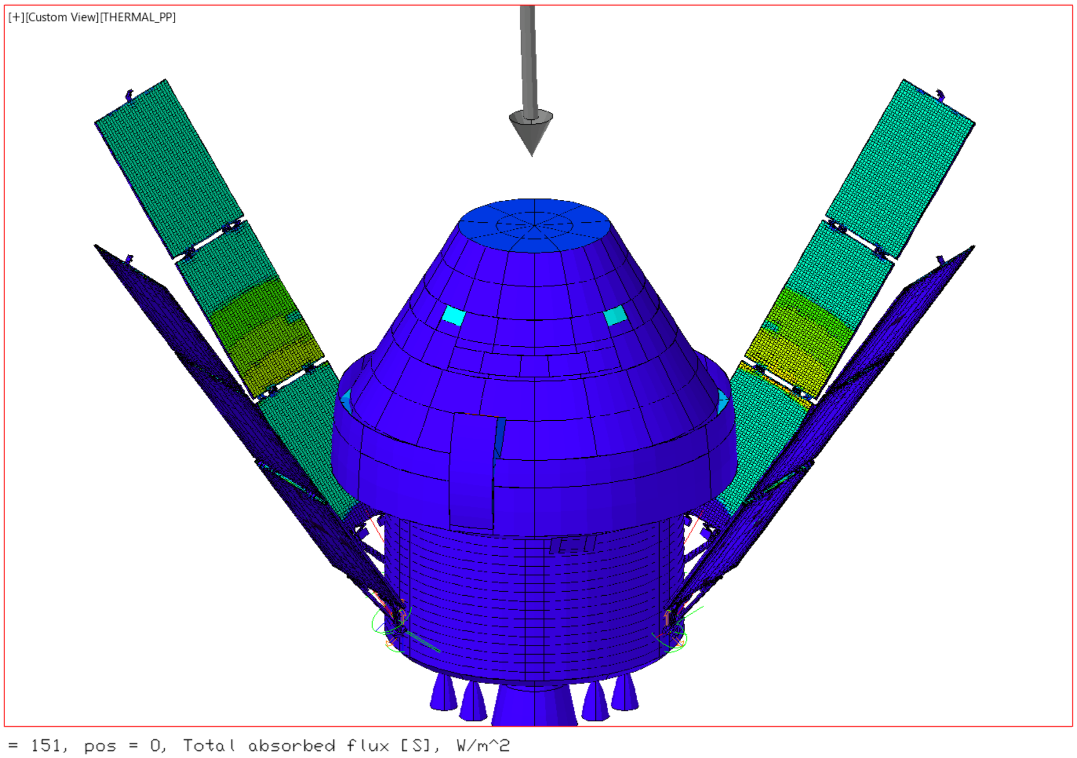




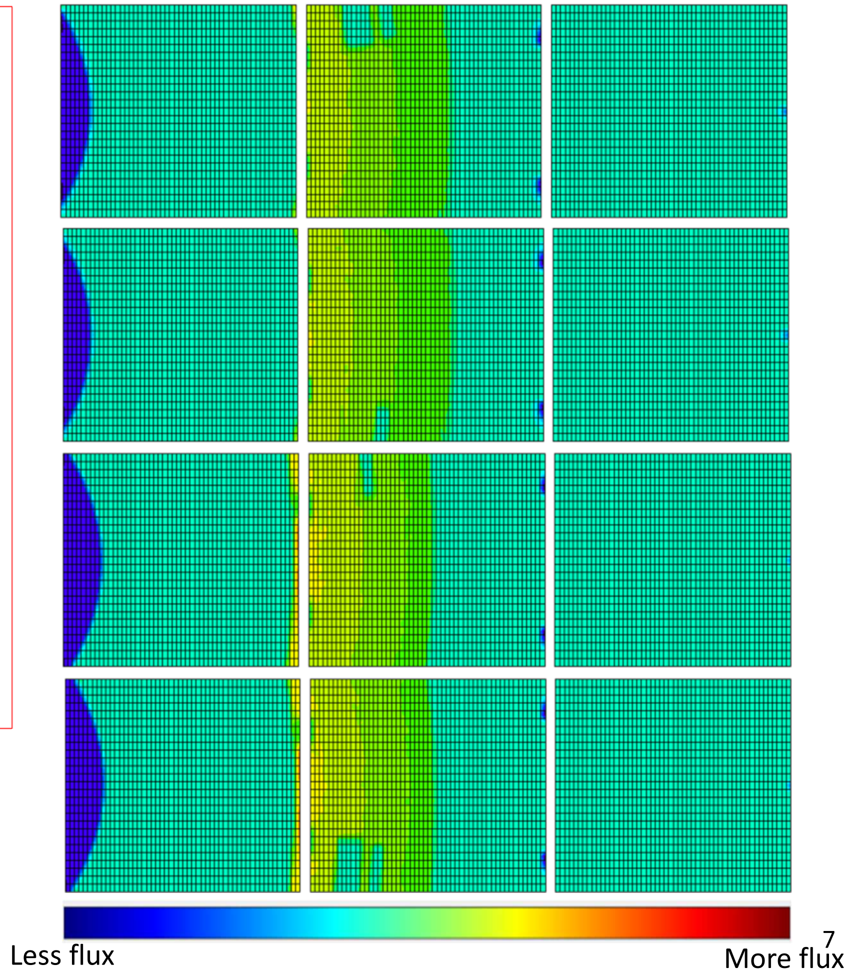


Changes as small as a few cm drastically change glint-generated current

