Proposed Surface Force Modelling Programme for the DORIS Satellites:

Cryosat, Jason-2, SPOT4, SPOT5, Topex-Poseidon

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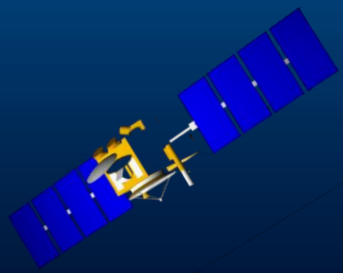


Motivation

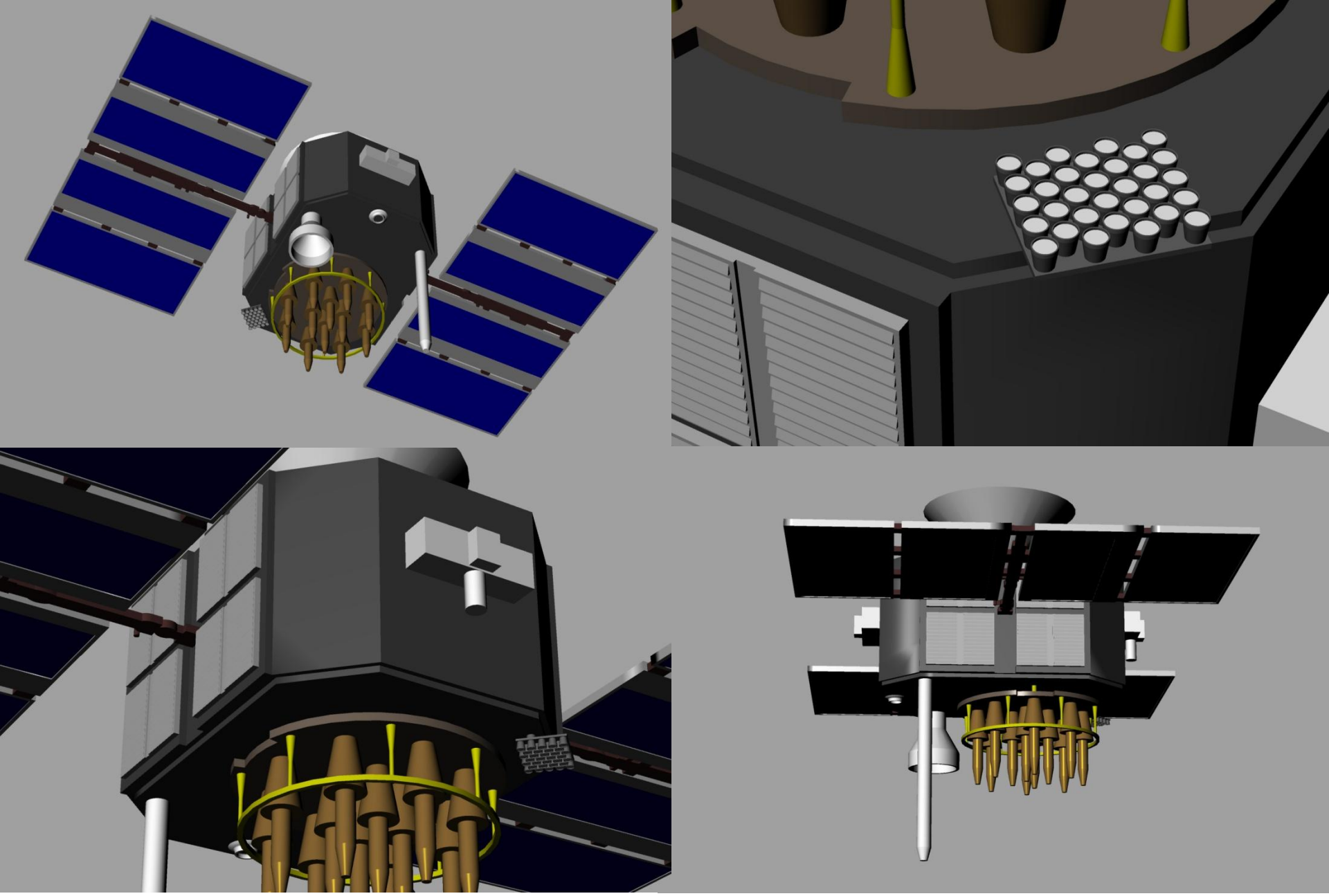
- High accuracy orbit determination of DORIS satellites is critical for earth science applications
- Requirement is for both (a) stable reference frame and (b) un-biased orbits
- In practice (a) and (b) cannot be separated
- Surface force modelling is a significant component of the error budget
- UCL SRP/TRR approach for Jason-1 has shown promise (scale factor ≈ 1.0, improved orbit centering, reduced correlation with other parameters); GPS/GLONASS results promising

