

# **Near Term Mission Applications for Solar Sails**

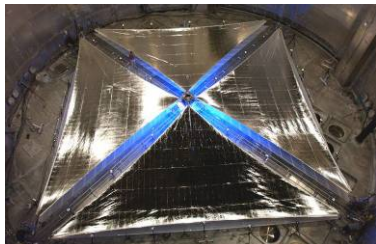
Colin McInnes

Department of Mechanical Engineering  
University of Strathclyde

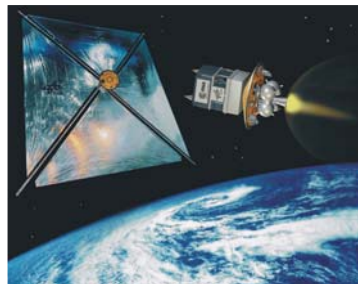
ISSS 27 June 2007

# Long term goals

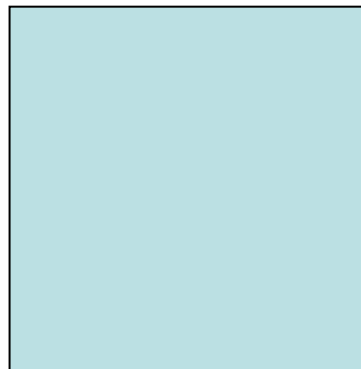
- Exciting long term missions enabled by solar sails (200 AU heliopause probe)
- Will require sequence of missions which verify new technologies for future
- Now at ground demo level - how do we bridge the gap to get to 200 AU ?



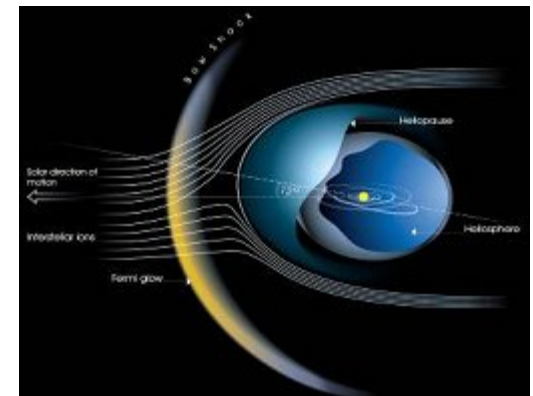
Ground tests



In-orbit test/demo

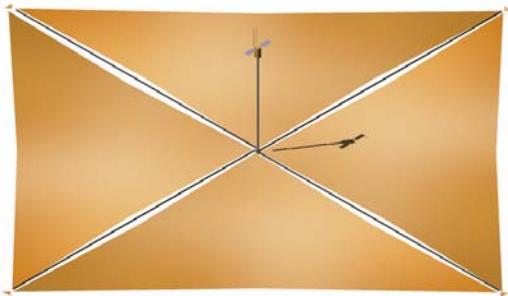


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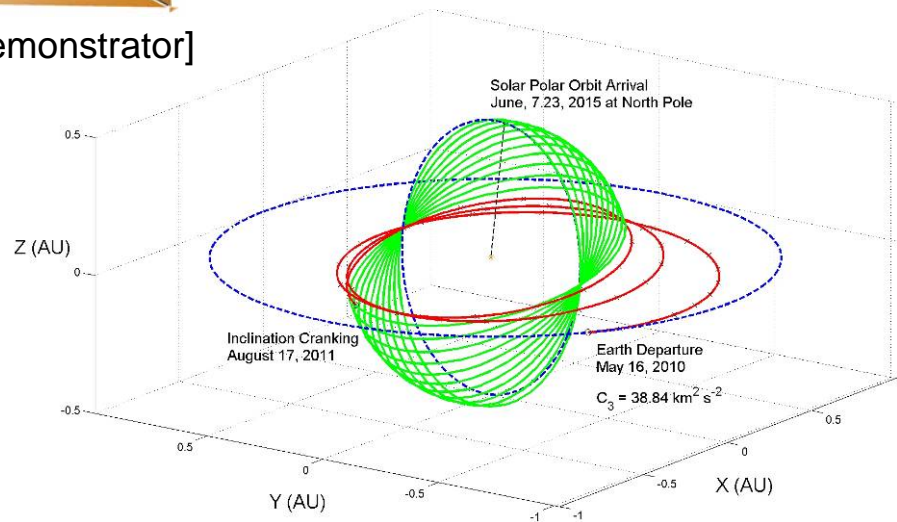