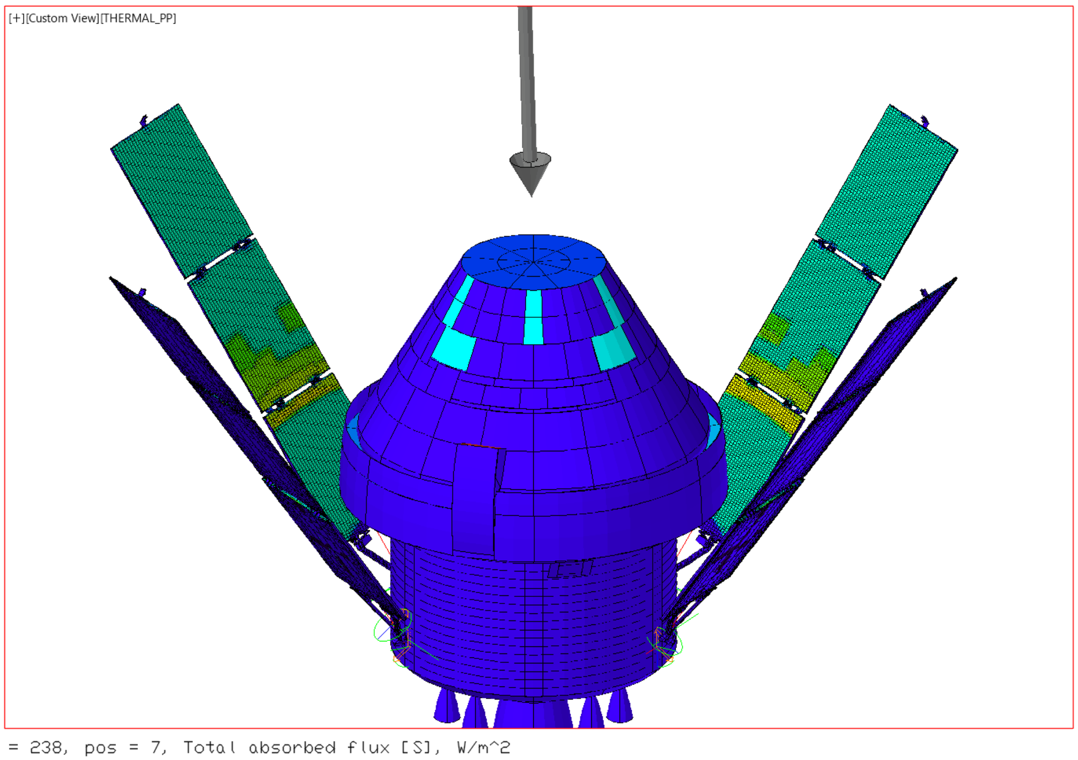
Before Model Geometry Changes



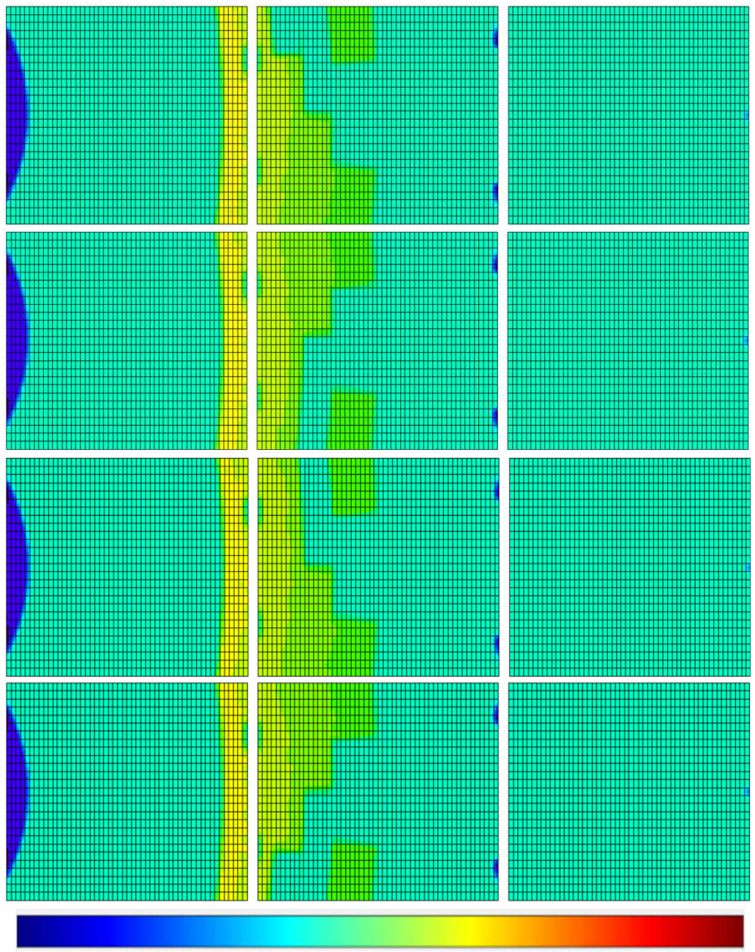
No glint on innermost panel, prominent shadowing