Aims of research

- Compute, test and implement SRP/TRR models for Jason-2, Cryosat, SPOT4, SPOT5 and Topex-Poseidon
- Extend GPS research on earth radiation pressure modelling to LEO satellites
- Develop enhanced drag and lift modelling capability
- Assess surface charge forcing effects
- Engage with DORIS analysis centres and community to share knowledge and models

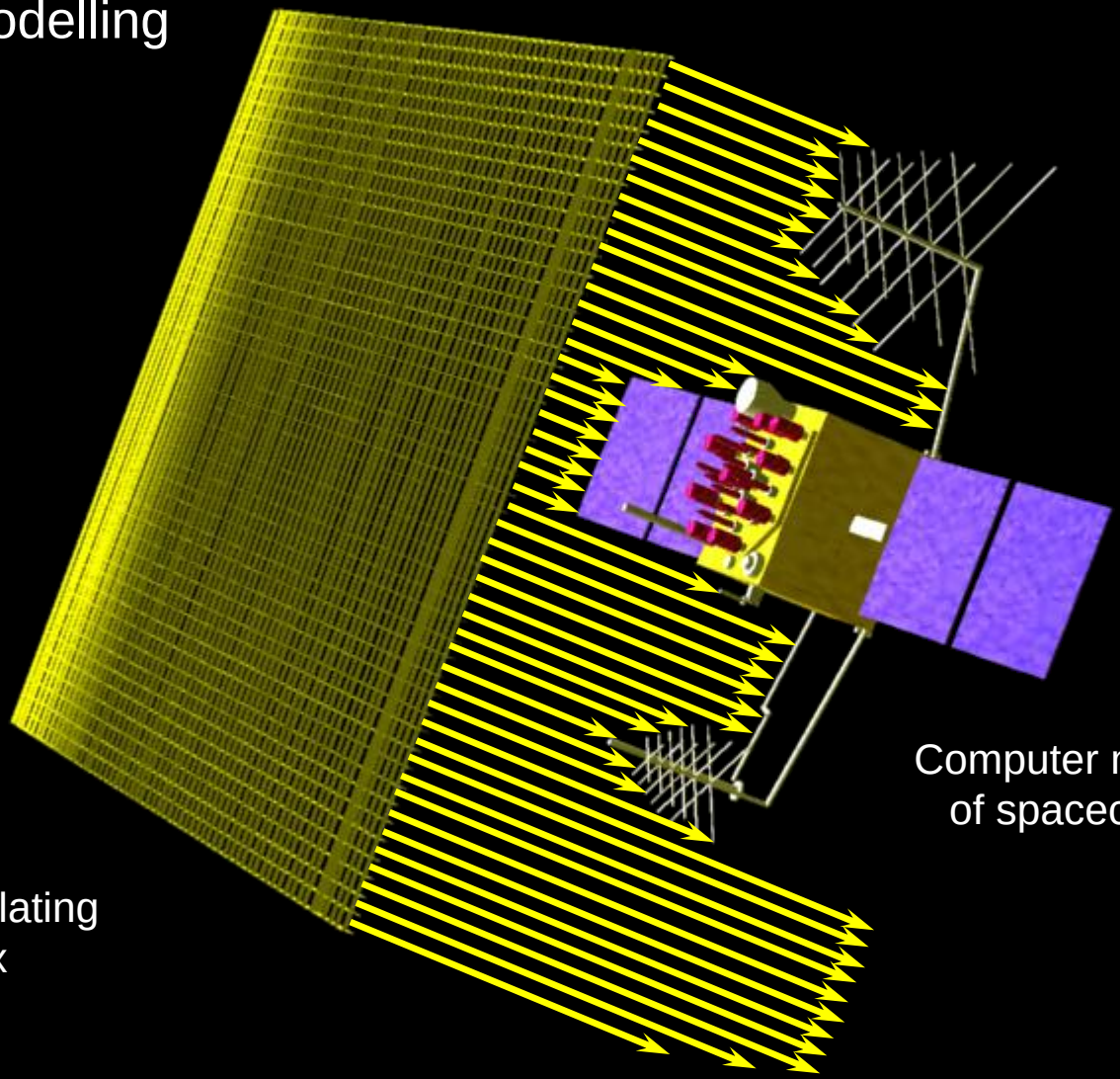
The good news

