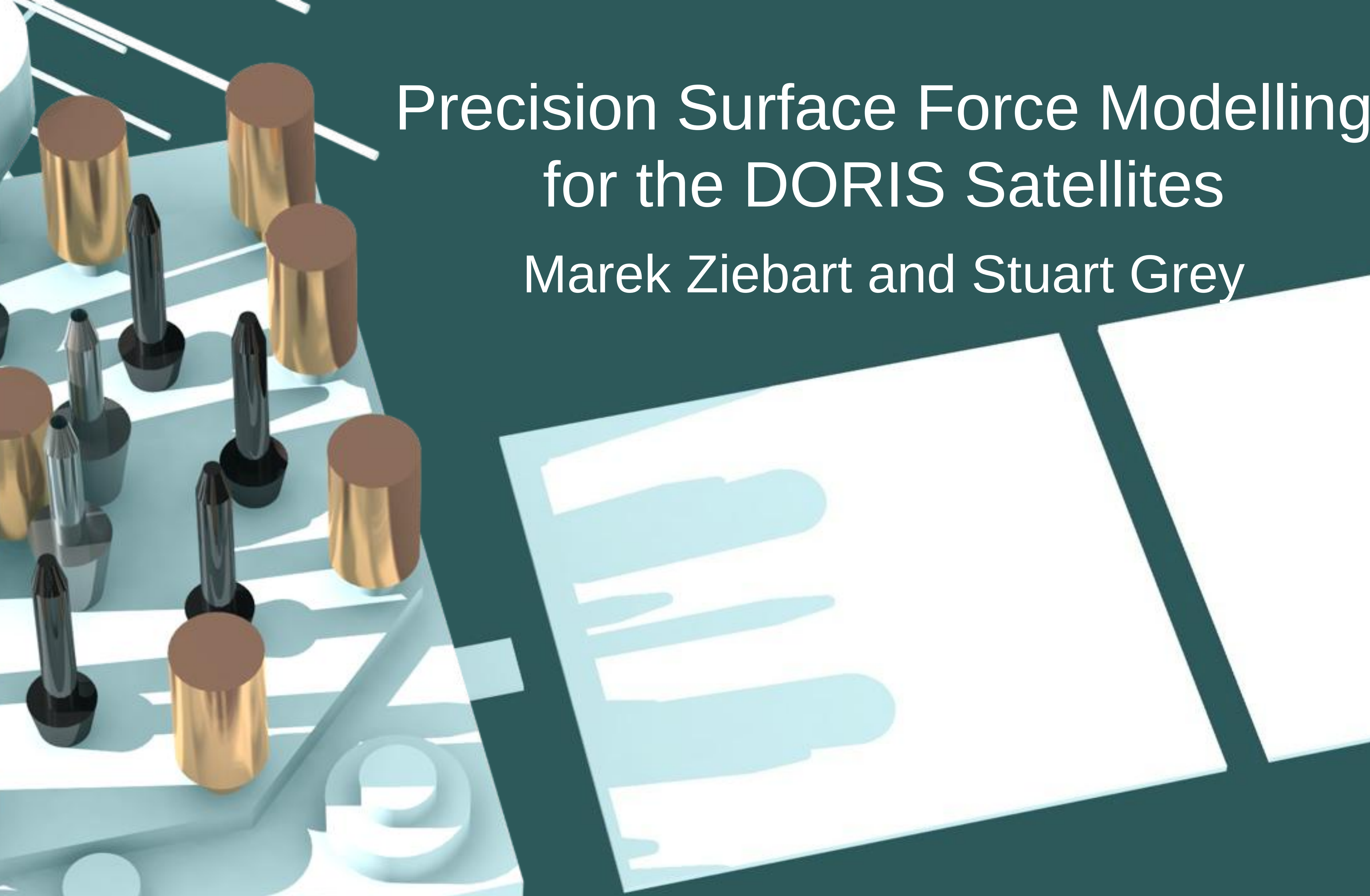
Precision Surface Force Modelling for the DORIS Satellites

Marek Ziebart and Stuart Grey

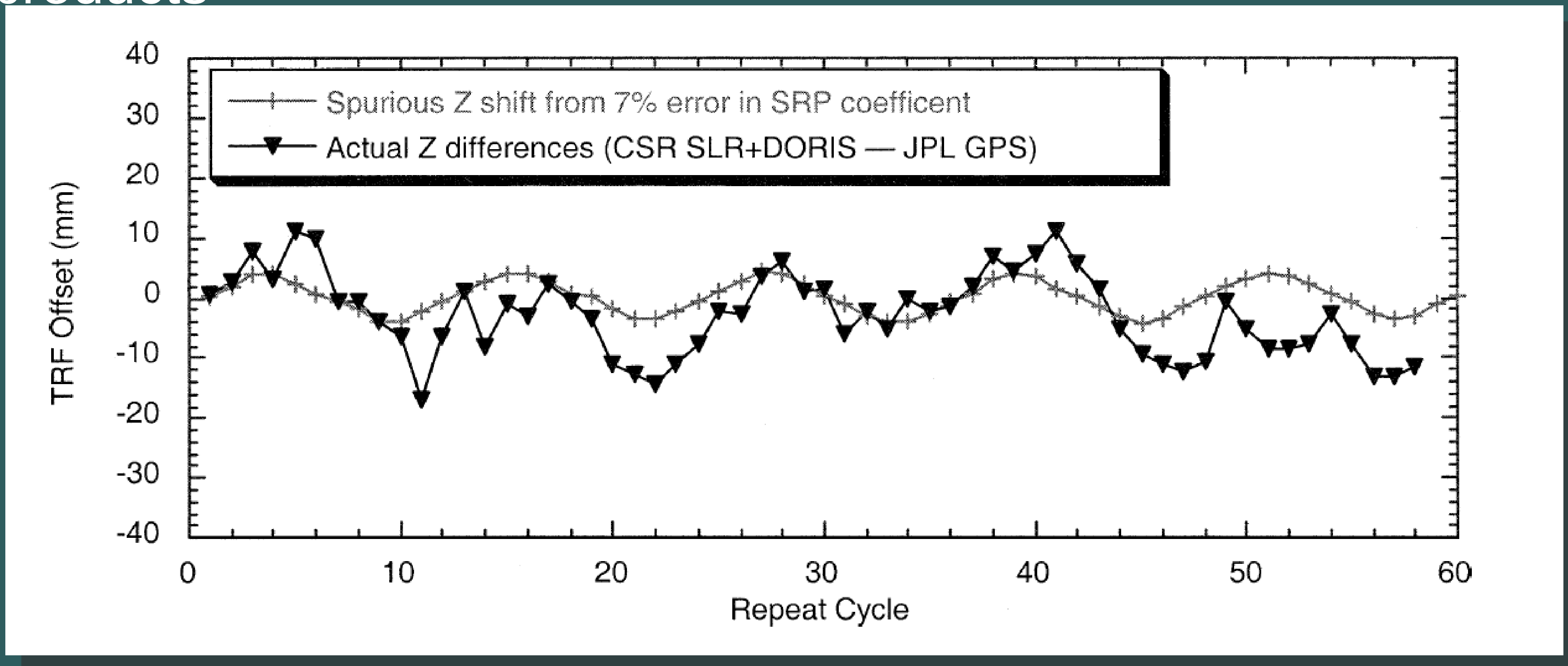


IDS Analysis Working Group
Paris - March 26-27 2014

UCL

Motivation

®’ dependent signals in orbits and data products



Jason-1 orbit centering (B.Haines, J.Ries and others)

Systematic biases in DORIS-derived geocentre time series (M.Gobindass, P.Willis and others)