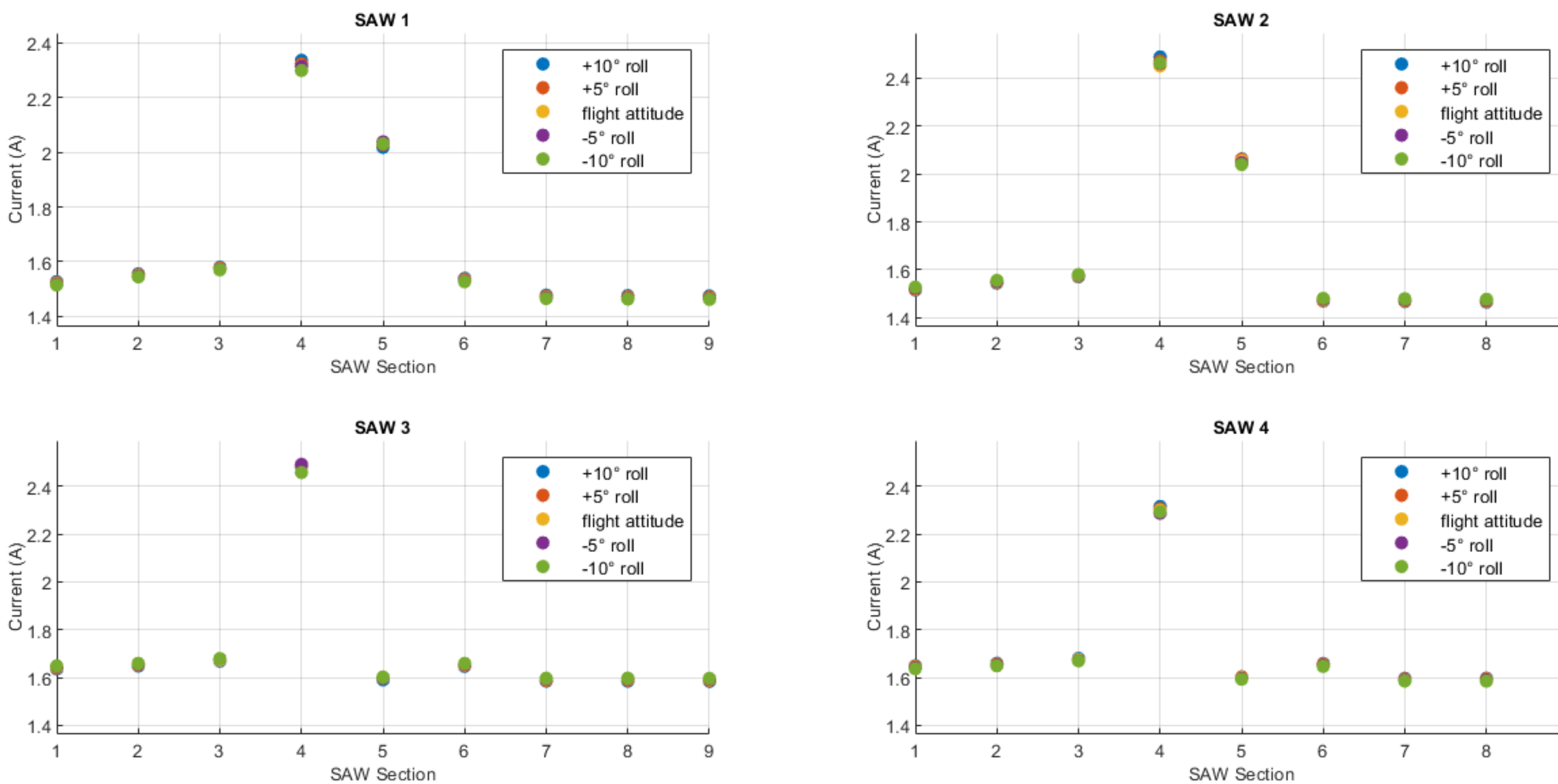
After Model Geometry Changes



Inner panel glinted, crew module