- UK research council grant has been won worth £0.72M
- Grant pays for two post-doctoral researchers for three years each
- Programme starts this September
- UCL group has 18 research staff
- Most tools are mature and tested (see later)
- Much of the structural data for the satellites has been acquired and tested (see later)



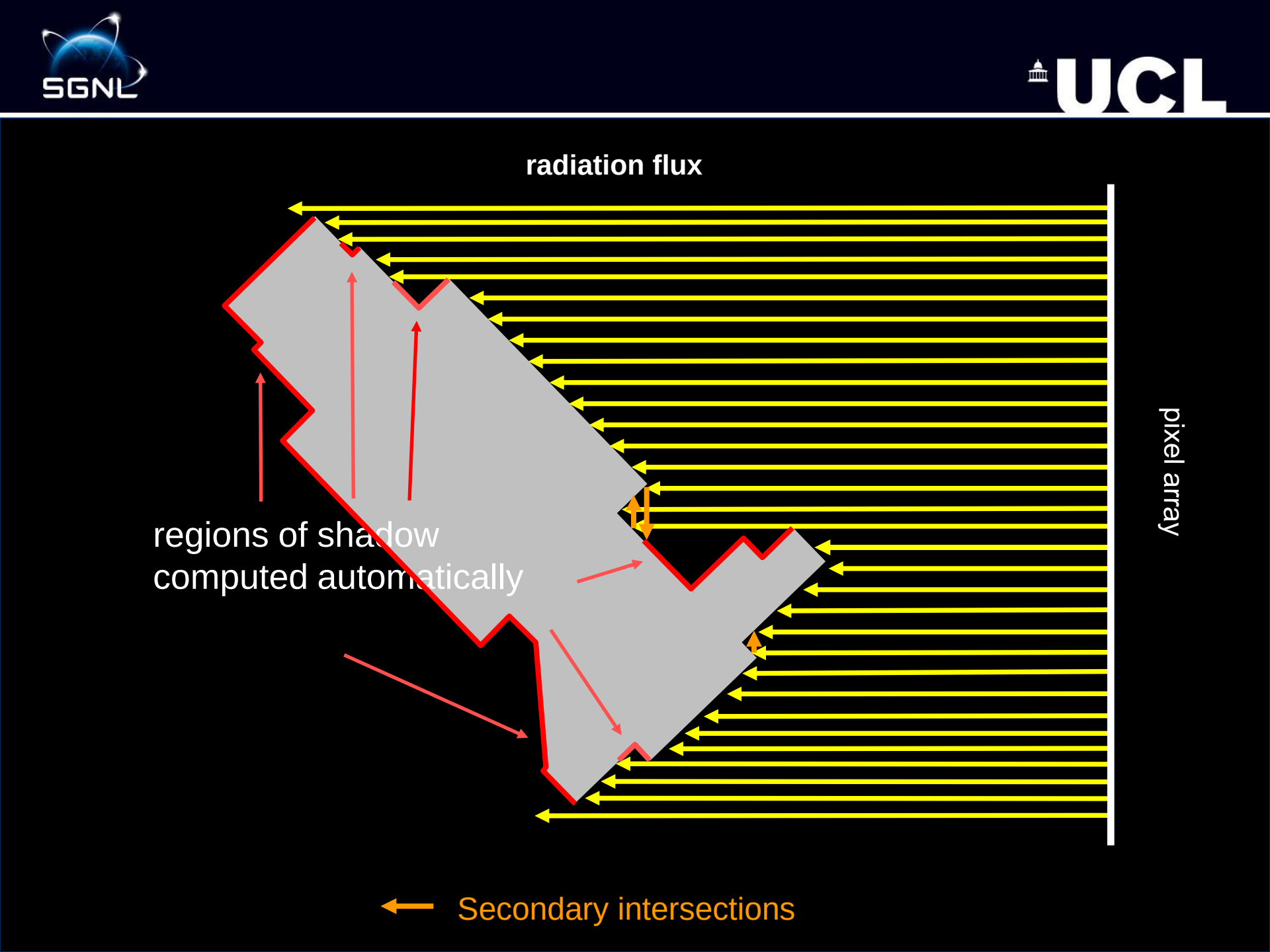
We develop a detailed structural computer model of the spacecraft

