ROYAL ASTRONOMICAL SOCIETY DISCUSSION MEETING

SOLAR SAIL MISSION APPLICATIONS

FRIDAY 10th MAY 2002

Lecture Theatre of the Geological Society
Burlington House, Piccadilly
LONDON

PUROPOSE

Solar sailing can enable a wide range of exciting new mission opportunities for planetary science, Earth observation, solar and space physics. Candidate mission opportunities include planetary sample return, high-energy comet rendezvous and payload delivery to solar polar orbits and the heliopause. This meeting will act as a forum to disseminate and discuss concepts for future mission applications and to review recent progress towards in-orbit technology demonstrations.

Organisers
Professor Colin McInnes (University of Glasgow) colinmc@aero.gla.ac.uk
Professor Carl Murray (University of London) c.d.murray@qmul.ac.uk

PROGRAMME

09:00-09:30 Registration and coffee

Session I (Chair - C. Murray)

09:30-09:50
Solar Sail Mission Opportunities
C.R. McInnes, University of Glasgow, colinmc@aero.gla.ac.uk

09:50-10:10
Solar Sail Technology Ground and In-Orbit Deployment Testing
M. Leipold, Kayser-Threde GmbH, Manfred.Leipold@kayser-threde.de

10:10-10:30
The Cosmos-1 Solar Sail Mission
L. Friedman, The Planetary Society, tps.ldf@planetary.org

10:30-10:50
GeoSail: Exploring Geospace Using a Small Solar Sail
M. Macdonald, University of Glasgow, m.macdonald@aero.gla.ac.uk

10:50-11:10
A Novel Method for the Deployment and Support of Solar Sails and Other Tensioned Membrane Structures
A. Daton-Lovat, Rolatube Technologies Ltd, ajdl@btinternet.com

11:10-11:40 Break

Session II (Chair - C. McInnes)

11:40-12:00
Advances in Photovolatile Coatings for Solar Sails
P. Willis, NASA/JPL, Paul.B.Willis@jpl.nasa.gov

12:00-12:20
Team Encounter: A Deep Space Delivery System
C.M. Chafer, J.E. Rogan, M.F. Lembeck, Team Encounter, L.L.C, Jim.Rogan@teamencounter.com

12:20-12:40
Low Cost Mercury Orbiter and Sample Return Missions Using Solar Sail Propulsion
G. Hughes, University of Glasgow, ghughes@aero.gla.ac.uk

12:40-13:00
Engineering and Environmental Considerations of Solar Sailing from an Industrial Perspective
R. Wall, Astrium-UK Ltd, ronan.wall@astrium-space.com

13:00-13:20 Open Discussion

13:20-14:00 Light lunch (available for purchase)