Heliopause (200 AU)

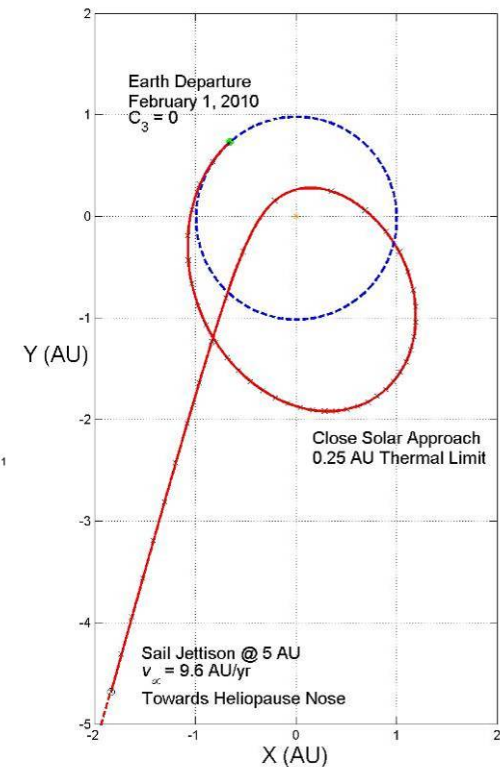
# ESA mission roadmap



Geosail [SMART demonstrator]

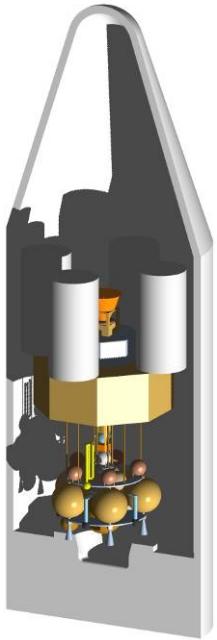


Solar Polar Orbiter [90° polar orbit]

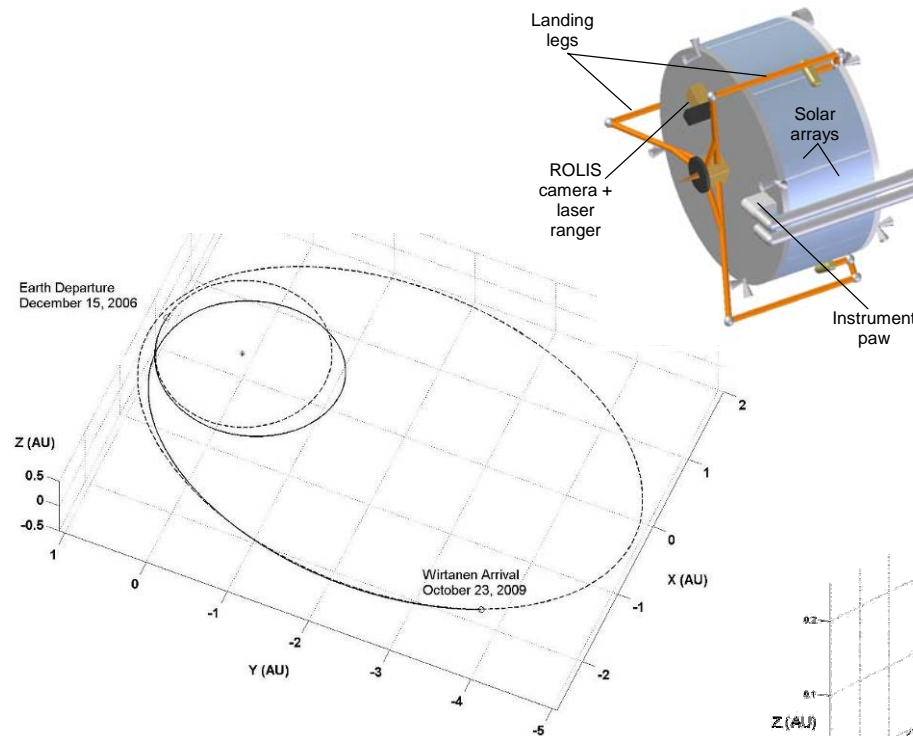


Interstellar Heliopause Probe [200 AU in 25 yrs]