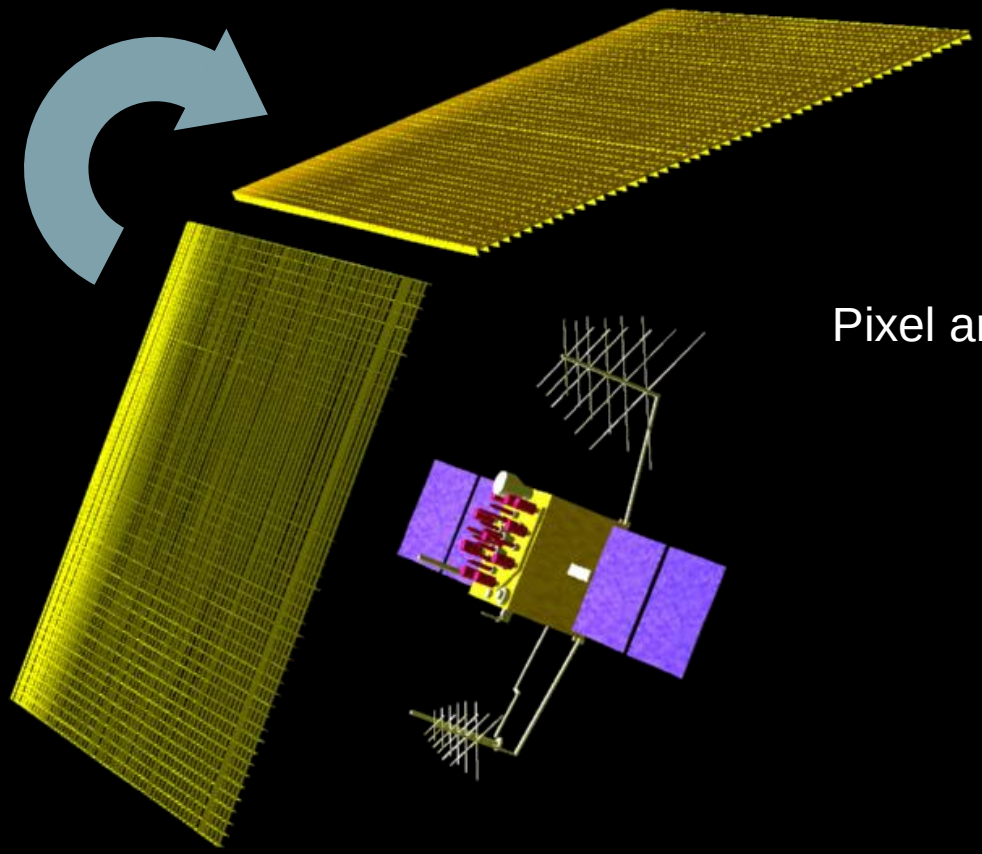
Photon force modelling



Computer model of spacecraft

Pixel array simulating photon flux


radiation flux
pixel array
regions of shadow
computed automatically
Secondary intersections



