Partnership Opportunity Document

for the

ST-9 Solar Sail Mission

Spacecraft Bus

NASA Goddard Space Flight Center

November 4, 2005

1.0 SCOPE

The NASA Goddard Space Flight Center's (GSFC) ST-9 Solar Sail mission is one of five competing technology validation concepts currently in a one year concept definition study sponsored by NASA's New Millennium Program (NMP). One of these concepts will be chosen by NMP in October 2006 to proceed into Phase-B. The fundamental objective of the Solar Sail mission is to design, build, test, and fly a solar sail that provides predictable, measurable, and steerable propulsive thrust using solar radiation pressure. Corollary objectives include validating structural, thermal, attitude control, thrust vector prediction and control, and environmental effects models that can then be used for the development of much larger solar sails for use on NASA's future strategic missions. In addition, the materials, tools, processes, and procedures used in the construction, deployment, and operation of the solar sail will also be validated.

The ST-9 Solar Sail Team will be submitting a concept definition Study Report (Mission Proposal) to the NMP Office in September 2006 to compete for the ST-9 technology validation flight opportunity. The overall schedule is shown below.

Phase-A Start	August 23, 2005
S/C Bus POD Release	October 31, 2005
POD Responses Due	November 19, 2005
Partner Selection	December 10, 2005
Phase-A Study Report Due	September 2006
Mission Selection by NMP	October 2006
Launch Readiness	September 2010
End of operations	Launch + 90 to 180 days

This partnership opportunity is being issued to select a teaming partner to:

- ❒ Develop an ST-9 Solar Sail spacecraft bus design for inclusion in the Phase-A Study Report/Proposal to NMP.
- ❒ Participate with the ST-9 Solar Sail Team in establishing and defining the spacecraft bus interfaces to other elements of the mission system.
- ❒ Develop plans and schedules for the spacecraft bus development.
- ❒ Prepare technical resource budgets for the spacecraft bus elements consistent with overall launch mass constraints (for both launch vehicle scenarios discussed later).
- ❒ Develop high fidelity cost estimates for design and production of the spacecraft bus and support for the bus-to-payload element integration, test, and launch operations.
- ❒ Optional**:** Provide mission operations services and associated cost estimate.

For this partnership opportunity dealing with the development of the spacecraft bus design for the Phase-A Study Report submission to NMP, the offeror is expected to provide the above support at no cost to the Government.
If the ST-9 Solar Sail Mission is selected to proceed into Formulation Refinement (Phase B), a contract award may be issued to the bus provider for Phase B and beyond.

2.0 ST-9 SOLAR SAIL MISSION DESCRIPTION

The top-level ST-9 Solar Sail Mission objectives are:

- Validate solar sail design tools and fabrication methods
- Validate controlled deployment
- Validate in-space structural characteristics
- Validate solar sail attitude control
- Validate solar sail thrust performance
- Characterize the sail's electromagnetic interaction with the space environment

The ST-9 Solar Sail mission is comprised of a spacecraft bus and the following three payload elements (illustrated in Figures 1 and 2):

- The primary payload is the Sail Propulsion System (SPS) which is being provided by L'Garde. L'Garde was selected as the SPS provider in July 2005 through the NASA Research Announcement (NRA) issued in August 2004.
- The Sail Imaging Metrology System (SIMS) is intended to provide imaging of the sail during and after deployment for static and dynamic shape measurements and for anomaly investigation. The SIMS will be provided by a third party to be selected during the concept definition phase.
- The Electromagnetic Characterization Suite (ECS) is intended to provide measurements of the induced electromagnetic environment and to characterize the interaction with the space environment. The ECS will be specified during the study phase and, after selection, a RFP will be issued in Phase B.