details visible, and reduced shadowing

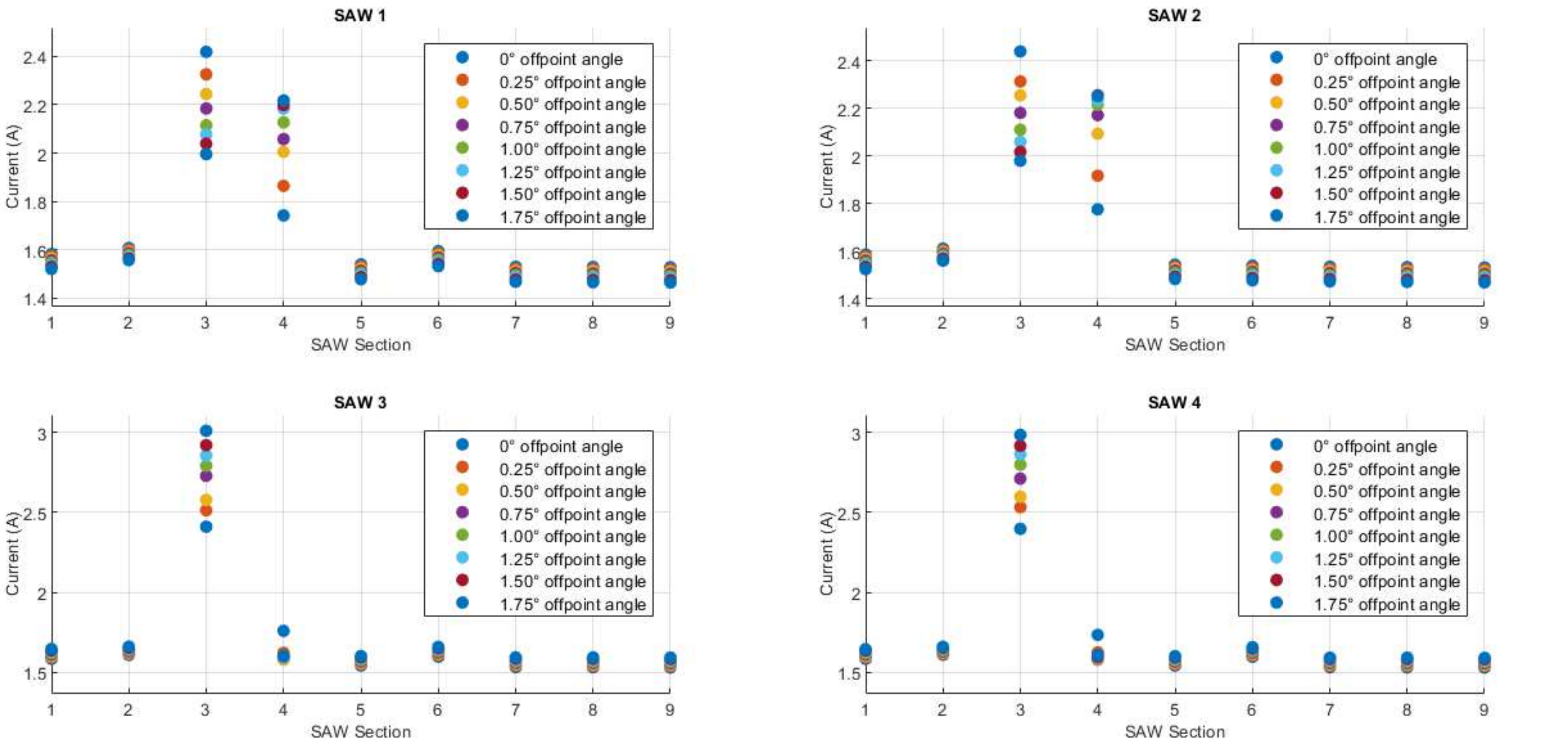


Sun Vector Roll Angle Sensitivity