Pixel array rotated around spacecraft, solar panels adjusted

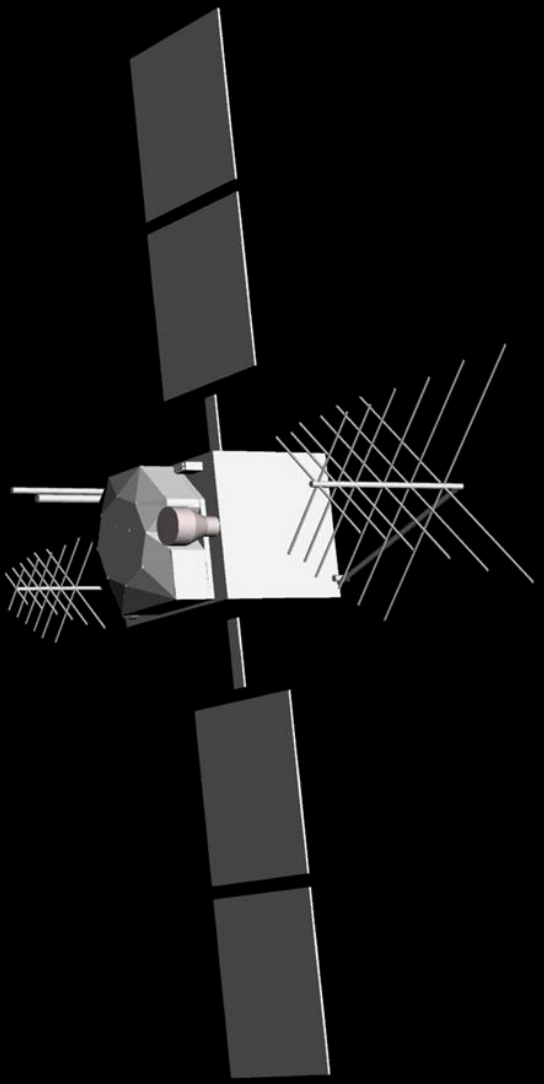
Publications:

Ziebart,M.,(2004) Generalised Analytical Solar Radiation Pressure Modelling Algorithm for Spacecraft of Complex Shape, Journal of Spacecraft and Rockets, Vol.41, No.5, pp 840-848(9)