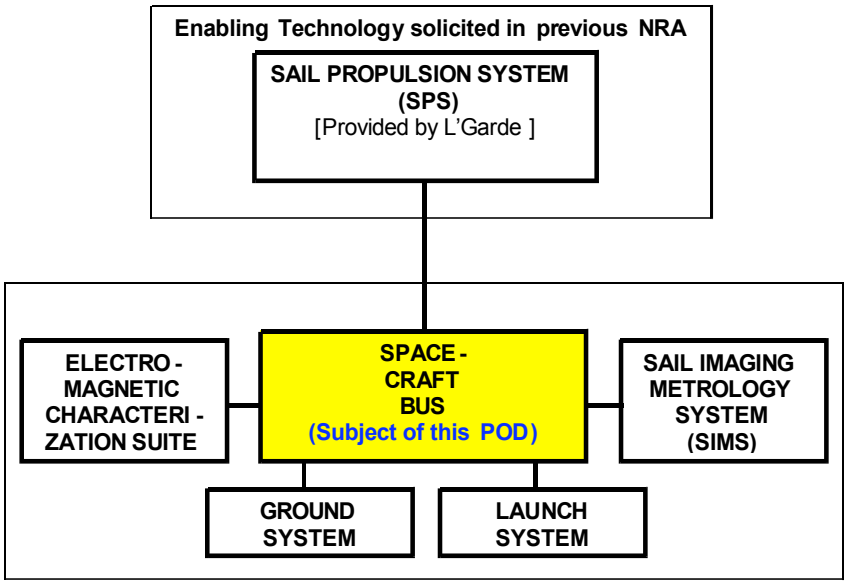

Figure 1. Major Elements of the ST-9 Solar Sail Mission

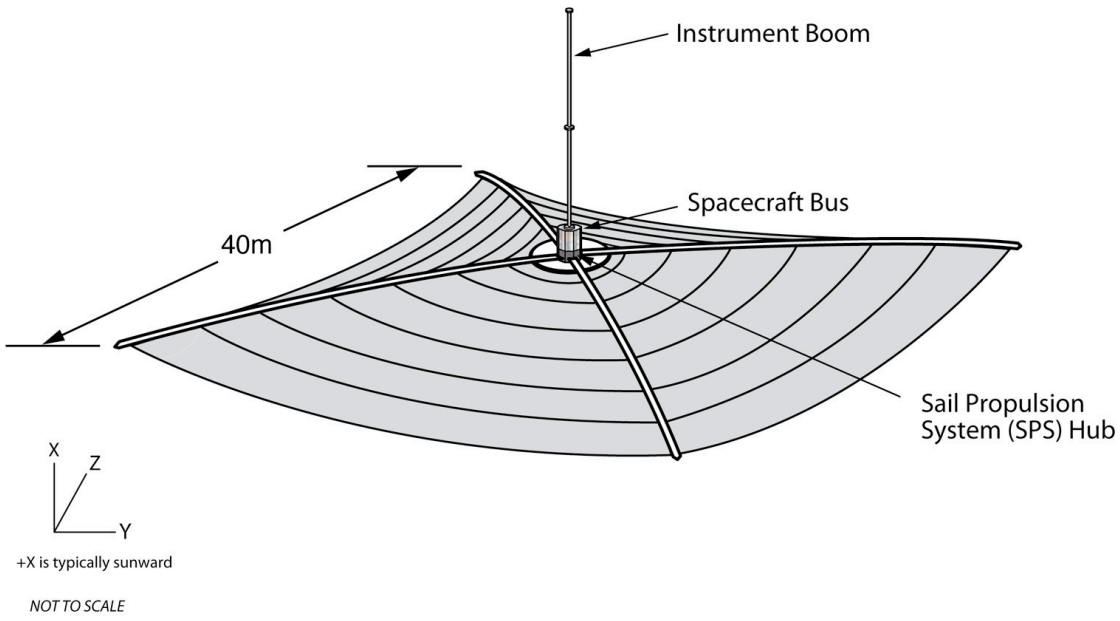

Figure 2: Spacecraft Bus with SPS in Deployed Configuration

(Note: Actual dimensions may change.
Final dimensions will be evaluated in Phase A trade studies.)