Requirement for orbital and reference frame stability for Cryosat GDRs

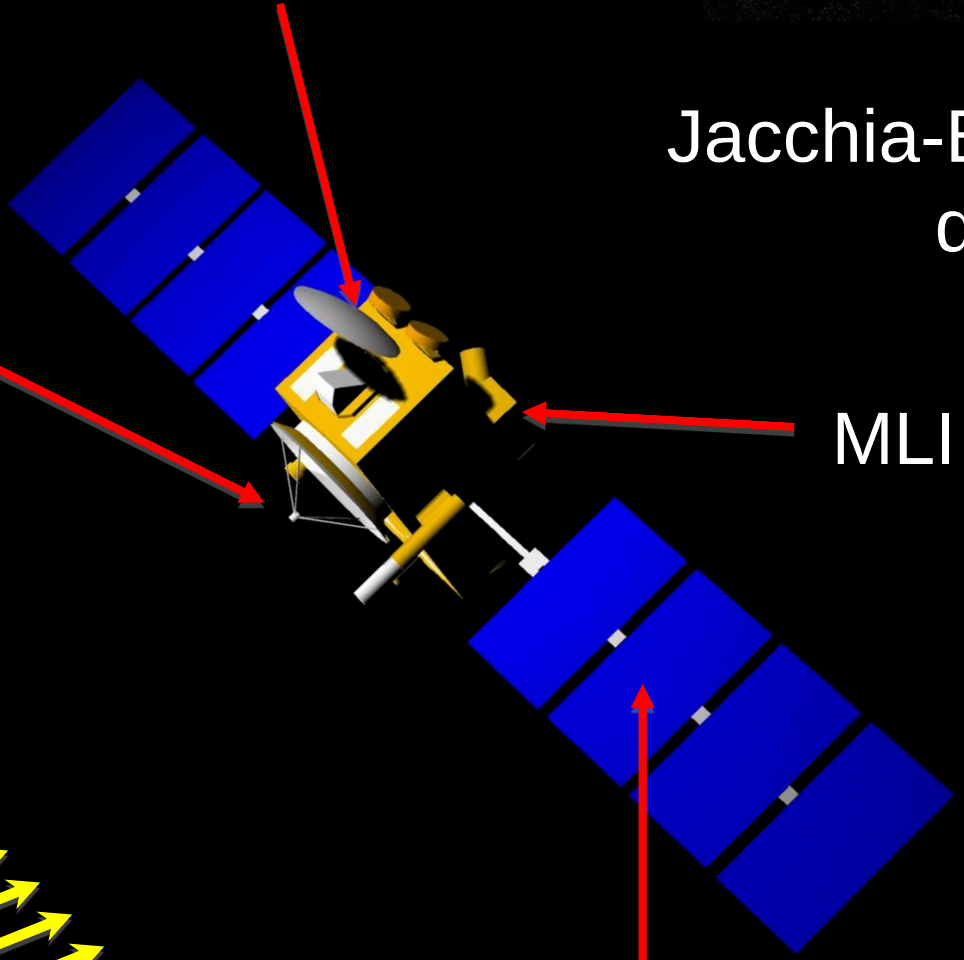
UCL modelling methods

CERES/ERBE earth radiation flux models

Detailed space vehicle models using geometric primitives

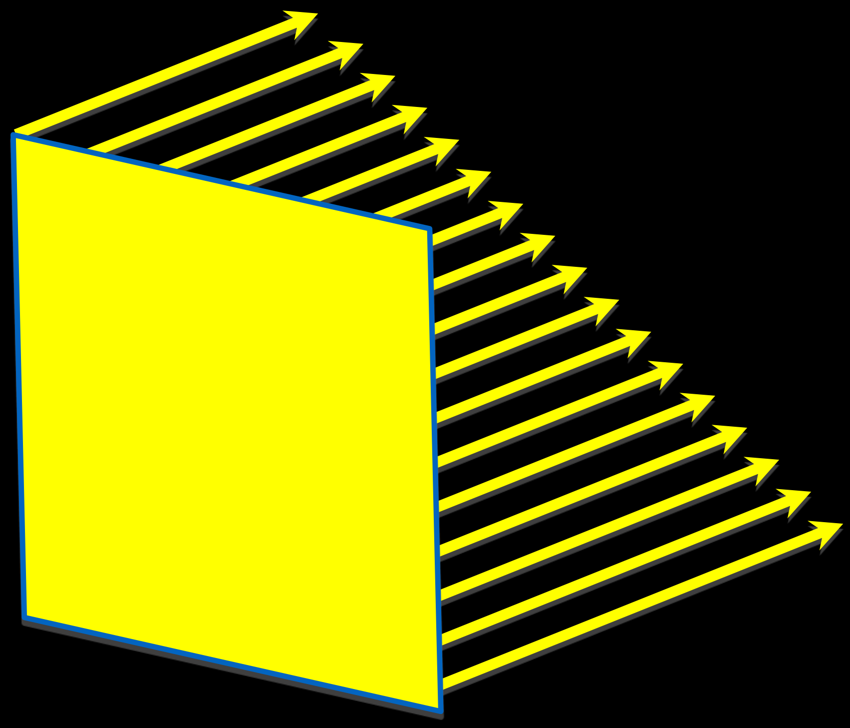
Jacchia-Bowman atmospheric density model