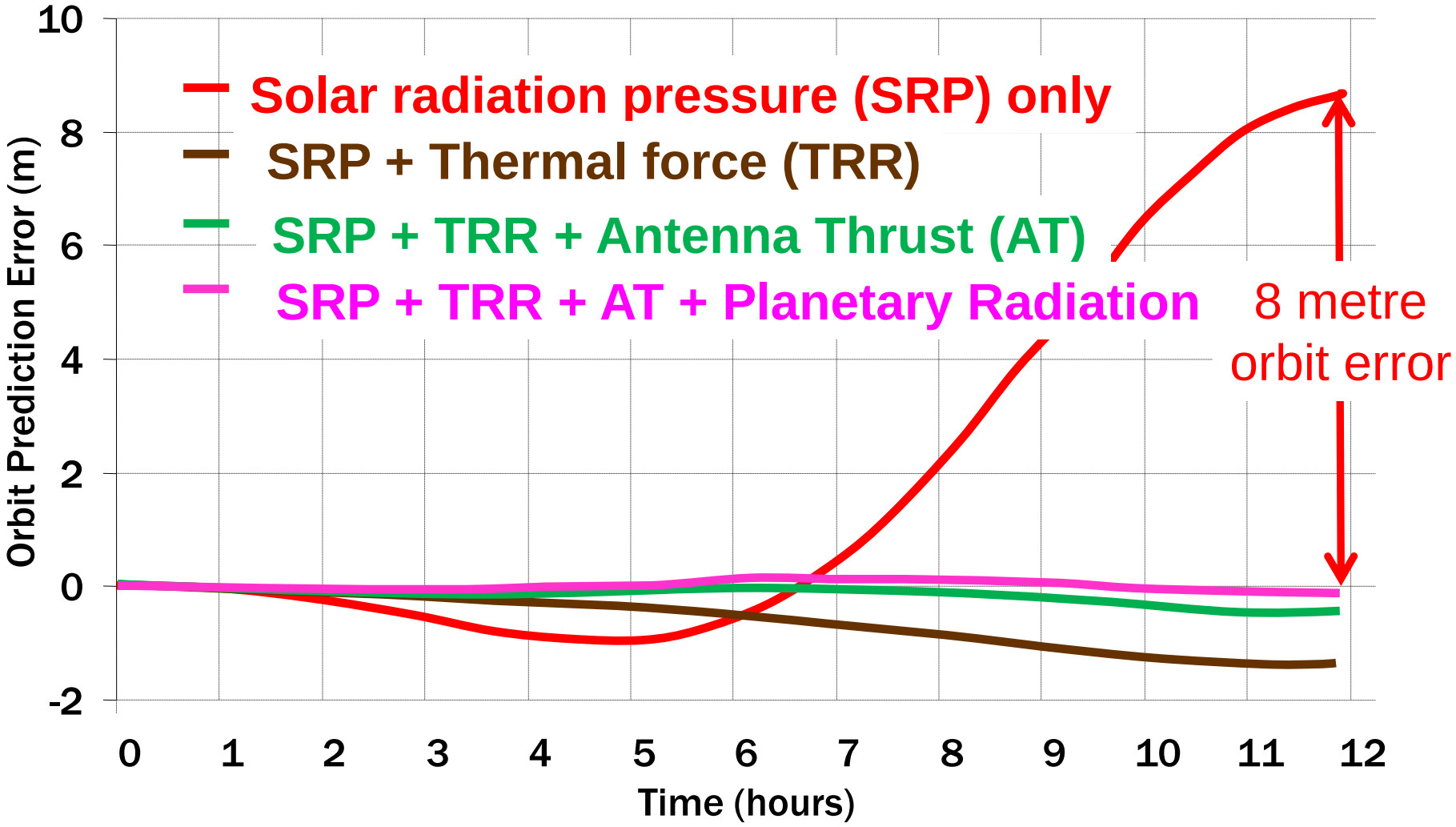
Ziebart,M., Adhya, S., Sibthorpe, A., and Cross, P., (2003) GPS Block IIR Non-conservative Force Modelling: Computation and Implications, Proceedings of ION GPS/GNSS 2003, Portland, Oregon, US (***winner of best paper award***, Science/timing application session)

Force modelling on GPS satellites

- Computer codes adapted to run on supercomputers
- Contract research for US Air Force/JPL
- Won several international awards
- Orbit determination accuracy of 2cm achieved
- Earth radiation pressure modelling adopted as international standard (IGS)
- Commercial contract to develop orbit prediction and orbit determination code for one of the world's largest providers of GPS positioning services
- Ziebart now serving on the governing board of the IGS, running a working group on orbit dynamics

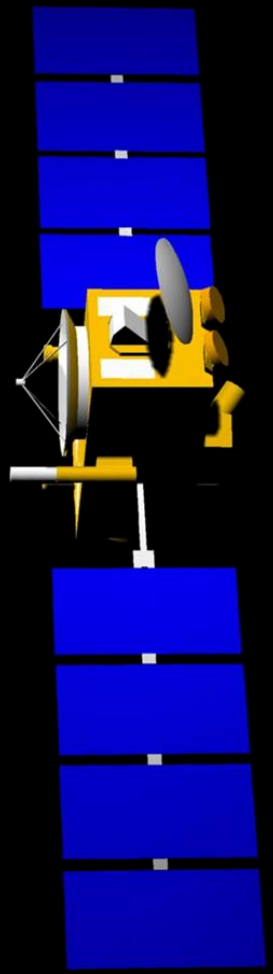


Along-track orbit prediction errors over 12 hours for one GPS satellite with different photon-based force models