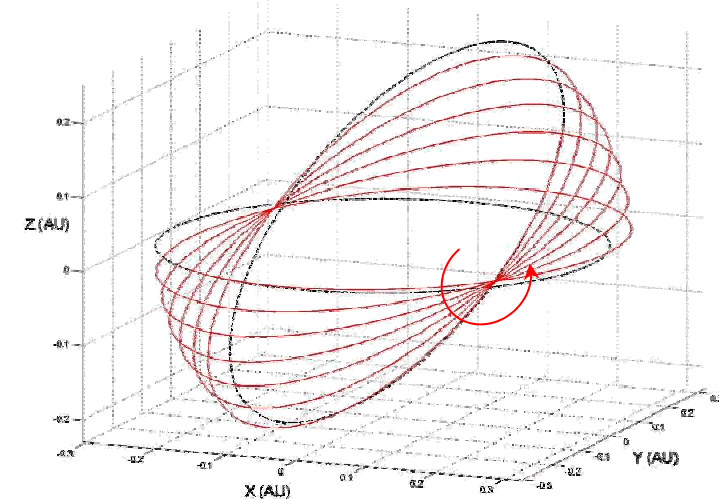
# Other mission concepts



Mercury sample return



High energy small body sample return



Retrograde orbit impact for NEO deflection

# Near term developments

- NASA/ESA forward plans focused strongly on lunar and Mars exploration
- Can solar sails become a key part of these long-term agency plans ?
- Can solar sails offer enabling missions for NEO survey/mitigation tasks ?



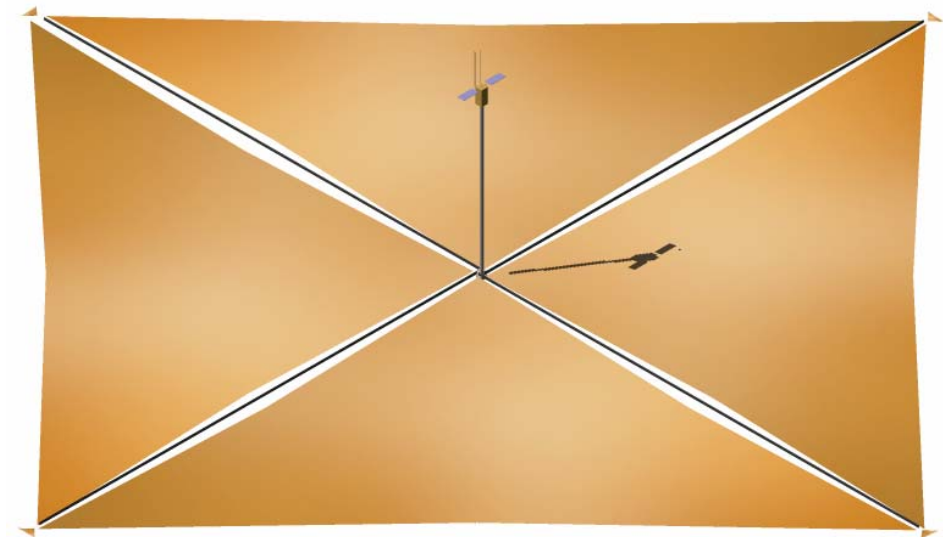
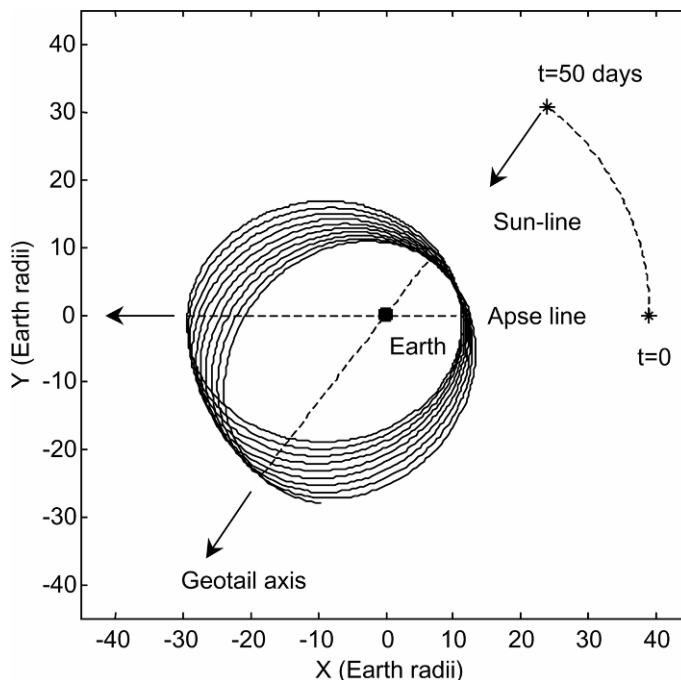
Constellation (NASA)