Antenna thrust



MLI thermal balance and forces

Mass history modelling

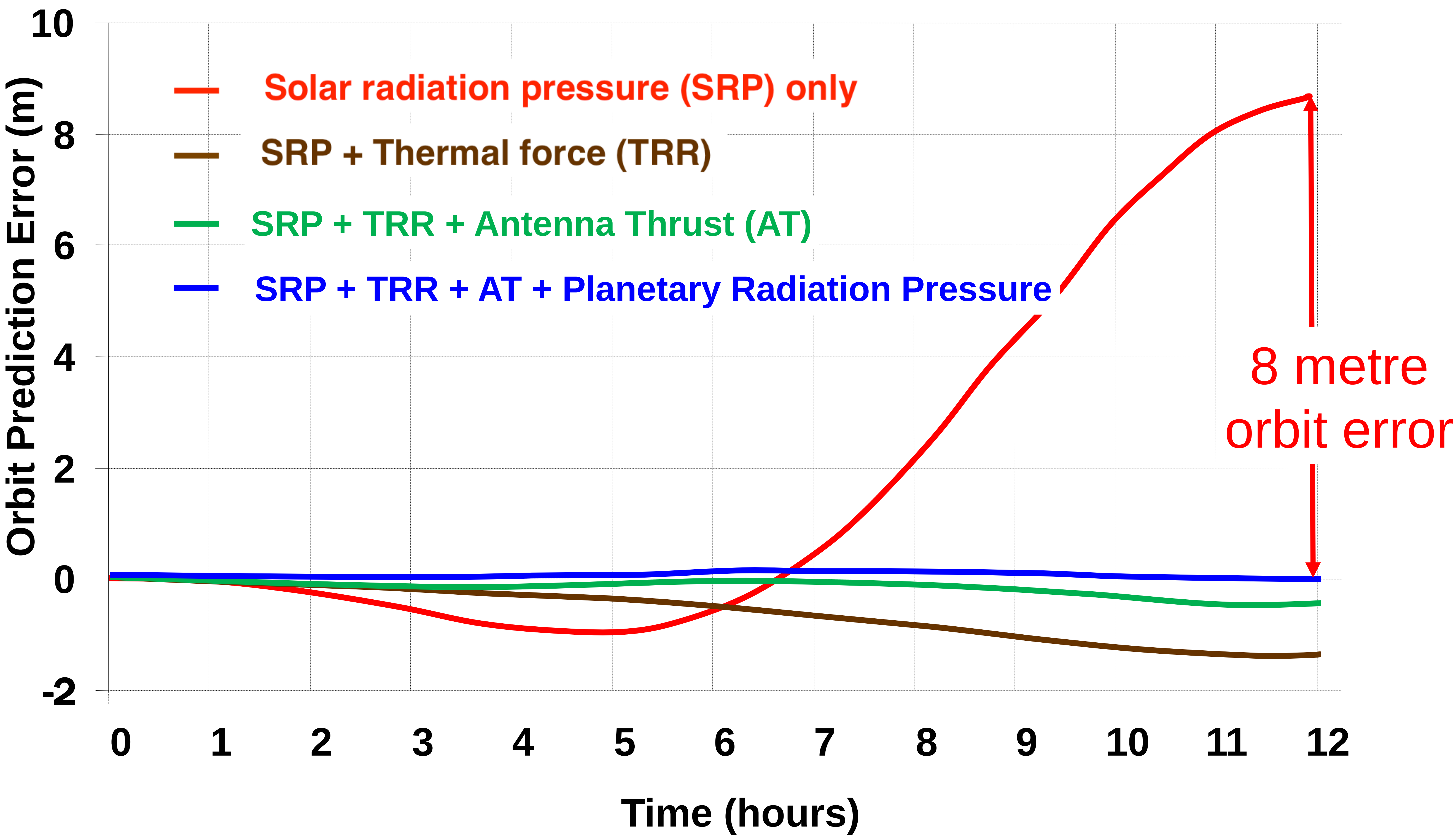


Solar panel thermal imbalance and power draw effects

Pixel array modelling of photon fluxes

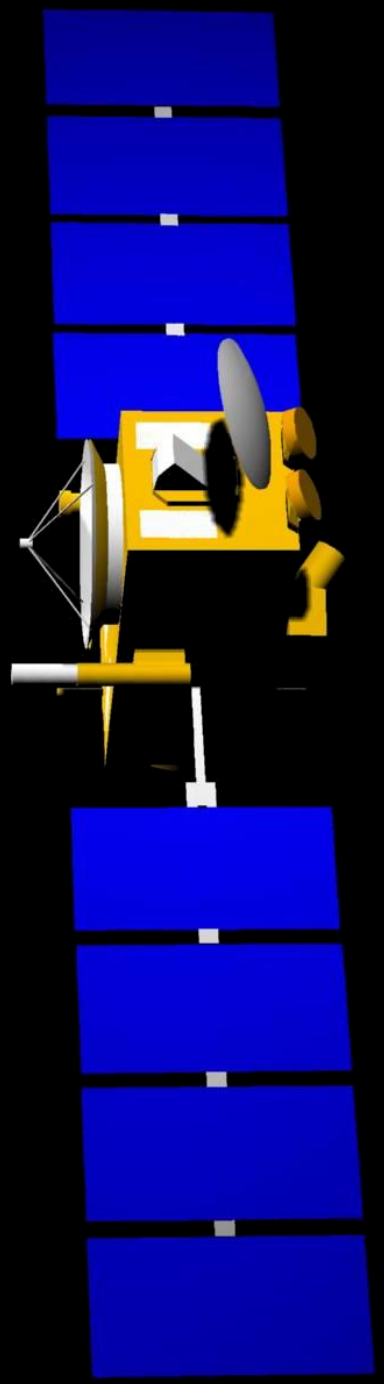
A simple test of our understanding of the physics……

Along-track orbit prediction errors over 12 hours for one GPS satellite with different photon-based force models



Jason-1 modelling (SRP and TRR)

- Extensive tests carried out at JPL
- Dynamic orbit improvements in cross overs, SLR residuals, orbit overlaps and scale factors
- Model subsequently tested by Goddard Space Flight Centre
- Anomalous 60 day period signature reduced
- Model adopted by NASA as operational standard



Current programme of work

Compute ‘Jason-1 standard’ force models for:

- Jason-2
- Cryosat
- SPOT4
- SPOT5
- TOPEX-POSEIDON (?)

Reprocess complete time series of mission orbits (with partners)

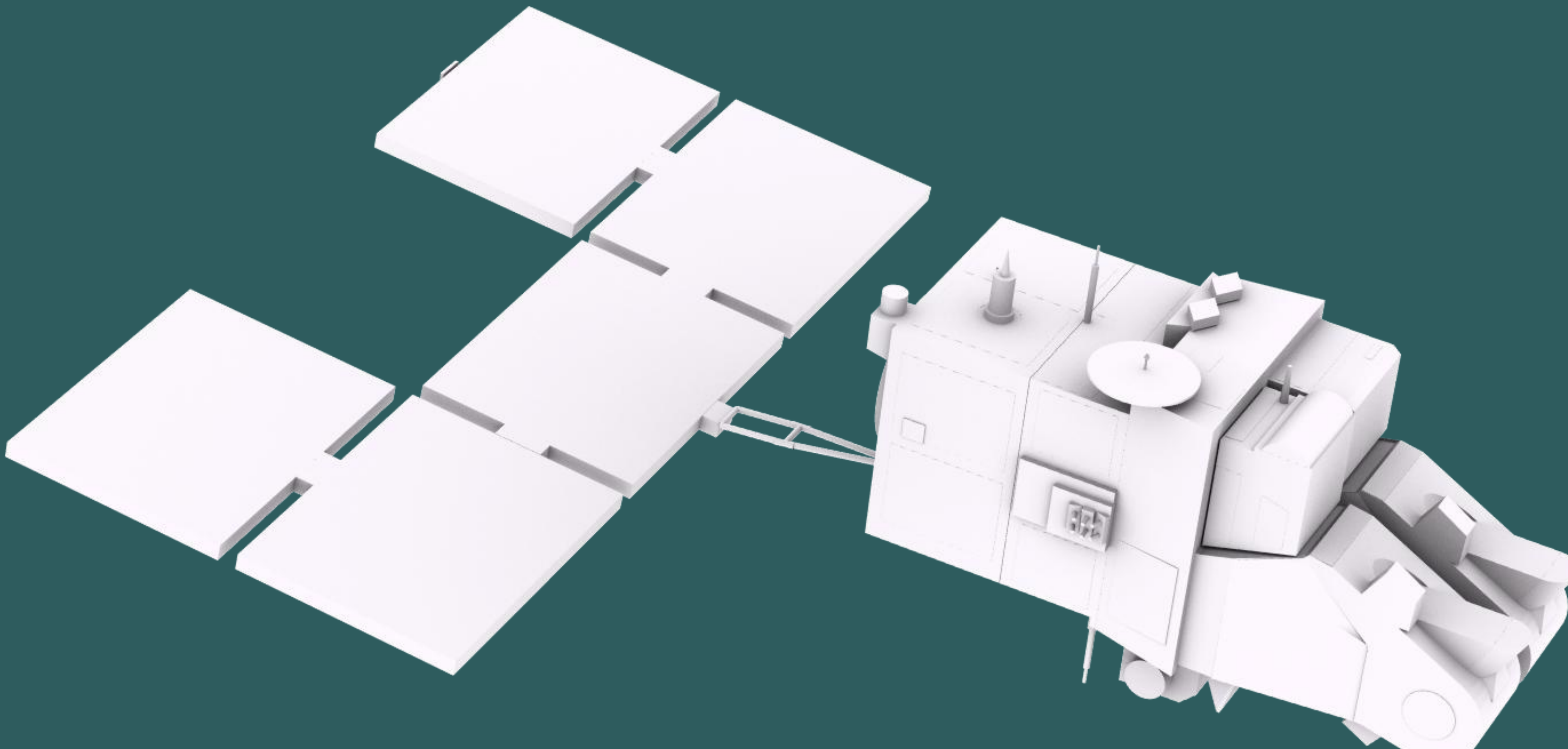
Analyse impact of enhanced force models on orbits, reference frame stability and realisation