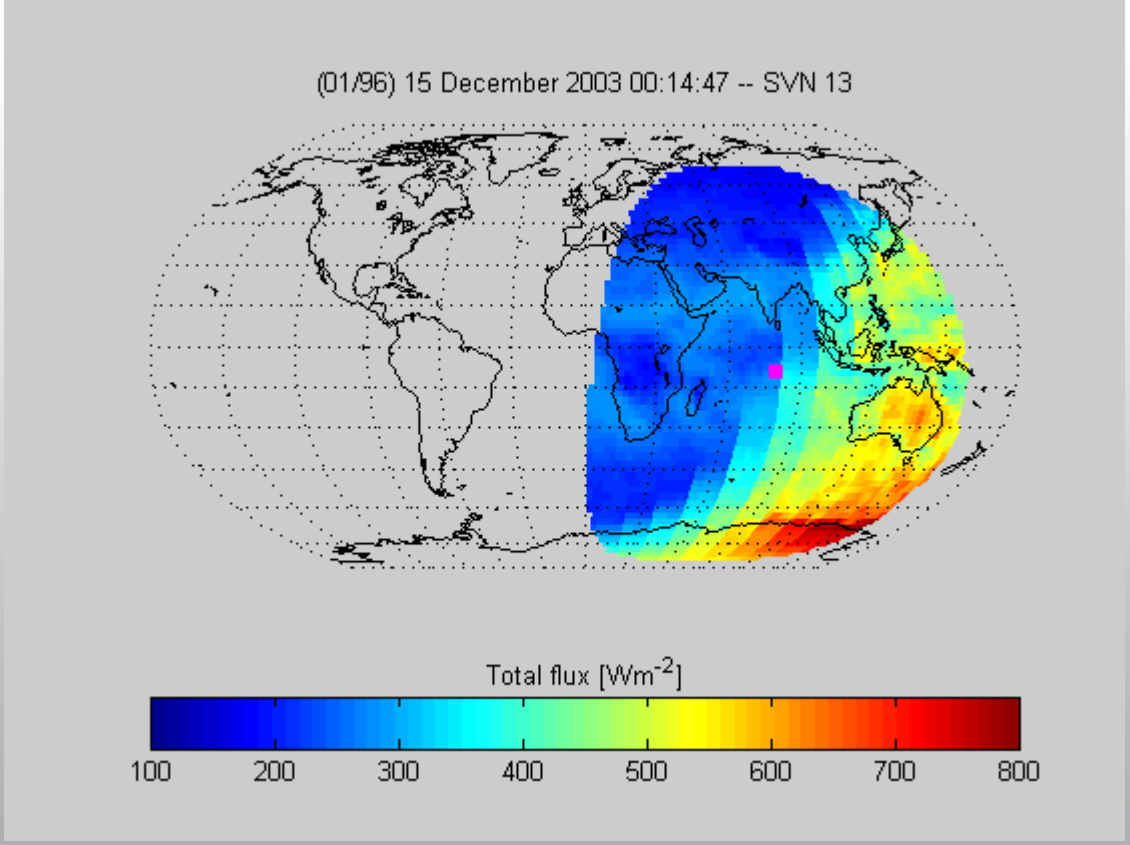
Jason-1 modelling (SRP and TRR)

- 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
- North hemisphere – South hemisphere mass transfer anomaly resolved
- Anomalous 60 day period signature reduced
- Model adopted by GSFC/JPL as POD standard