Aurora (ESA)

# GeoSail: demonstrator

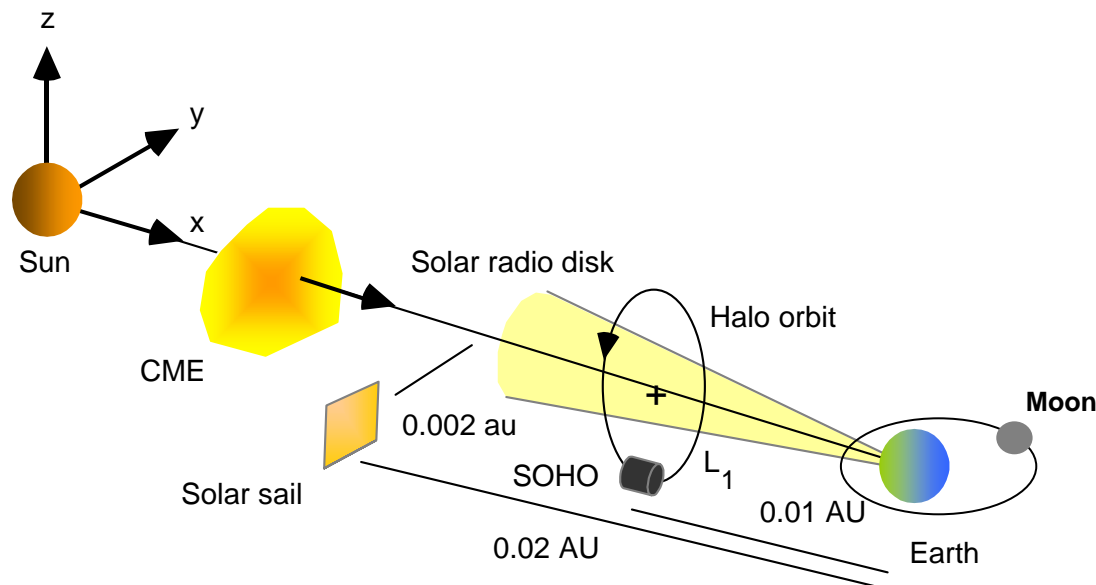
- Small sail provides orbit precession of order 1 deg/day - artificial forced orbit
- Use to keep space physics payload permanently within the geomagnetic tail
- SMART class demonstrator to validate functionality of a 3-axis solar sail



[43 x 43 m sail 172 kg launch mass inc. bus]