Mission lifetime is planned for 3 months with a possible extension of an additional 3 months for a total of 6 months. The mission orbit is planned to be circular, Sun-synchronous, dawn-dusk, at an altitude between 1000 and 1500 km. The launch will be either as a secondary payload on a Delta-II using the Reduced-Height Dual Payload Attach Fitting (RH-DPAF) or as primary payload on a Pegasus XL class launch vehicle. The Pegasus launch vehicle is considered to be the constraining case with respect to launch mass. The actual mission altitude (between 1000 and 1500 km) will be determined by launch vehicle performance capability given the final launch mass.

The launch accommodation concepts for the Delta-II RH-DPAF and Pegasus-XL options are shown in Figures 3 and 4 respectively. The offeror is requested to provide details on how the proposed spacecraft bus accommodates both of these launch scenarios.

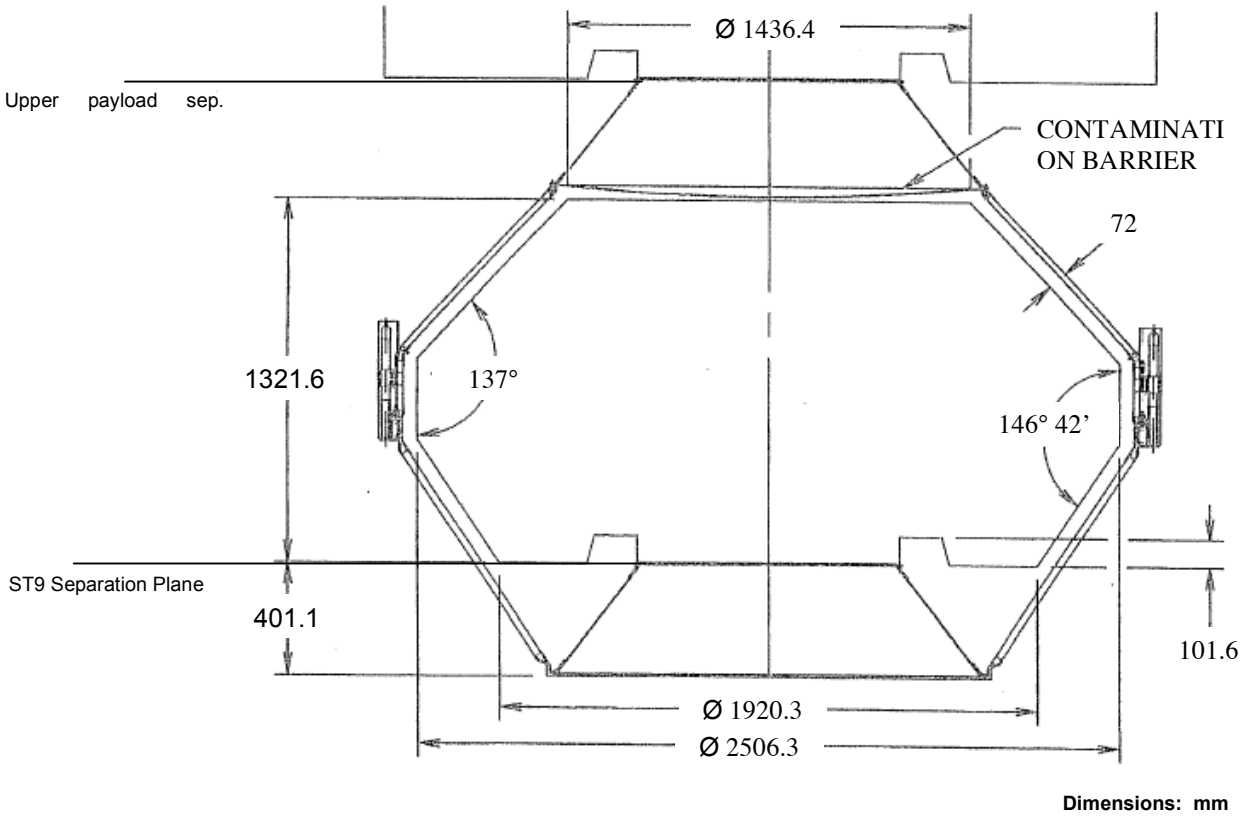

Figure 3. Delta_II Reduced Height Dual Payload Attach Fitting (RH-DPAF)