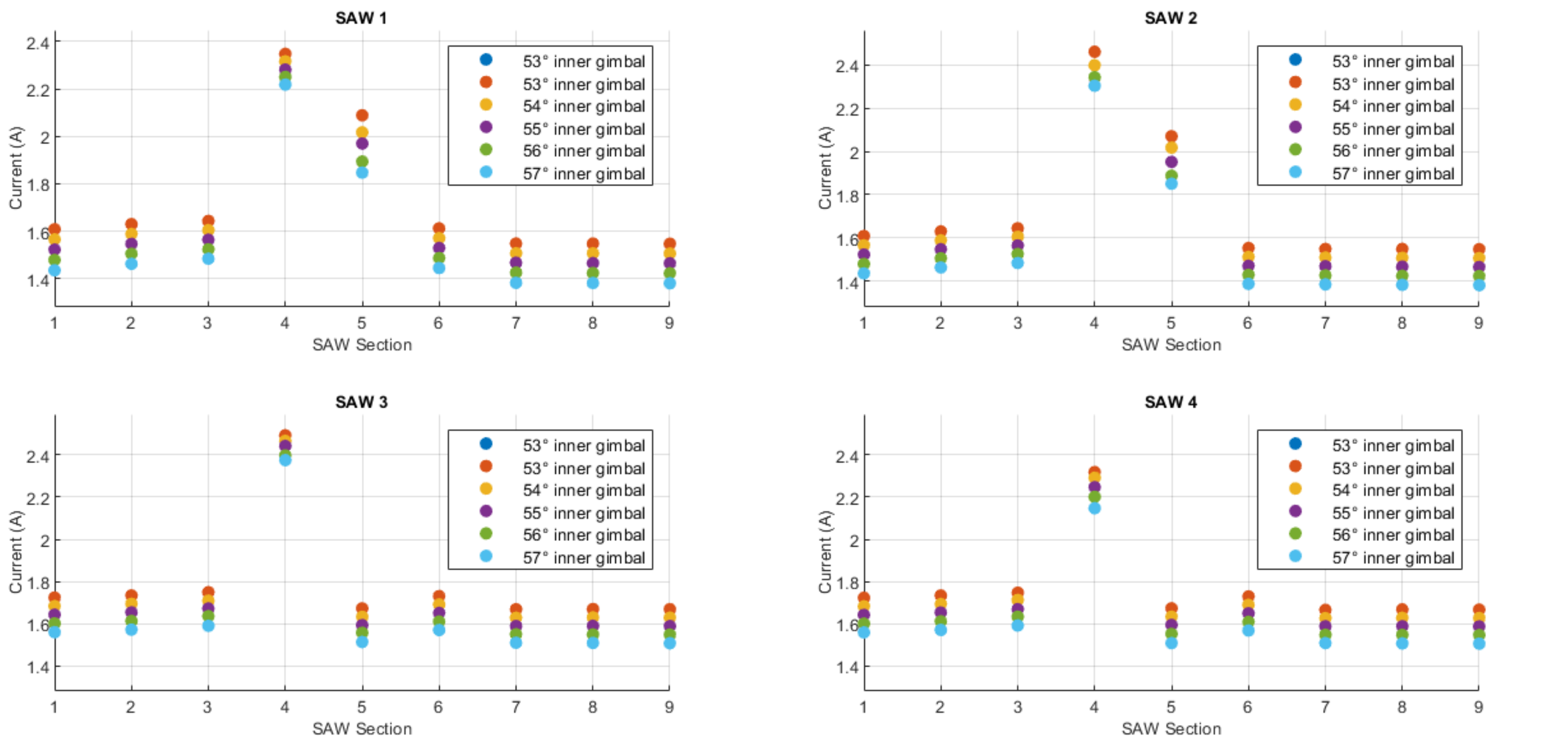
Little variation in current across a ±10° range