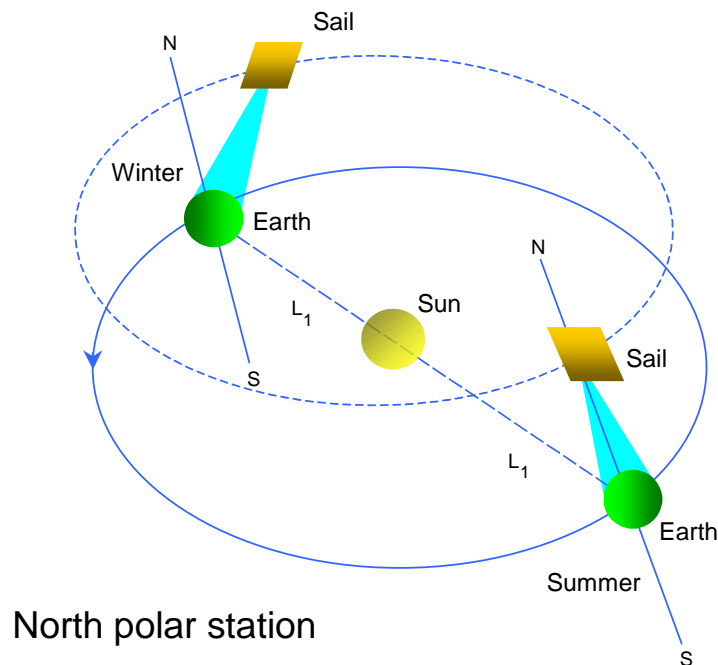
# Geostorm: space weather

- Use artificial equilibrium point sunward of classical  $L_1$  point (off Sun-line)
- Early detection of solar storms ( $\sim 90$  min warning) for terrestrial/LEO users
- *An essential tool for crew safety for trans-lunar and lunar surface crews ?*



# Polar Observer: unique platform

- Artificial equilibria with sail enables real-time observation of polar regions
- Applications for real-time imaging + telecomms (NOAA, Antarctic facilities . . )
- *An out-of-plane platform for continuous lunar and Mars telecomms ?*



Winter solstice

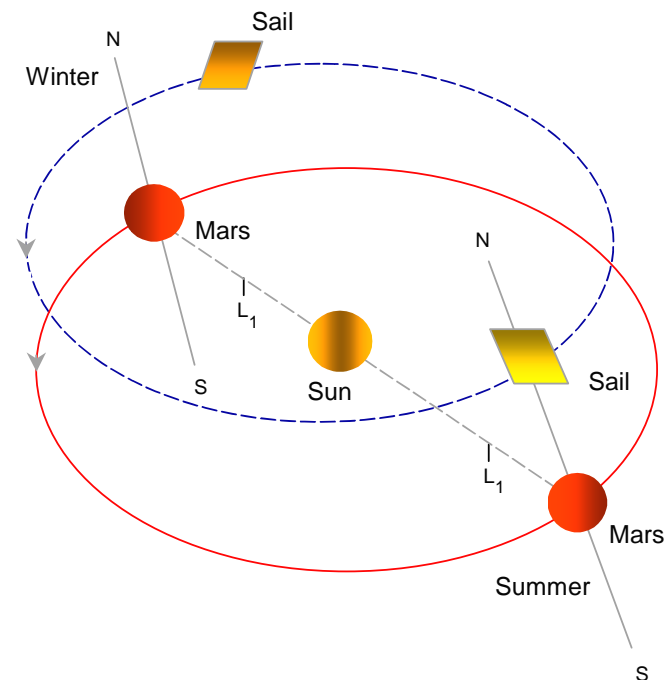
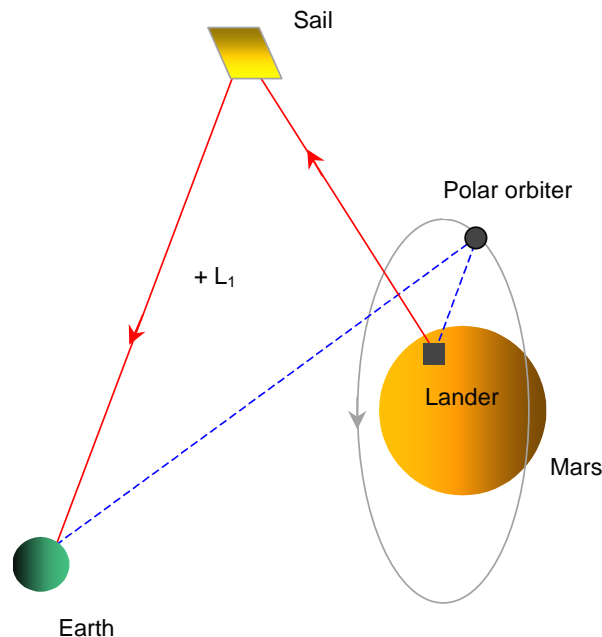