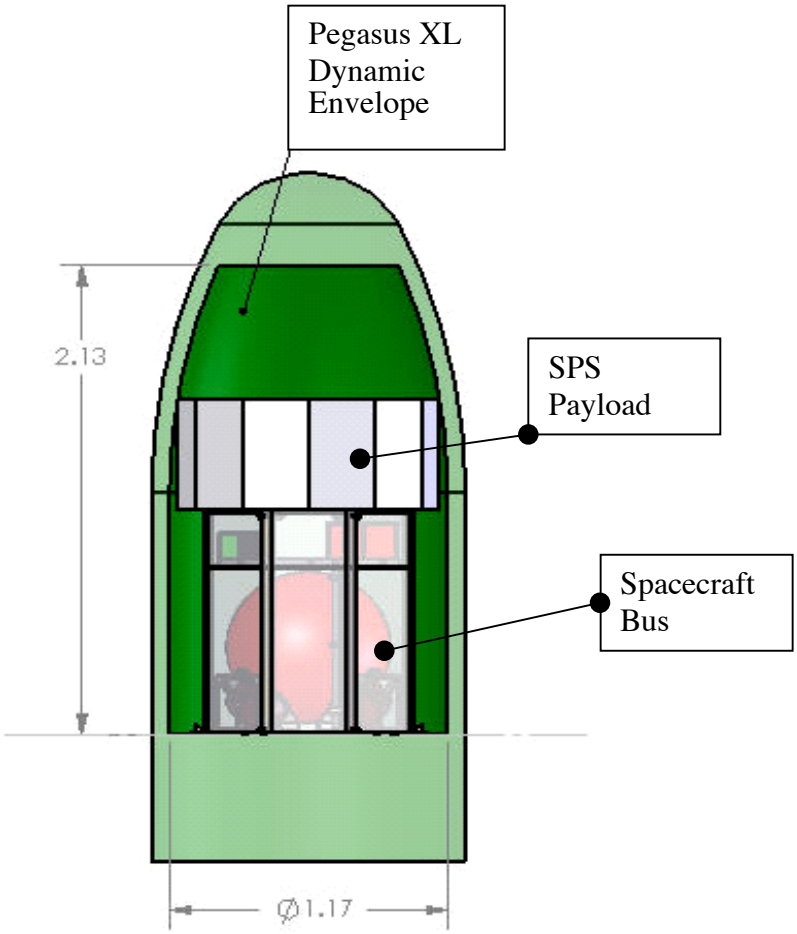

Figure 4. Concept for ST-9 Solar Sail System in Stowed (Pegasus-XL)

The ST-9 Solar Sail spacecraft bus partner will be selected via this Partnership Opportunity Document through NASA GSFC procurement.

2.1 Mission Profile

- Orbit: For the Pegasus launch scenario, the ST-9 Sailcraft will be launched into a 220 km x 1000 km insertion orbit. Then perigee raising and orbit circularization will be accomplished using on-board liquid propulsion. A final orbit higher than 1000km is desirable but will be governed by launch mass and Pegasus capability. For the Delta-II option, launch mass is not as critical and the achievable final orbit will depend largely on orbit placement for the primary payload in the dual payload configuration.
- Sail Deployment: Once the sailcraft is stabilized and basic systems checkout is completed, the solar sail will be deployed. This deployment is expected to last under two hours during which the bus

attitude control system will be required to maintain attitude such that the plane of the solar sail is sun-facing. The deployment will be monitored by the SIMS and spacecraft bus GN&C sensors. Real-time communications (at low data rate) will be required in order to monitor the deployment.