14:15 Annual General Meeting, Scientific Socities Lecture Theatre, Savile Row

15:30 – 16:00 Tea at Scientific Socities Lecture Theatre, Savile Row*

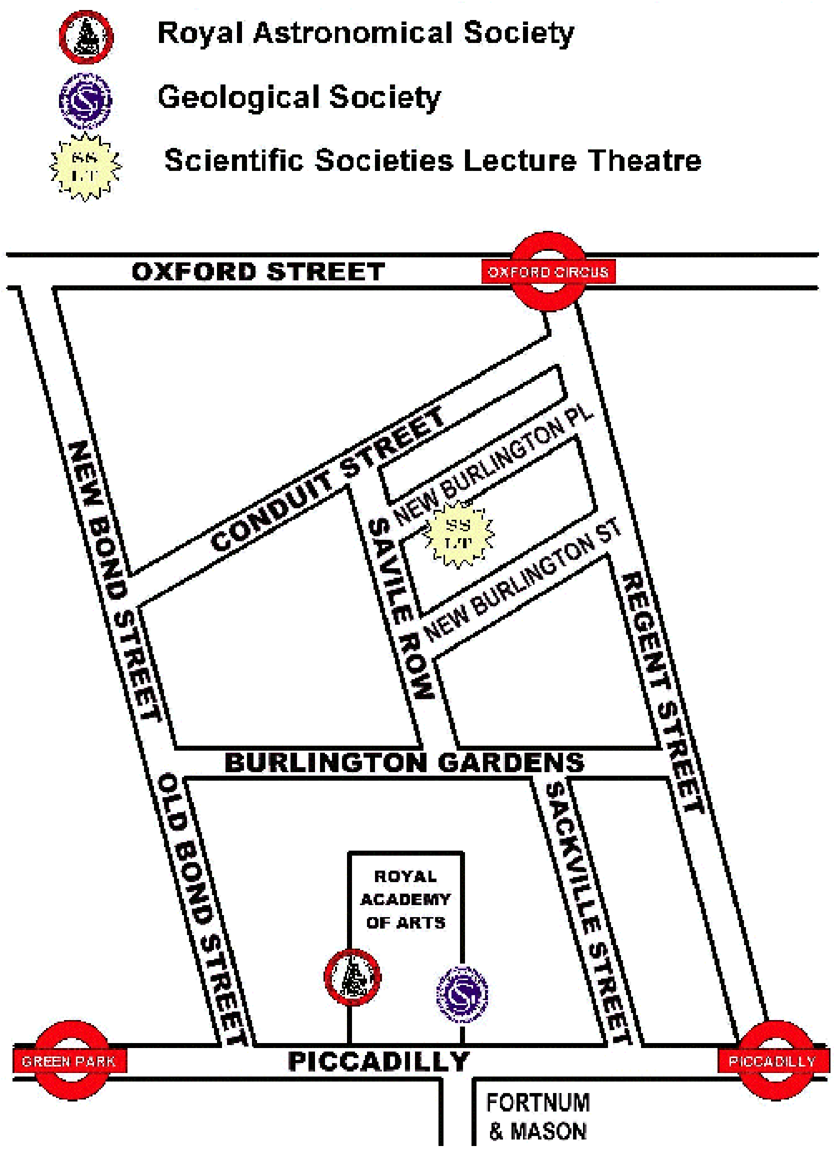
16:00 – 18:00 RAS Monthly A&G (Ordinary) Meeting*

18:00 – 19:00 Drinks Party at Savile Row*

*****Participants (whether members or not) are encouraged to attend the Monthly A&G (Ordinary) Meetings, at which topics are presented at a level suitable for a general audience. Official Society business is always kept to a minimum, and rarely occupies more than five minutes at the start of the meeting.

Travel
The meeting will be held in the Lecture Theatre of the Geological Society, Burlington House, Piccadilly, London. The nearest tube stations are Green Park and Piccadilly Circus.

Note 1 – Meeting Location Map



Note II – Meeting Abstracts

Solar Sail Mission Opportunities
C.R. McInnes, University of Glasgow, colinmc@aero.gla.ac.uk

Solar sailing is a unique and elegant form of propulsion which transcends reliance on reaction mass. Solar sails can therefore enable new high-energy mission concepts, and enhance some existing mission concepts by significantly reducing launch mass. Future missions which are enabled by solar sails include a solar polar orbiter, planetary and small body sample return and fast missions to the outer solar system. This talk will discuss near, mid and far-term mission applications for solar sails and will identify the engineering requirements necessary to enable these missions.

Solar Sail Technology Ground and In-Orbit Deployment Testing
M. Leipold, Kayser-Threde GmbH, Manfred.Leipold@kayser-threde.de

Solar sail technology holds the promise of significantly enhancing the transportation infrastructure for low-cost interplanetary space exploration missions in the new millennium by exploiting the freely available space resource of solar radiation pressure for primary propulsion. By making use of this innovative means of low-thrust propulsion, extended missions in our solar system and beyond, which require a Δv of several tens of kilometers per second, would become possible. For missions with such high propulsion energies, solar sails could either be enhancing or even enabling compared to the more traditional means of space propulsion.