Summer solstice

# Lunar telecommunications

# Mars telecommunications

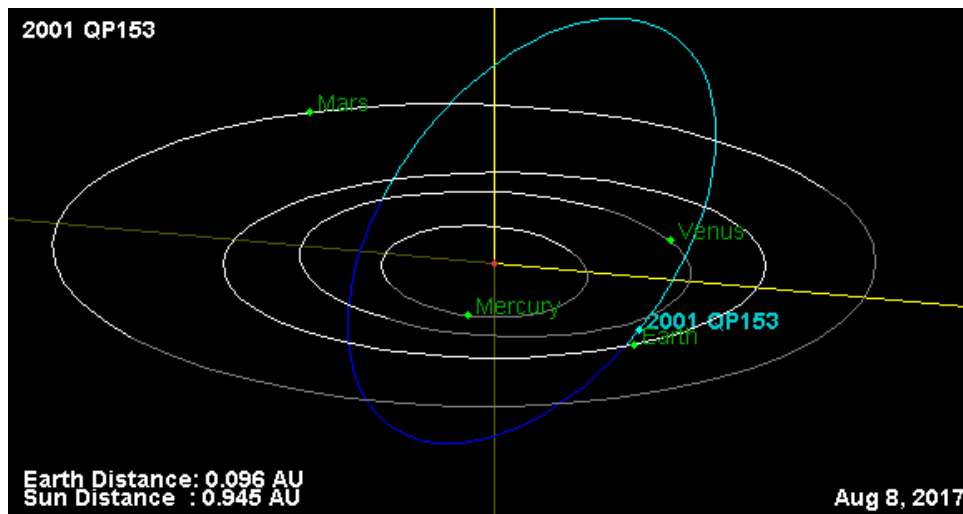
- Solar sail above/below Sun-Mars  $L_1$  point can view Mars north/south poles
- Orbiter relay has relatively short telcomms session with lander once per orbit
- Provide continuous telecomms to Mars polar lander with single solar sail



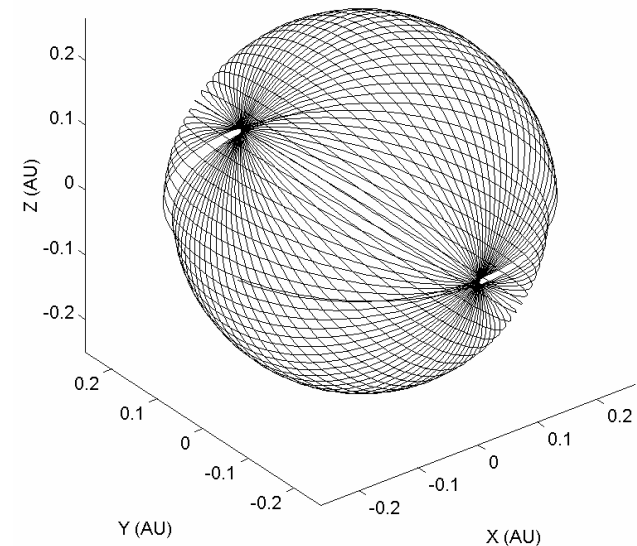
Mars polar data relay

# NEO rendezvous/impactor

- Growing agency/international interest in NEO hazard mitigation missions
- Solar sailing is a key tool for multiple target surveys and high energy targets
- Sail can deliver an impactor to a retrograde solar orbit ( $\sim 60$  km/s NEO impact)