Additional techniques

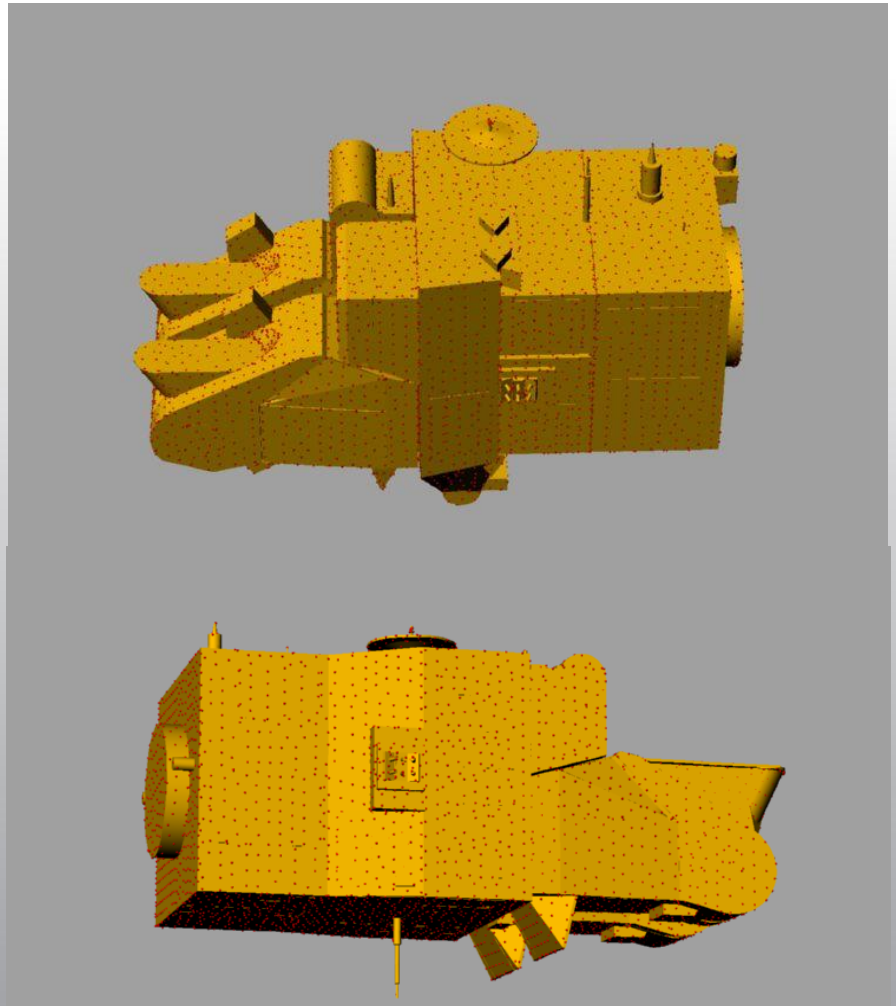
- Thermal imbalance force (solar panels), power draw
- Thermal imbalance force (thermal blankets)
- Earth radiation pressure (IR and visible, emitted and reflected)
- Penumbra flux scaling
- Antenna thrust
- Eclipse transition prediction based on ellipsoidal earth model



Earth radiation flux on GPS satellite SVN13
24 hours of modelling

SPOT4/SPOT5

- Structural models complete and tested
- Open questions about surface material properties, power draw
- Open questions about attitude models



Model formats/languages

- Preferred format is a grid file modelling acceleration along a given spacecraft body-fixed axis as a function of the radiation source latitude/longitude
- Interface for this approach coded and tested in GIPSY and Geodyne
- Code in either Fortran or C++
- Other model formats exist (Fourier series, spherical harmonics)

Conclusions

- Initial research builds SRP/TRR models for Jason-2, Cryosat, SPOT4 and SPOT5
- Experimental/developmental work on: earth radiation pressure; ram profiling/lift; surface charging effects
- Aim is to support Jason-2/Cryosat POD and reference frame but also long term reprocessing
- Funding for three years
- I welcome feedback, and hope for a good engagement with the DORIS community

Discussion?