Although the basic idea behind solar sailing appears simple, challenging engineering problems have to be solved. Since the propulsion efficiency depends on the overall spacecraft mass to solar sail area, technological solutions for in-orbit deployable, ultra-lightweight sail surfaces are required. The main technical challenges are to manufacture sails using ultra thin, lightweight films and deployable ultra lightweight booms, to package the sails and booms into a small volume, to deploy these lightweight structures successfully in space, and to control and navigate the resulting deployed large structures.

Prior to any ambitious deep-space solar sail mission, the technology has to be developed towards a reliable in-orbit propulsion system. Based on promising results obtained during system studies, a joint effort for the development and demonstration of several critical technologies was initiated by DLR and ESA in 1998. As a first major milestone in terms of demonstration, a 20m x 20m breadboard model was developed, manufactured and finally ground-tested in December 1999. It demonstrated the feasibility of a fully deployable lightweight solar sail structure in simulated 0-g and ambient environmental conditions. In a next development step the in-orbit deployment of the upgraded solar sail hardware will be attempted. Such a relatively low-cost flight validation is a prerequisite to proof the basic principles of solar sail manufacturing, stowage, and controlled in-orbit deployment. The lessons-learned from such an in-orbit deployment test would then be used for the design and manufacturing of larger sails to realize a thrust and acceleration level required for a deep space science mission.

The presentation is accompanied with a 2-minute video summary of the successful solar sail ground deployment test in December 1999 at DLR Cologne.

The Cosmos-1 Solar Sail Mission
L. Friedman, The Planetary Society, tps.ldf@planetary.org

Cosmos 1 is a privately sponsored mission of The Planetary Society sponsored by Cosmos Studios. Our goal is to accomplish the first solar sail flight with a earth orbiting mission this year. The spacecraft development and launch are being conducted in Russia. Work on the spacecraft development and mission plan will be presented.

GeoSail: Exploring Geospace Using a Small Solar Sail
M. Macdonald, University of Glasgow, m.macdonald@aero.gla.ac.uk

Conventional magnetosphere missions utilise long elliptical orbits to explore the length of Earth's magnetotail. However, since the orbit is inertially fixed observation periods are severally restricted due to the continual re-alignment of the magnetotail maintaining position along the anti-Solar vector, thus accurate data acquisition is limited to one month from the tail axis. GeoSail utilises solar sail propulsion to artificially precess the apse-line of an elliptical orbit in a sun-synchronous manner, this enables the science payload to maintain nearly constant presence in the geotail, providing an exciting opportunity to probe the rapid and dynamic evolution of energetic particle distributions in this critical region of geospace, including studies of magnetic reconnection and electron dynamics. The level of solar sail performance required to fulfil the science goals of GeoSail is well within current technology range, GeoSail can therefore provide both technology validation and a unique science return from a first solar sail mission.

A Novel Method for the Deployment and Support of Solar Sails and Other Tensioned Membrane Structures
A. Daton-Lovat, Rolatube Technologies Ltd, ajdl@btinternet.com

The nature and structure of a pneumatically deployed strut, suitable for the deployment of tensioned membrane structures will be described. An arrangement of such struts, which takes advantage of the characteristics of these struts, will be demonstrated.

Estimates of the total and component masses of systems suitable for the deployment of 20 and 100 meter solar sails will be given. This will include descriptions and estimates of masses of a three-axis steering system.

Other ideas for utilising the nature of this strut/deployment technology will be presented, including methods allowing the bonding of flexible film solar cells to areas of solar sails and the use of fibre optics, embedded within the struts, to provide data lines connecting instrumentation and processing packages distributed around the spacecraft.