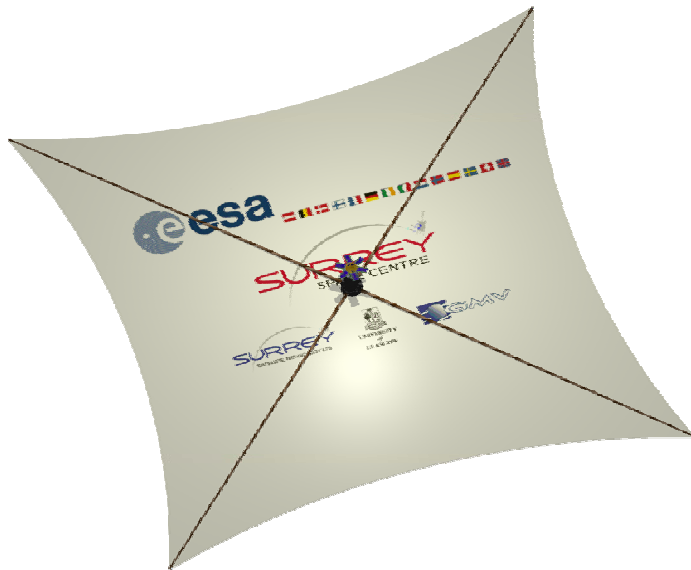
2001 QP153, inclination  $50.1^\circ$



Crank orbit inclination by  $180^\circ$

# Cubesat solar sail

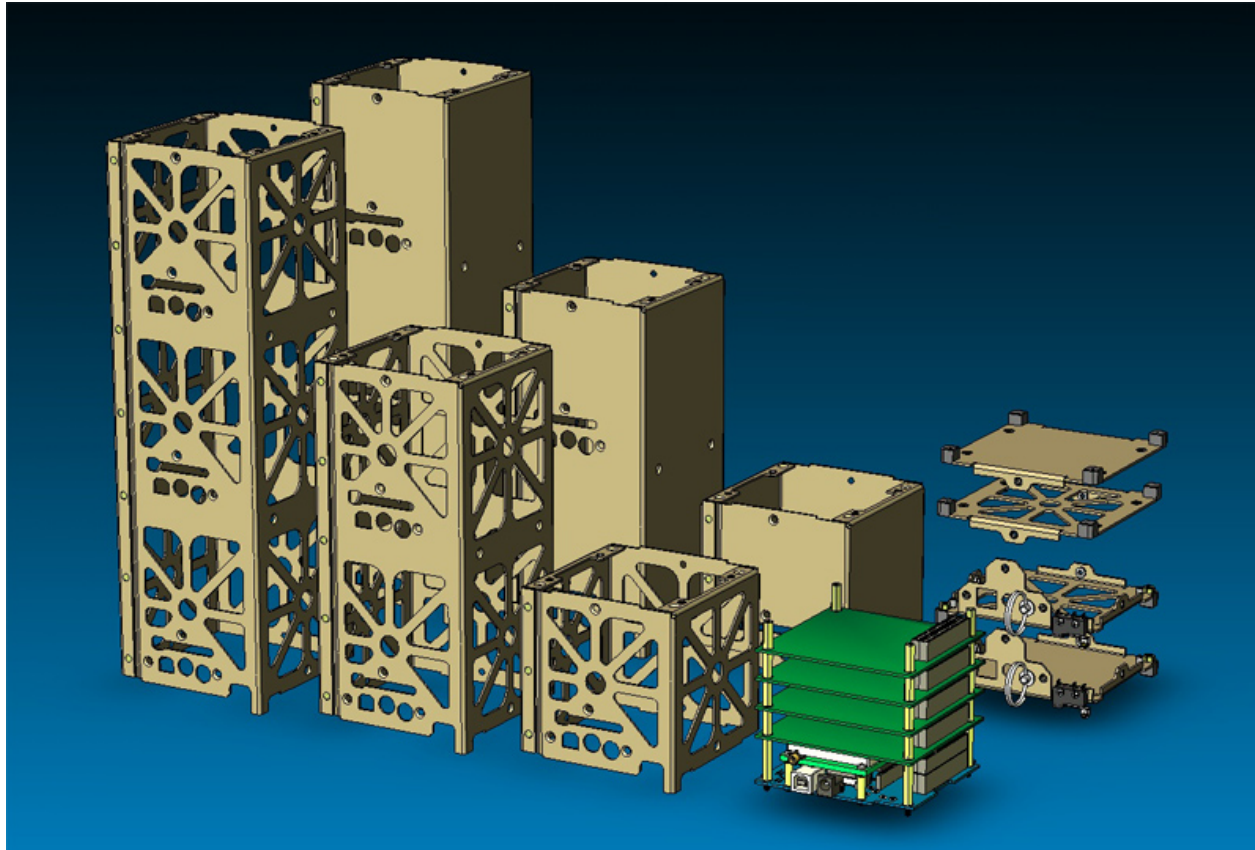
- Cubesats (1-3 kg) now offer a low cost bus to flight test new technologies
- Studies by Surrey and others on 5 x 5 m 'solar kite' with small ~1 kg bus
- Is a 5 x 5 m solar sail worthwhile ? Could use to validate ACS algorithms ?