- Mission Operations: In the operations phase an extensive series of maneuvers will be performed to exercise control algorithms and validate thrust models. During this phase data will be collected to support the viability of solar sail as a means of propulsion.
- End of Mission Disposal: At the completion of the mission objectives, the on-board propulsion system will be used to lower the perigee to approximately 450 km where the drag forces will cause the orbit to quickly decay leading to re-entry and disposal.

2.2 Payload Characteristics

The characteristics of the payload elements described in Paragraph 2.0 are given in Table 1.

Table 1. ST-9 Solar Sail Payload Element Parameters

System	Mass	Launch Power[1]	Average Power	Peak Power	Average Data Rate	Peak Data Rate
SPS	39 kg	15 W	15 W	150 W[3]	1 kbps	40 kbps
SIMS	10 kg	10 W	30 W	55 W	20 kbps[2]	2 Mbps[2]
ECS	4 kg	1 W	3 W	3 W	20 bps	20 bps
Margin (30%)	16kg	6.5 W	19W	35 W	6.5kbps	0.61Mbps
TOTAL	69 kg	32.5 W	67 W	243 W	27.5 kbps	2.65 Mbps

1 Heater Power
2 Assumes 50:1 data compression
3 SPS peak power duration: ~ 30 minutes

Sail Propulsion System

The SPS is the primary payload element. It consists of the solar sail deployment booms, the sail membranes plus structural support, and the associated deployment and monitoring electronics required to accomplish the on-orbit deployment and operation of the sail. The SPS may include a Sail Attitude Control System (SACS) that can be used to orient the sail thrust vector. The bus ACS will, however, have the primary responsibility for meeting the control authority, knowledge, and stability requirements stated in Section 3. For planning purposes, the SPS dimensions in launch configuration shall be assumed to be 1.1 meter in diameter and 0.6 meter in height or smaller (see Figure 6.1). The deployed SPS will be a square

configuration of approximately 40 meters on a side providing a total reflective area of 1600 m^2 (see Figure 6.2).

Sail Imaging Metrology System

The SIMS concept consists of an array of cameras or sensors that are used to collect data during and after deployment. The imaging is required to determine the general condition of the sail and sail shape (both global and local) and validate essential structural, dynamic, GN&C, and thermal models of the solar sail. Other sensors (accelerometers, strain gauges, thermistors, etc.) will collect data that enable the validation of sail thermal and structural models to be used in designing larger sails for future strategic missions.

Electromagnetic Characterization Suite

The ECS concept consists of a magnetometer and a solar wind plasma analyzer that will provide characterization of large scale induced currents in the sail surface and charging on the sunward side of the sail.

2.3 Spacecraft Bus Requirements

The spacecraft bus must accommodate the payload characteristics given in Table 1 and meet the other requirements given below in Table 2.

Table 2. Mission and Spacecraft Requirements

Payload Mass (kg)	69 (includes 30% margin)
Payload Power (EOL) Required (W)	67 avg., 243 peak (includes 30% margin)
Mission Data Downlink/Band (Mbps)	2.25 (S-band to GN, commercial, DSN, TDRSS as req'd)
Antenna Coverage	Near spherical (requires two omnis)
Science Data Storage (Mbits)	500 (after 50:1 compression)
Command Uplink/Band	2 kbps, S-band
Redundancy	Selective (Limited by mass constraints)
Pointing Knowledge (degrees)	0.1
Pointing Control (degrees)	0.5
Pointing Stability (Jitter) (deg/sec)	0.5
Sail inertial properties (deployed)	Ix=8000 kg-m^2; Iy=Iz=4000 kg-m^2
Orbit determination	Ground tracking range/range rate and/or GPS
Star Trackers	1
Launch Readiness Date	September 2010
Mission Life	3 months required; 6 months (extended goal)
Launch Vehicle	Delta II RH-DPAF or Pegasus-XL
Orbit (km)	1000 to 1500 km Sun-synch, dawn-dusk (>1000 km desired)
Orbit Knowledge	TBD
Total Radiation Dosage (kRads)	5.0