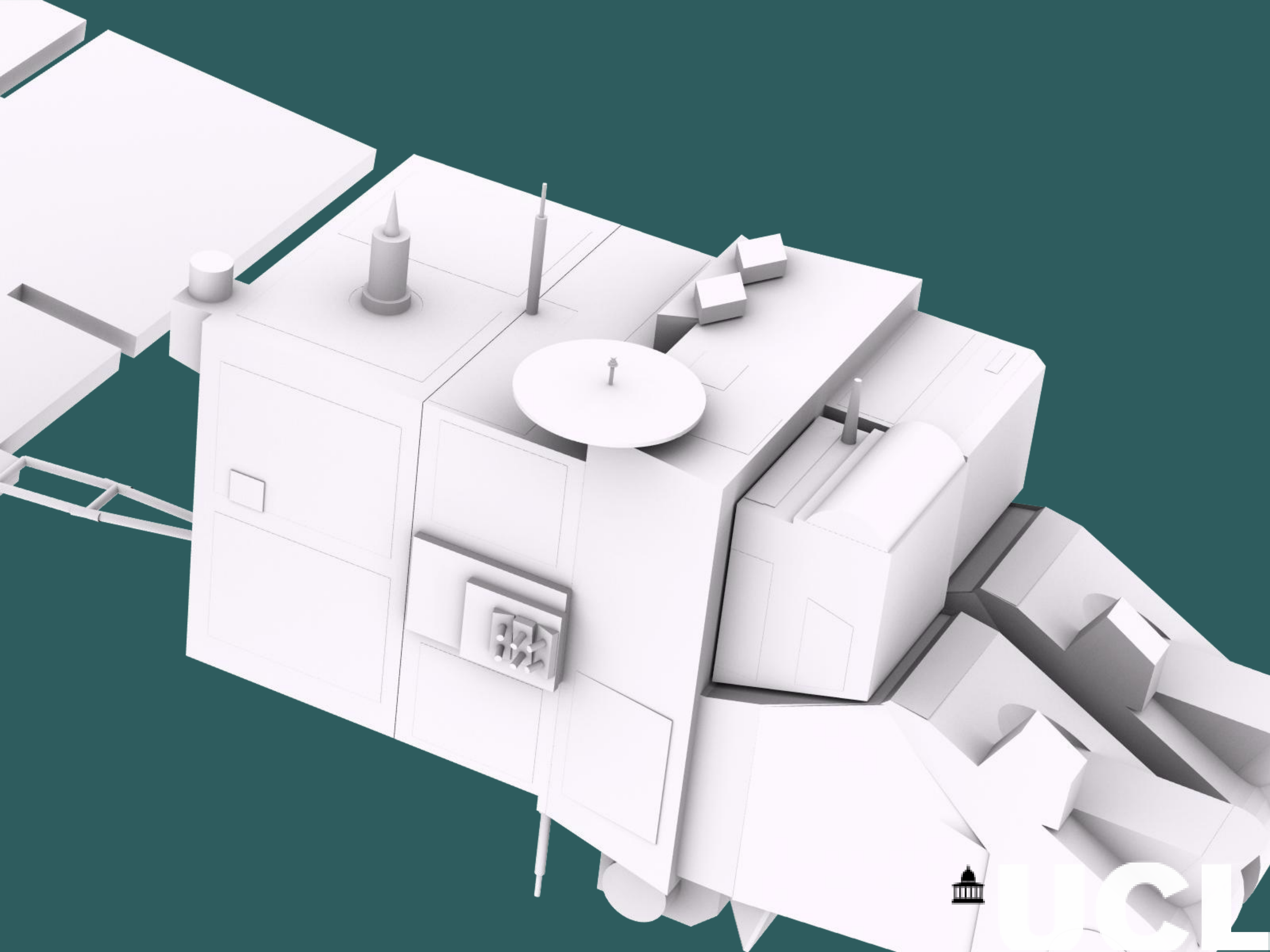
Spacecraft Structural Model Generation

- Acquire Spacecraft Model
- Convert to format suitable for ray tracing
- Acquire data for the surface properties of each spacecraft element
- Visually inspect each model using the web based tool

- Progress in structural models for DORIS satellites:

SPOT 4

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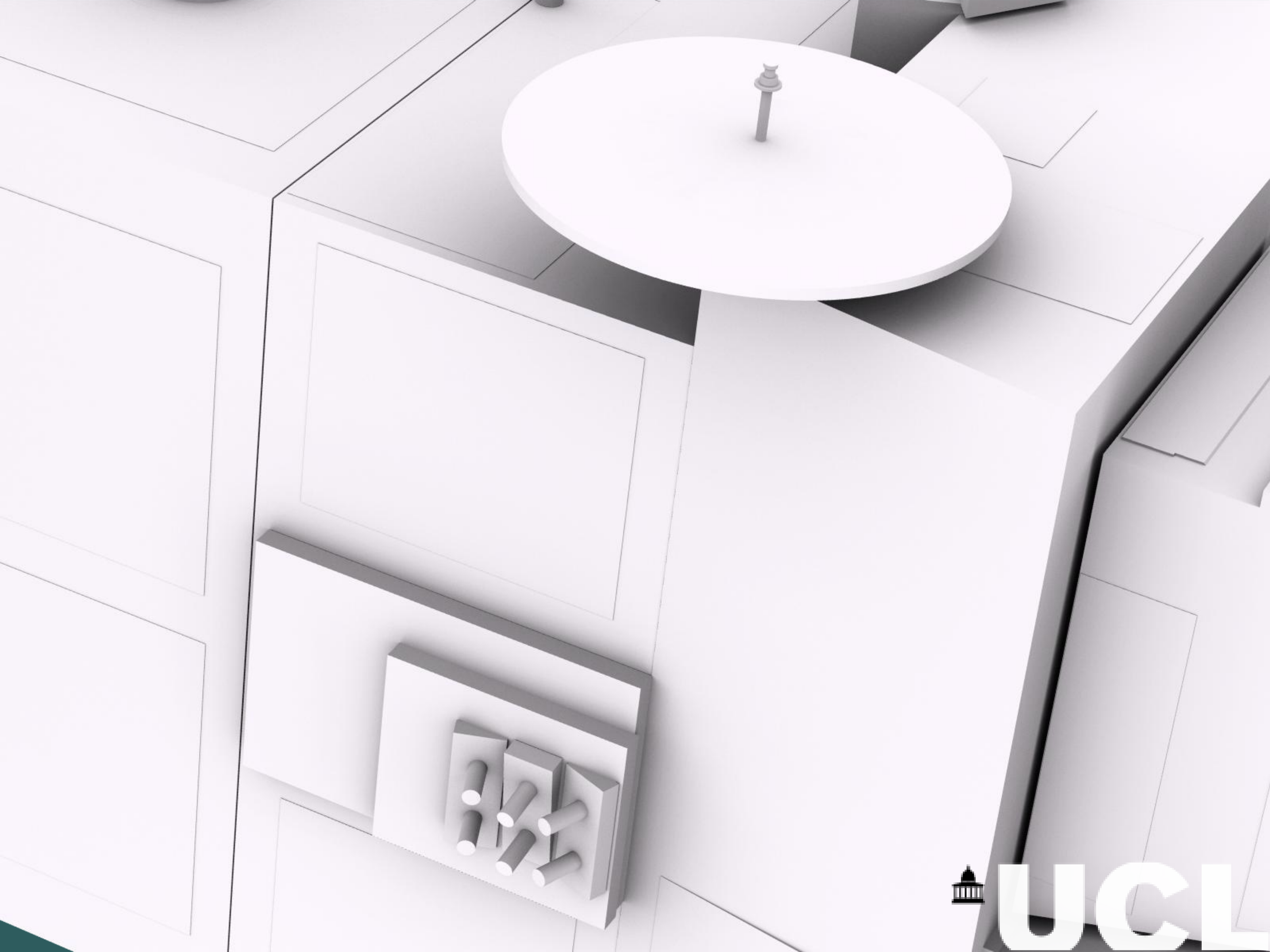
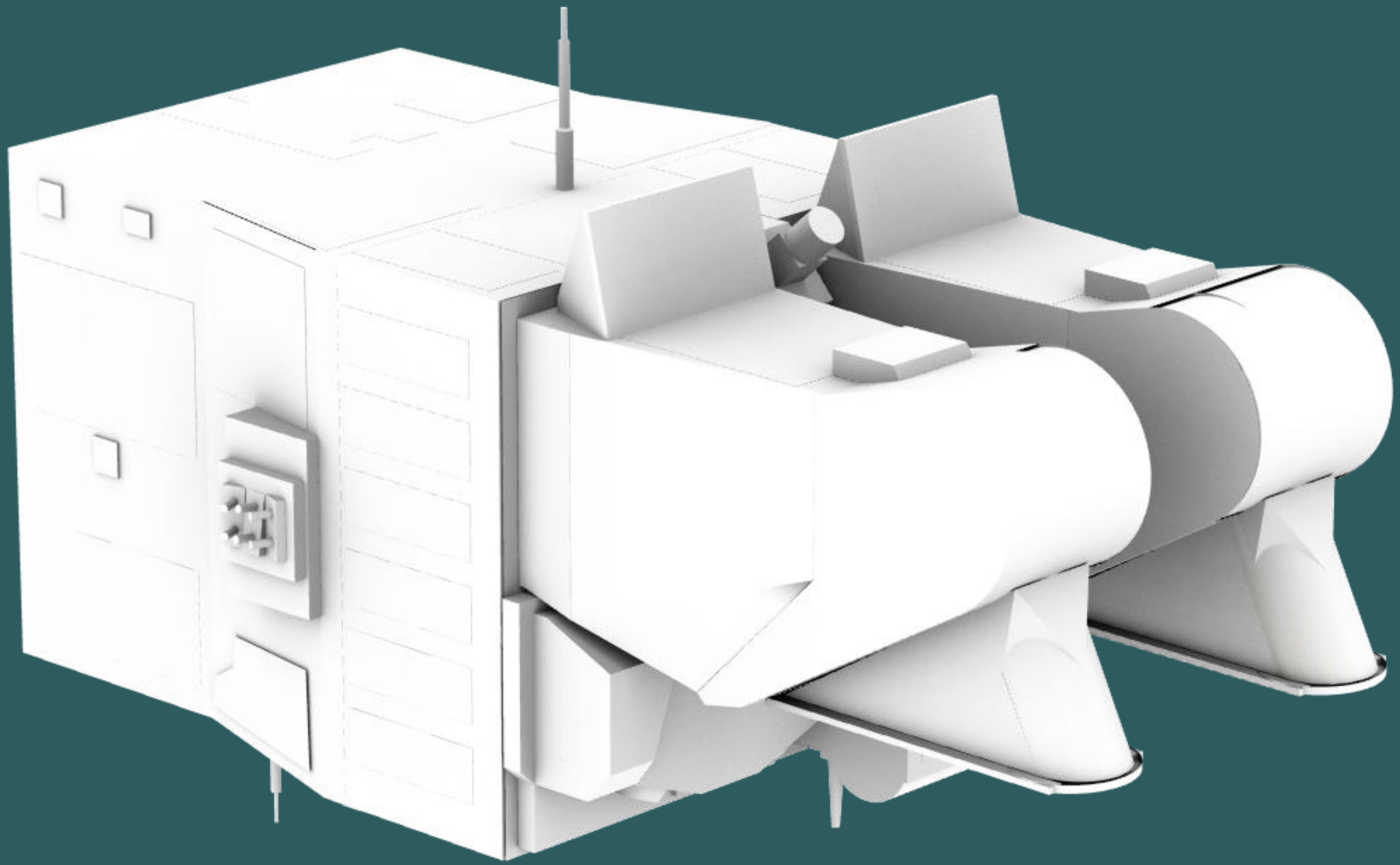