5 x 5 m 'solar kite' concept



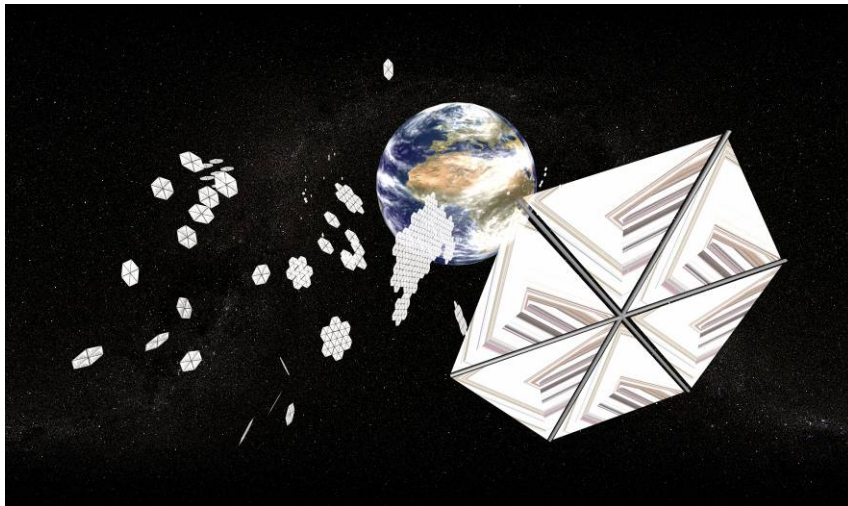
5 x 5 m sail mock-up (Glasgow 2003)



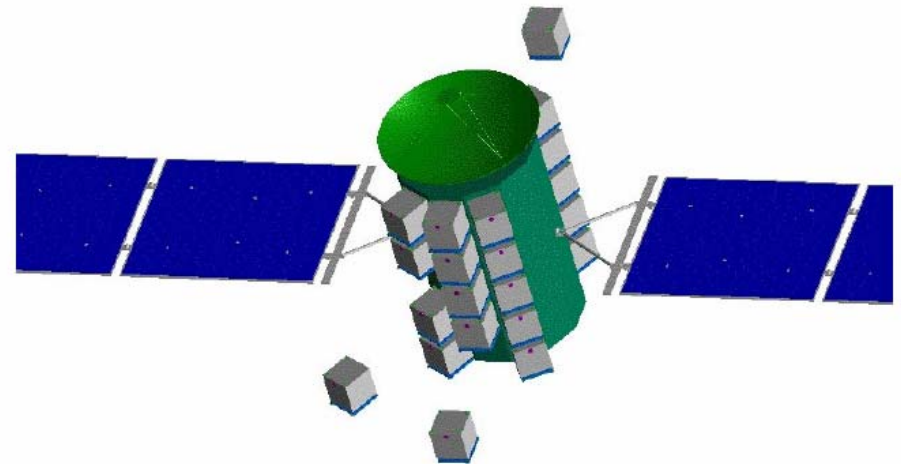
1,2 and 3 bay cubesats (Calpoly)

# Solar sail swarms

- Can 'swarms' of small (5 x 5m) sails provides useful mission returns?
- Swarm concept for GeoSail - multi-point space physics data in Geotail
- Swarm in proximity to Earth for NEO flybys (density from fly-by + image)



ESA/ACT (D Izzo)



APIES mission (Astrium/ESA)

# Summary

- Clear science requirement for solar sails - issue is how to make first steps
- May be some benefit in aligning with agency goals (lunar, Mars, NEOs etc)
- Small solar sails may be a low cost means to validate ACS algorithms etc
- May in fact be interesting missions with swarms of small solar sails . . .



EPSRC grant EP/D003822/1

"Dynamics, Stability and Control of Highly Non-Keplerian Orbits" [2006-2009]



ESA contract ESTEC/16534/02/NL/NR

"Science Payloads Transported Through Solar Sailing " [2002-2005]