Propulsion requirement	Propulsion needed to raise perigee, circularize orbit, back-up attitude control, back-up momentum dumping, and end of mission disposal. The thruster sizing will be constrained by the gossamer nature of the solar sail.
Processing for data compression (optional)	50:1 data compression for imaging during deployment and dynamics testing (may be done within SIMS or, optionally by the bus C&DH processor)
Other considerations	Bus ACS must be capable of four basic maneuvers: • 3-axis stabilized inertial hold without actuator resultant forces • Local Vertical, Local Horizontal (LVLH) hold with Z-axis nadir pointing • Orbit Maneuvering • Safe-hold (X-axis toward the Sun) Gravity gradient is the dominant torque on the deployed sailcraft system

3.0 OFFER FORMAT AND INSTRUCTIONS

Proposals are not page limited and standard fonts will be acceptable. Embedded graphics are to be in commonly used formats, i.e. JPEG or GIF. Offeror may feel free to attach additional appendices that describe their capabilities further. Responses to this POD shall be in Adobe Acrobat Portable Data Format (PDF), MS Word, or MS Powerpoint.

Your written offer package must include the following:

- ❒ The approach for supporting the preparation of the ST-9 Solar Sail Phase-A Study Report as pertains to the spacecraft bus
- ❒ A demonstration of clear understanding of, and ability to meet or exceed, the ST-9 Solar Sail spacecraft bus mission requirements and technical challenges

3.1 Statement of Work

3.1.1 Phase-A Study/Proposal Support

During the Phase-A Report/Proposal preparation period, the offeror will participate as part of the ST-9 Solar Sail proposal team. In response to this POD the offeror will describe briefly the proposed approach to supporting the Phase A study. The offeror shall also address the design and performance information on the topics listed below. Upon selection the offeror will provide detailed information on these topics as well as provide cost information on the spacecraft bus and mission operations (optional) for inclusion in the Phase-A Report/Proposal.

The offeror will be expected to support, at a minimum, the following meetings:

1. Weekly teleconferences
2. Face-to-face meeting at GSFC every other month (except January and March 2006)
3. Concept Review at L'Garde (Tustin, CA), 3 days, late January 2006
4. Integrated Mission Design Center (IMDC) exercise at GSFC, March 20-23, 2006
5. TRL assessment/site visit at L'Garde, 1 day, September 2006

The following Statement of Work elements shall be included in the offeror's proposal:

I. Spacecraft Bus
    1. S/C requirements
    2. Payload accommodations
    3. Spacecraft bus description and block diagram
    4. Launch vehicle interface-drawings (for both launch vehicle scenarios)
    5. S/C subsystem elements: C&DH, RF Communications, ACS, power, thermal, and mechanical/structural
    6. Resource/Margin table

II. Observatory I&T
    1. Facilities (location) and Flow
    2. Environmental tests planned
    3. End-to-end testing
    4. Ops training and procedure validation

III. Ground System and Mission Operations (optional)

3.1.2 Phase B and Implementation The offeror should present briefly in the response to this POD the concept for developing a spacecraft bus for the ST-9 Solar Sail mission, a preliminary plan for observatory integration and test, and a preliminary plan for the launch campaign including proposed schedules. The offeror shall briefly identify the proposed approach for engineering support to monitor the health and safety of the spacecraft including flight software maintenance during launch and early orbit followed by as-needed support during mission operations. Included in this section is a description of facilities or other capabilities of the offeror that would enhance the implementation of the ST-9 Solar Sail mission.