SPOT 5



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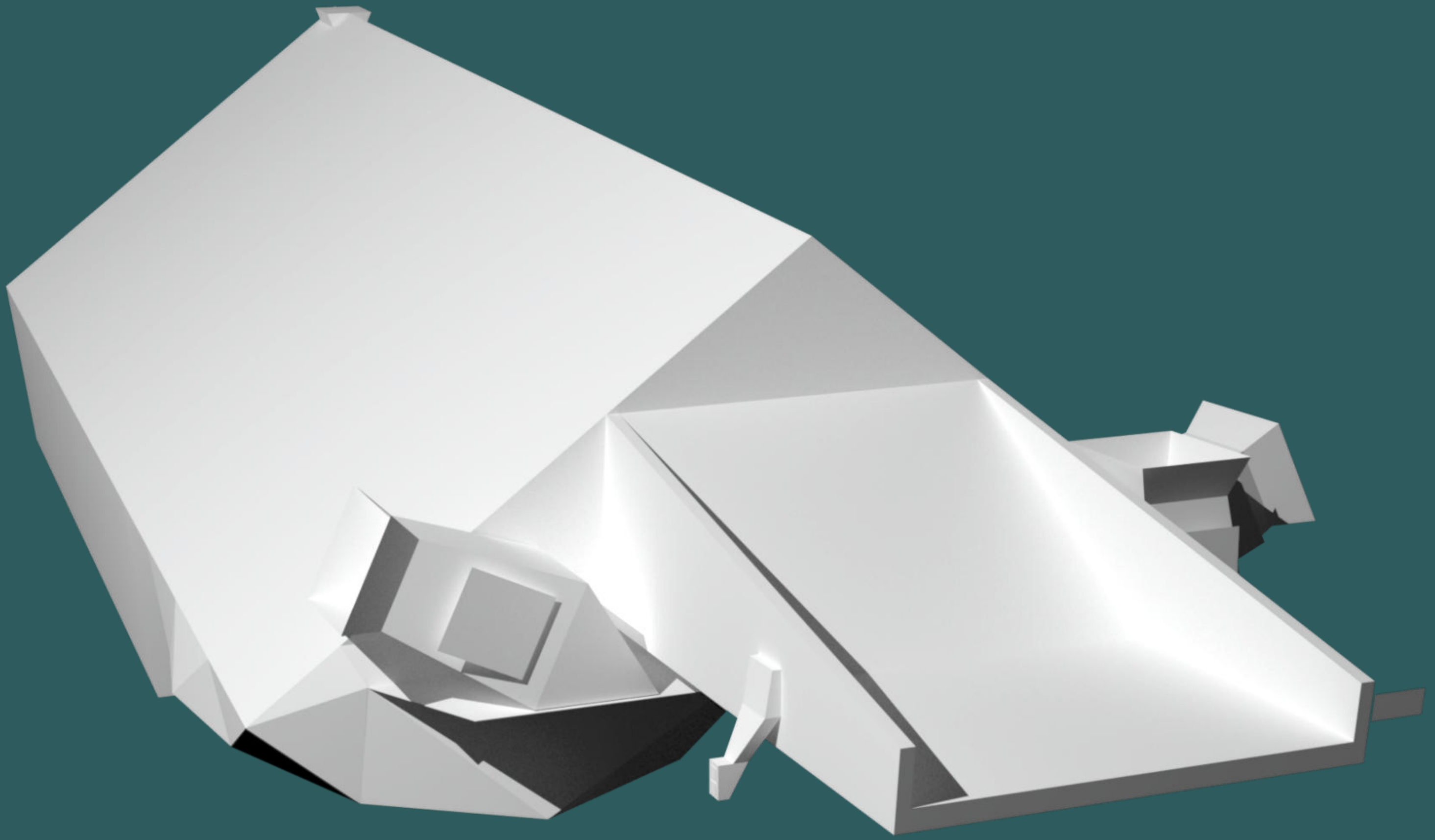
CRYOSAT-2



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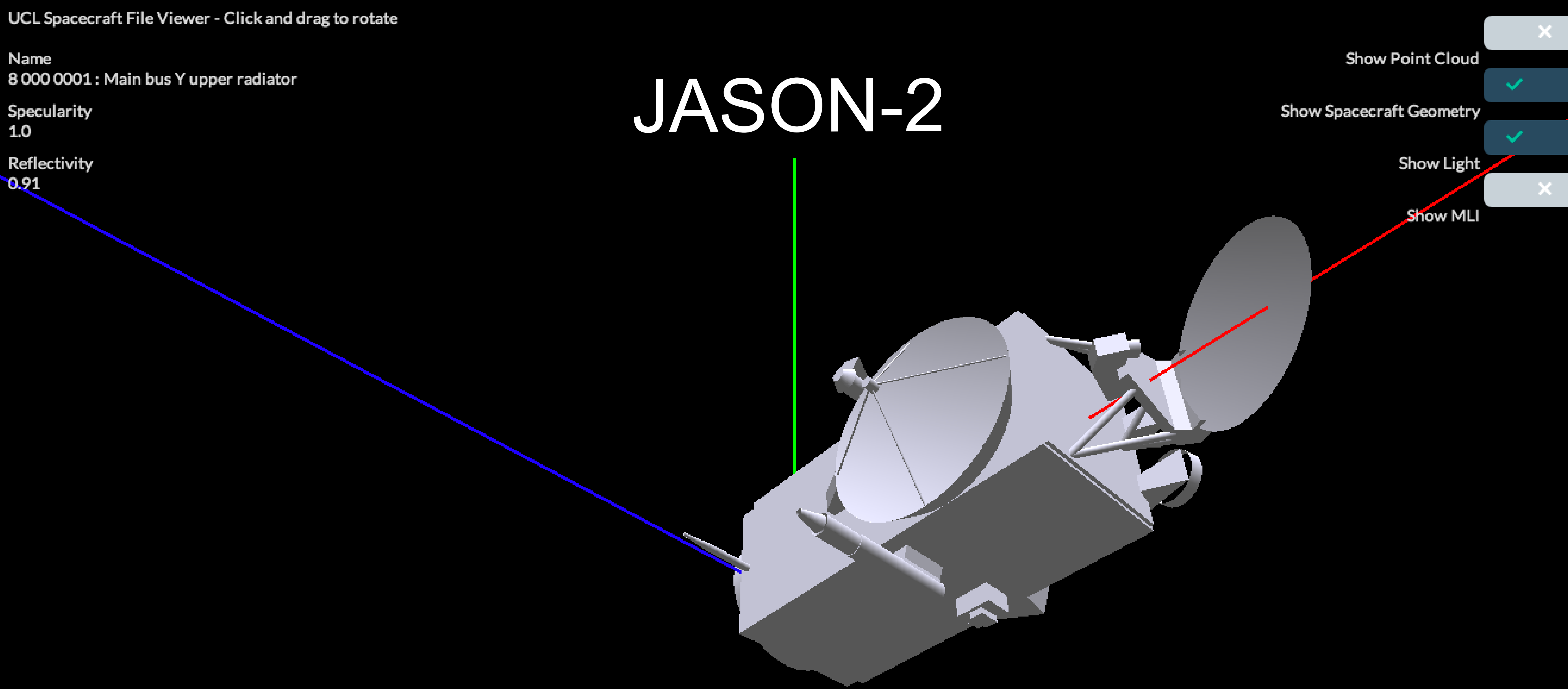
JASON-2