Sun Vector Off-point Angle Sensitivity



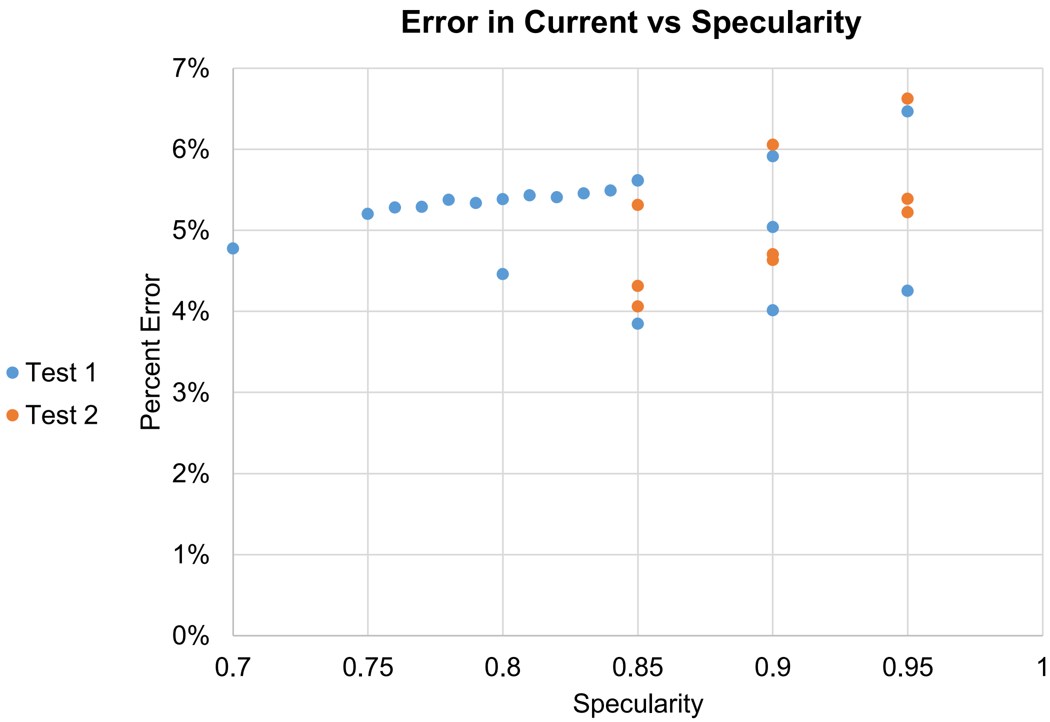
Significant variation in glinted current from 0-1.75°