3.2 Evaluation Factors and Criteria

The evaluation team will use the following factors in selection and award.
The Government will evaluate the proposals submitted in response to this POD based upon the following three evaluation factors: (a) Mission Suitability, (b) Price, and (c) Relevant Experience/Past Performance. These evaluation factors are of equal importance. The ability to prepare a winning proposal will also be a selection factor.
Proposal/Pre-selection support point break down (Total - 100 points):

(a) Mission Suitability (30 points),
(b) Price (30 points),
(c) Relevant Experience/Past Performance (30 points), and

(d) Proposal win-ability & presentations skills (10 points).

The following criteria of the proposals will be evaluated:
(a) Mission Suitability: Offerors will be evaluated on their overall understanding of the requirements and their proposed concept to meet the requirements of the ST-9 Solar Sail mission. Offerors will be evaluated on their recognition of the objectives of the program, technical soundness, and innovation of proposed approach as well as the methods to be used in planning, controlling, and completing the Statement of Work requirement.
(b) Price: The price factor is important in determining the Offeror's understanding of the requirements of the mission and the resources required. Price will be considered in evaluating and assessing the validity of the approach proposed for accomplishing the Statement of Work. The Offeror will be evaluated on:

- ❒ The proposed price for delivery of the ST-9 Solar Sail spacecraft bus, including support for payload element to bus integration, system-level test and verification, launch operations, and mission operations.
- ❒ The ST-9 Solar Sail will be very cost sensitive; list ideas and methods of keeping costs low and the risk of cost growth low.

(c) Relevant Experience/Past Performance: Emphasis will be given to the extent of direct experience and quality of past performance on previous contracts/task orders that are highly relevant to the effort defined in the POD. The Offeror will be evaluated on:

- ❒ Narrative summary describing briefly the offeror's relevant experience and past performance similar to the NMP ST-9 Solar Sail spacecraft bus development. Additional information may be added in the appendices.

4.0 INSTRUCTIONS FOR PRESENTATION PREPARATION

Potential respondents are asked to notify the ST-9 Solar Team of their intent to respond by November 10, 2005, 3:00pm EST. This contact shall not be considered binding, but shall serve to help the ST-9 Solar Sail Team disseminate any additional relevant information to potential partners. Questions can be asked during the first week after release of this document. All questions and answers will be sent to those who express a desire to respond, while the source of the questions shall be held confidential. For questions pertaining to this partnership opportunity document, the ST-9 Solar Sail contact is: Timothy Van Sant, John.T.VanSant@nasa.gov, 301-286-6024.

Presentation packages must be received by 6pm EST, November 21, 2005. The respondents shall deliver the requested information in a report or presentation format. Please provide either a hardcopy or an electronically formatted presentation (MS Word, MS Powerpoint or PDF formats) to Timothy Van Sant, NASA GSFC, Code 462, Greenbelt, MD 20771. Responses will be treated as proprietary information and controlled as such.

5.0 ACRONYM LIST

ACS	Attitude Control System
C&DH	Command and Data Handling
CY	Calendar Year
ECS	Electromagnetic Characterization Suite
GN	Ground Network
GN&C	Guidance Navigation and Control
GPS	Global Positioning System
GSFC	Goddard Space Flight Center
LVLH	Local Vertical-Local Horizontal
NLT	No later than
NMP	New Millennium Program
NRA	NASA Research Announcement
NTE	Not to exceed
PDF	Portable Data Format
POC	Point of Contact
POD	Partnership Opportunity Document
RF	Radio Frequency
RFP	Request for Proposal
RH-DPAF	Reduced Height Dual Payload Attach Fitting
ROM	Rough Order of Magnitude
SACS	Sail Attitude Control System
SIMS	Sail Imaging Metrology System
SPS	Sail Propulsion System
ST-9	Space Technology - 9
TBD	To be determined
TDRSS	Tracking and Data Relay Satellite System