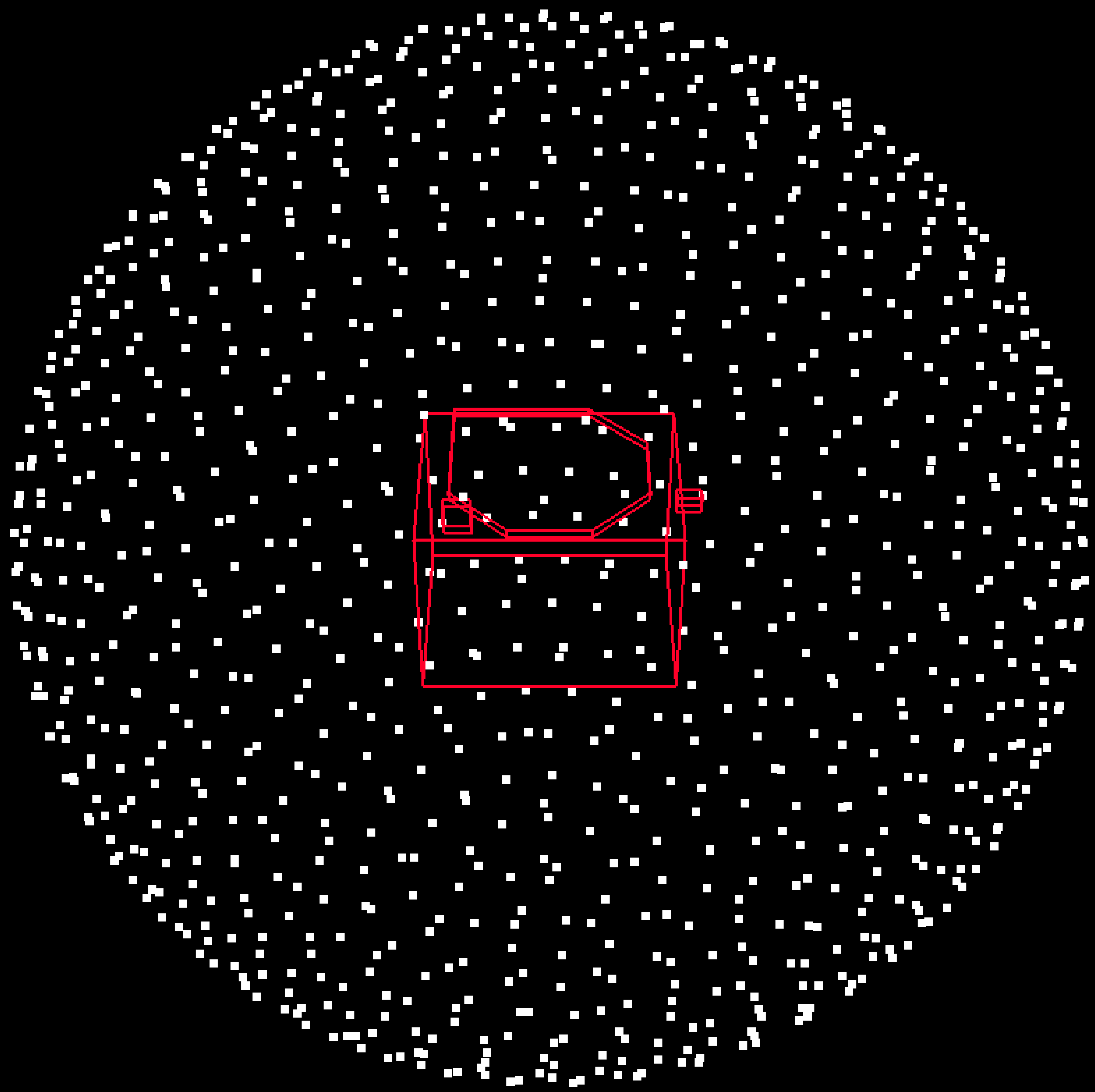


Models can be validated using a web based viewing tool

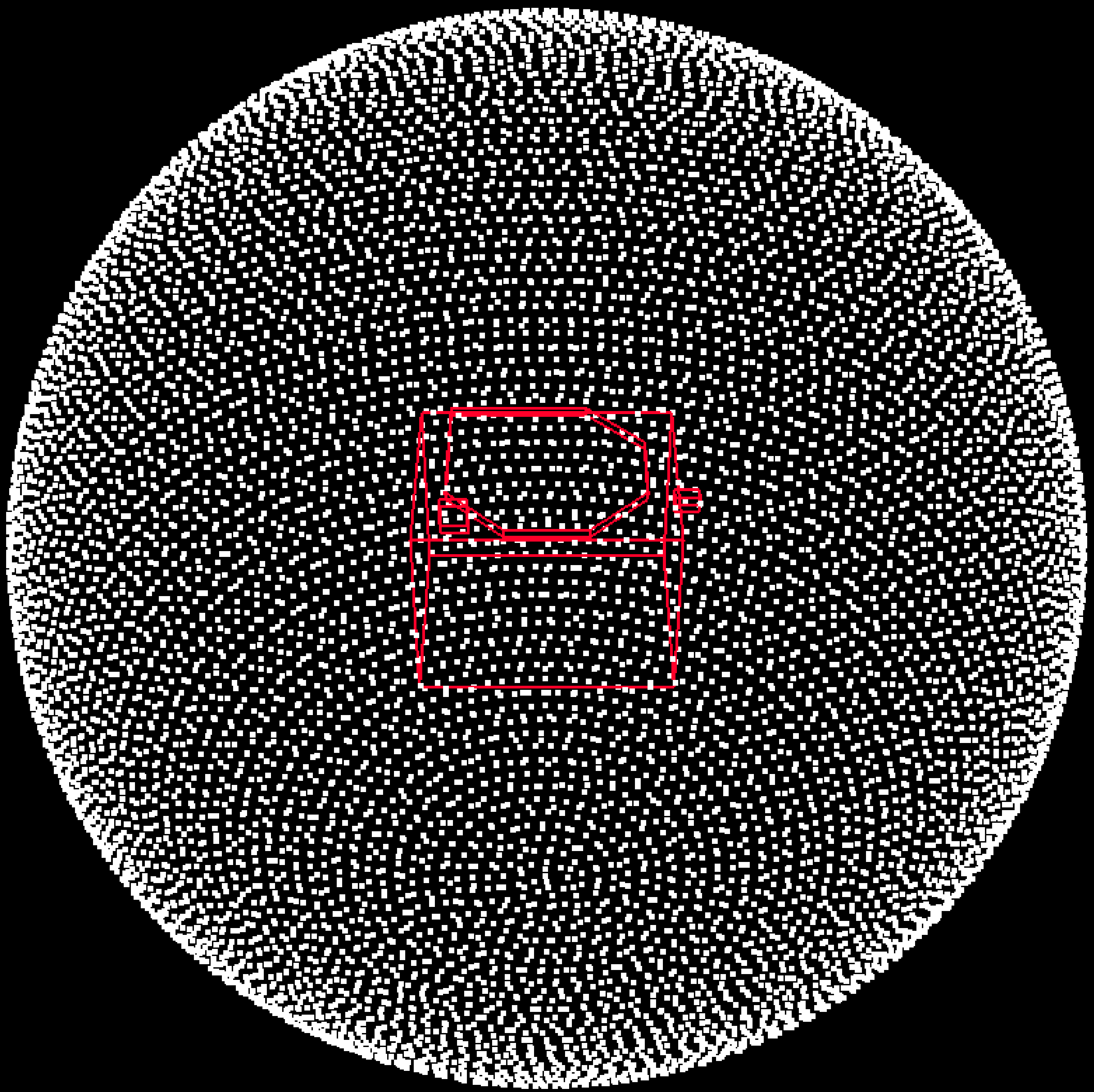
Automating the Generation Process: A Model Production Line

- Runs on the Legion Supercomputing Cluster at UCL.
- 5378 cores available. Runs on ~1000 cores for 3 days
- Calculate spacecraft response from 10,000 directions (spiral points)
- Calculate spacecraft response from another 1000 directions (EPS Strip)
- Generate gridded data for the 10,000 spiral points

1000 Spiral Points



10000 Spiral Points



At each point we use a pixel array to model the Photon flux incident on the space vehicle

Implementation and Support (I)

What UCL supplies

1. Output is a set of grid files modelling the spacecraft response to SRP/TRR in the spacecraft body frame
2. Error metrics are generated by comparing values from the interpolated grid to the set of specifically generated verification values
3. Grid files are in plain text format along with summary statistics
4. C/C++ code to load grid files into memory and interpolate between values is also supplied
5. Thermal gradient and SRP modelling for solar panels supplied separately

Implementation and Support (II)

The Process for the Analysis Centre

1. AC checks out the grid files for the spacecraft in question and the grid file interpolation code from the version control system