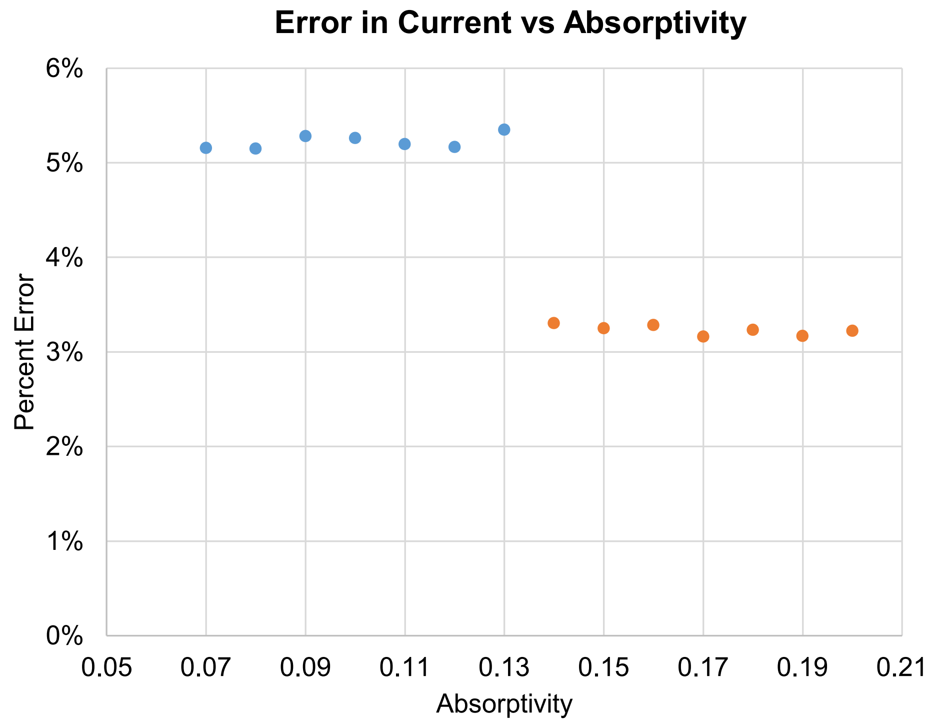
Solar Array Inner Gimbal Angle Sensitivity



All sections impacted the same, regardless of glint

Optical Property Sensitivity





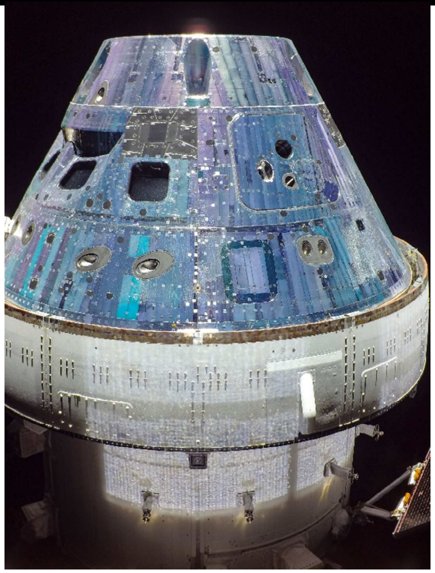
Results are more sensitive to specularity than absorptivity, but results were inconsistent
Optical properties may have changed over several weeks between two tests
Trend suggests specularity is <1 (worst-case prior assumption)

Conclusions

- **Glint can significantly impact current generation for a solar powered spacecraft**
  - Important to model correctly to avoid inadvertent hardware damage
  - Observed >50% current increase in glinted sections
  - Risk from glint must be considered and analyzed when adding specular surfaces to a spacecraft
- **Artemis I flight test data shows model predictions were conservative**
  - Earlier worst-case analysis is bounding
- **Sensitivity testing revealed parameters that most impact the modeling of glinted current**
  - Sensitive to error in:
    - Spacecraft surface geometric features and details
    - Off-point angle component of the sun vector
  - Less sensitive to error in:
    - Solar array position
    - Optical properties of surface

Future Analysis

- **Continue preflight glint analysis on future Artemis missions**
  - Model the effects of glint interaction between different spacecraft
  - Orion docking to other vehicles
- **Conduct a more in-depth study of the effects of sun vector on glint**
  - Uncertainty measurement in sun vector telemetry (including tolerance)
- **Study reflection of light off cover glass of cells**
  - Lights up crew module adapter in flight images



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Questions?

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