Advances in Photovolatile Coatings for Solar Sails
P. Willis, NASA/JPL, Paul.B.Willis@jpl.nasa.gov

Solar sails are being explored for space travel due to their lack of need for propellant; solar photons serving as the propulsive force. A new series of coatings has the potential to enhance the efficiency of these sails via: (a) mass reduction, and (b) decomposition thrust. The coatings consist of thin layers of polymers that decompose to small molecules when exposed to sunlight. This coating provides strength and toughness to the sail film to survive deployment stresses, and then evaporates away to leave the film in its final ultra-low mass and reflective state. The evaporation of small molecules from the decomposing coating results in constant thrust with continually decreasing mass, and appears to follow the traditional rocket equations. The coatings being investigated include acrylates, poly(vinyl methyl ketone), and poly(silylenes). These polymers are tested for photo-decomposition in vacuum, with measurements of activation spectrum, quantum yield, volatilization rate, kinetic constant, and developed thrust. The goal is to identify a coating with high quantum yield that maximizes the thrust per mass, with complete disappearance at the end of its decomposition time.

Team Encounter: A Deep Space Delivery System
C.M. Chafer, J.E. Rogan, M.F. Lembeck, Team Encounter, L.L.C,
Jim.Rogan@teamencounter.com

Team Encounter, LLC is developing a deep space delivery system that will ultimately utilize a solar sail to deliver a 3 kg payload out of the solar system. While the benefits of using solar sails for long duration missions have been discussed extensively, to date, no solar sail missions have been executed. Using a base material one-seventy-sixth the thickness of a human hair, the Team Encounter sail will be 76 m by 76 m with a total mass of approximately 18 kg – including payload – resulting in an areal density (mass per unit area) at least 3 times lower than any other sail proposed. This high performance sail design represents a major advance in space propulsion enabling mission to the outer solar system that are virtually impossible with any other existing technology.

Team Encounter recently completed the preliminary design phase and is anticipating the start of the final design for the first technical demonstration flight deploying a 30m by 30 m sola sail in Geosynchronous Transfer Orbit (GTO). Flight One has an anticipated launch date of June 2004. The deployment will be imaged by on-board cameras and sent to the ground stations for relay to the Team Encounter Mission Control. Secondary payload accommodations are also available for commercial customers on the Team Encounter flights.

Flight Two is the deep space mission with an anticipated launch date of 2006. The spacecraft consists of a carrier with a solid rocket motor to transport the sail outside of Earth's gravity well, and the sailcraft which transports its 3 kg payload beyond the solar gravity well. The carrier is designed by AeroAstro and the sail and the inflatable booms is designed by L'Garde. Mission Systems Engineering, Integration, and Operations will all be undertaken by Team Encounter.

Low Cost Mercury Orbiter and Sample Return Missions Using Solar Sail Propulsion

G. Hughes, University of Glasgow, ghughes@aero.gla.ac.uk

The use of solar sail technology is investigated for both Mercury orbiter (MeO) and Mercury sample return missions (MeSR). It will be demonstrated that solar sail propulsion can significantly reduce launch mass and enhance payload mass fractions for MeO missions, while MeSR missions are enabled, again with a relatively low launch mass. Previous investigations of MeSR type missions using solar electric propulsion have identified a requirement for an Ariane V launcher to deliver a lander and Earth return vehicle. The analysis presented in this paper demonstrates that, in principle, a MeSR mission can be enabled using a single Soyuz-ST launch vehicle, leading to significant reductions in launch mass and mission costs. Similarly, it will be demonstrated that the full payload of the COLOMBO orbiter mission can be delivered to Mercury with a Souyz-Fregat launch vehicle, rather than Ariane V, again leading to a significant reduction in mission costs.

Engineering and Environmental Considerations of Solar Sailing from an Industrial Perspective

R. Wall, Astrium-UK Ltd, ronan.wall@astrium-space.com

Solar Sail technology has the potential to revolutionise low-thrust propulsion missions, as well as leaving a heritage to be exploited by future science missions. This paper will describe some benefits and explore concerns about solar sailing from an industrial perspective. Comparisons of solar sail propulsion will be drawn with alternative low-thrust techniques. General technology drivers of large solar sail spacecraft will be examined from a system engineering perspective. This paper will also outline a debris and meteoroid-related risk assessment, especially for geocentric missions.