2. The analysis centre then runs the supplied test suite and compares against UCL's values

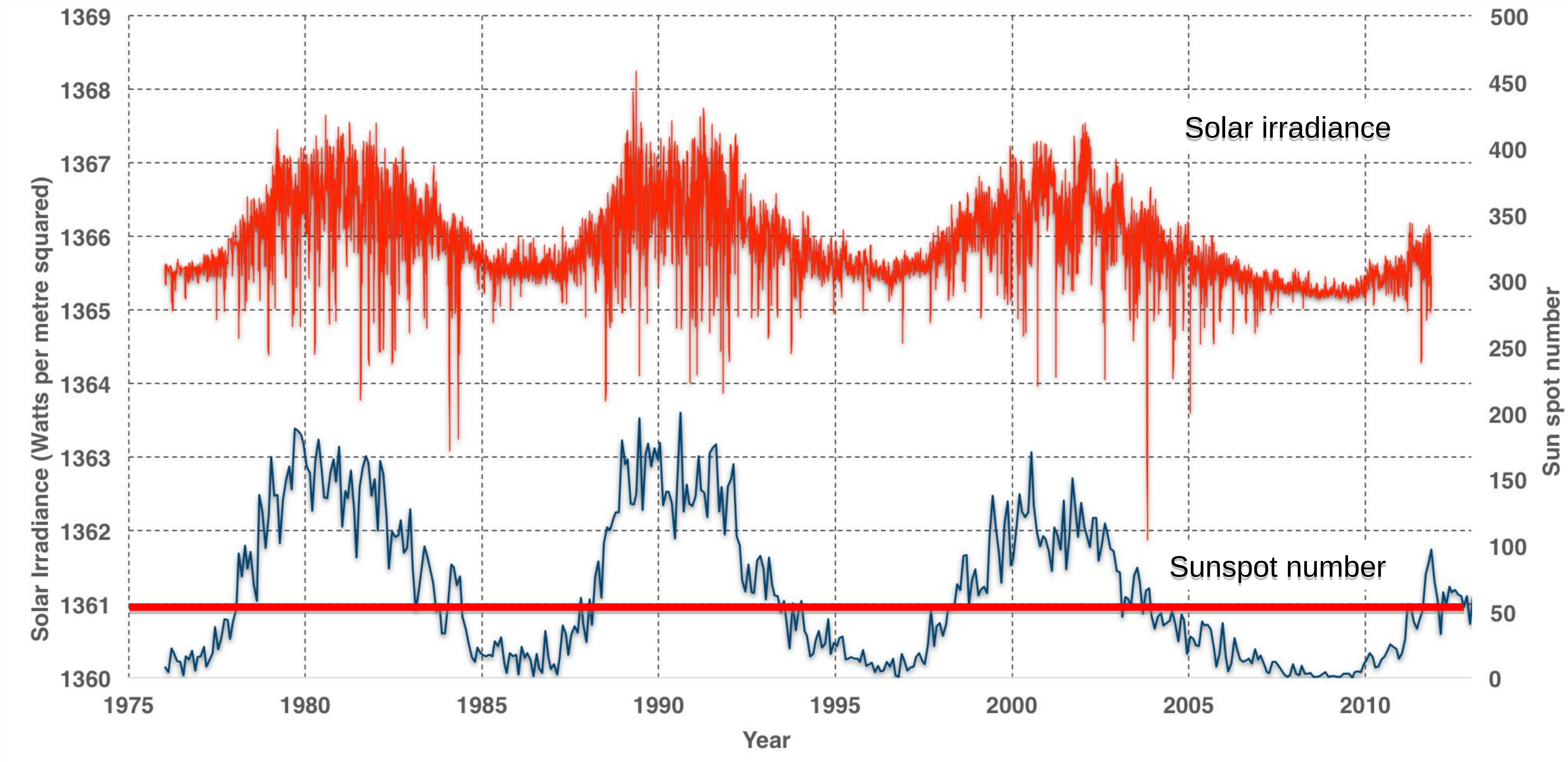
3. UCL and the analysis centre collaborate on integrating the platform specific requirements, these are then added to the version control system for future use

4. The analysis centre runs their analysis using the models

Validation Tests

- Prior to model delivery we propagate an orbit prediction using the generated force model
- Non conservative forces are modelled (70x70 GRACE Gravity, 3rd bodies, general relativity)
- The SRP/TRR forces are then added and compared to precise orbits

Total Solar Irradiance:
re-defining the mean and modelling variations



-0.5% change in solar scale: consistent with experimental data (JPL/GSFC/UCL)

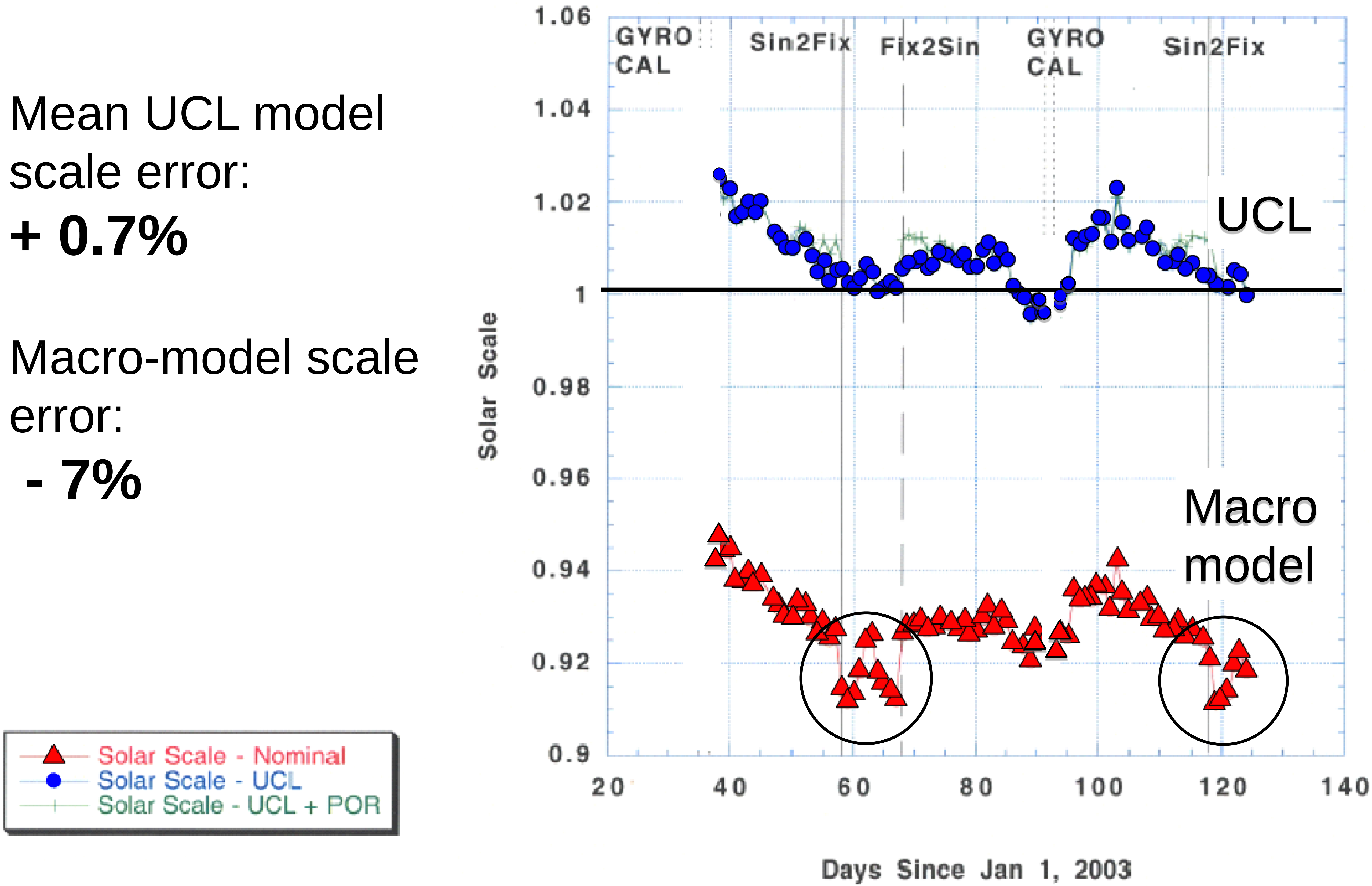
Jason-1 Solar pressure scale factors over 80 days (JPL, GIPSY)

Mean UCL model scale error:

+ 0.7%

Macro-model scale error:

- 7%



Proposed experimental plan

UCL completes model generation in consultation with IDS

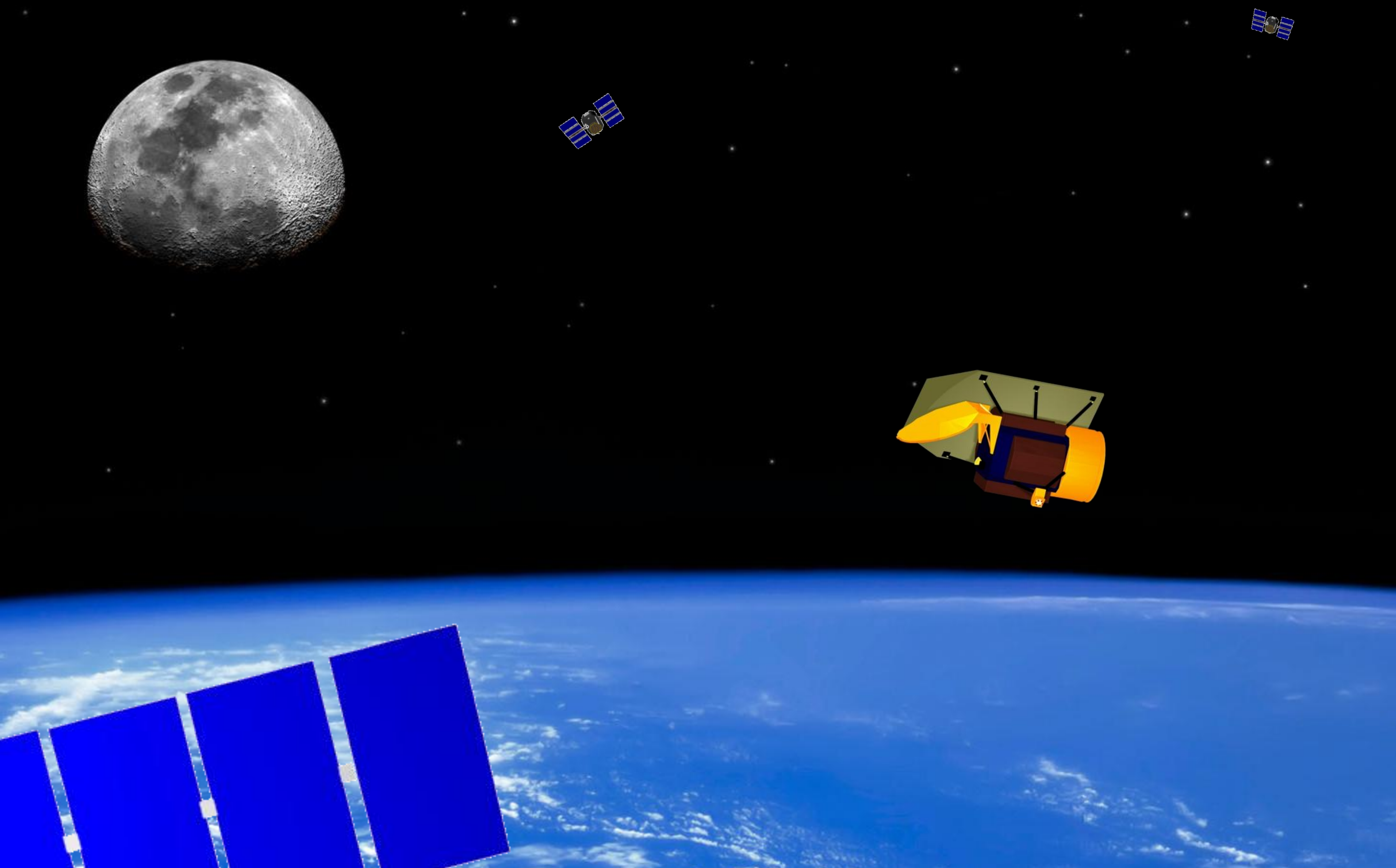
Implementation and validation phase (Summer 2014)

Orbit computation and analysis (at least one β' cycle, Autumn 2014)

Tests on re-definition of solar scale (Winter 2014)

Review, publication, forward plan (Christmas 2014)

Conclusions



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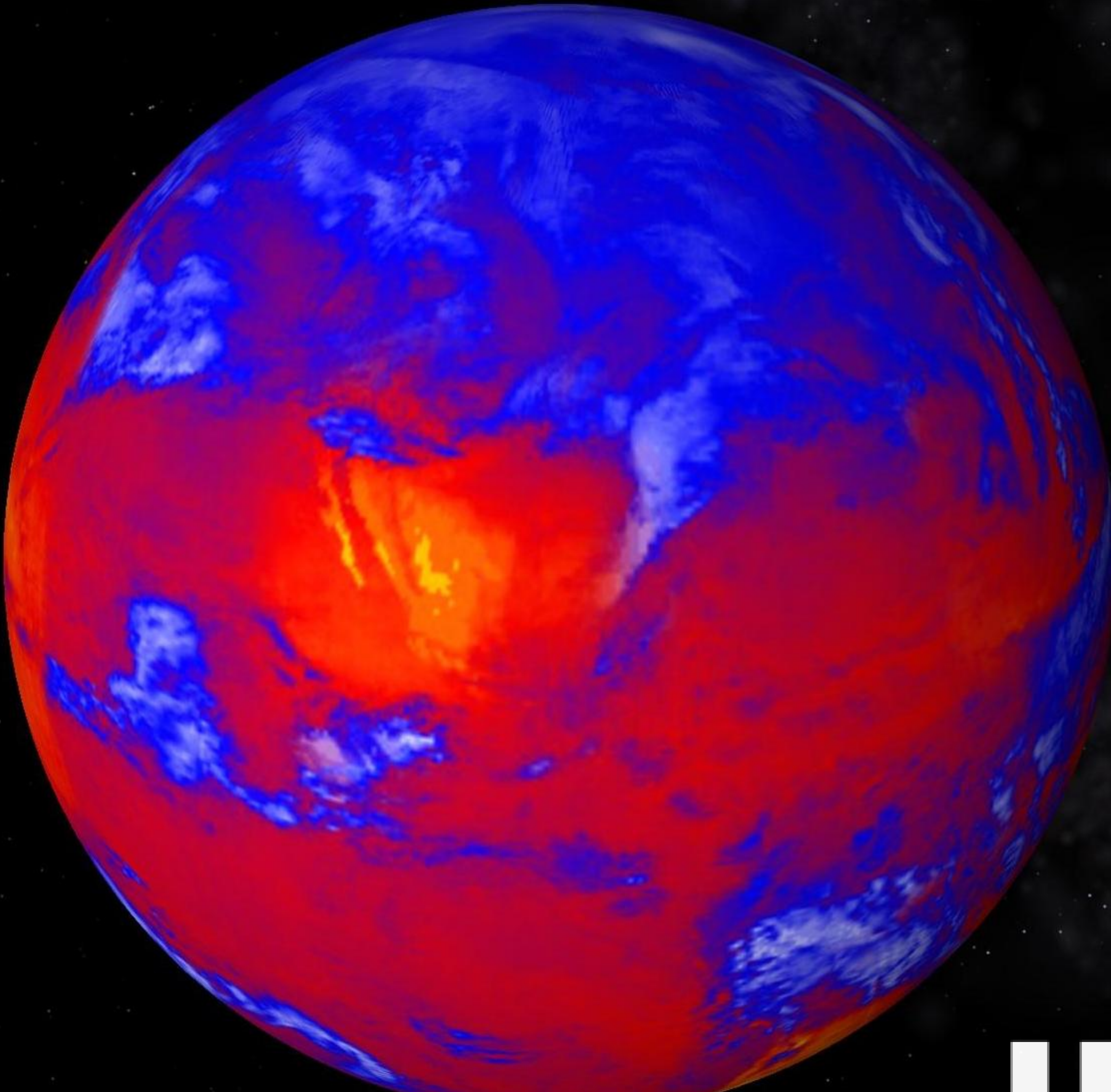
Planetary Radiation Pressure

- Replace the Solar flux with Planetary Flux
- Reflection and Emission from the Planet
- With the coverage achieved by 10000 spiral points the incident flux direction can be from any direction
- Use the same high fidelity spacecraft model used in SRP

Planetary Radiation Pressure

- The flux coming from the planet can be calculated from the CERES top of atmosphere fluxes
- All of the visible cells can be summed into a single radial flux
- For low altitude missions the fluxes can be treated individually



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