Request For Information (RFI)

Title: AtmOS Access to Space (ATS) RFI	**Date:** June 16, 2021
Reference Number: RFI- # AtmOS ATS	**RFI Responses Due Date:** July 28, 2021

1.0 REQUEST FOR INFORMATION (RFI)

NASA/Goddard Space Flight Center (GSFC) is hereby soliciting information on spacecraft systems and/or hosted payload concepts, including innovative approaches, to launch six different candidate instruments into LEO orbit, with cost effective and innovative approaches for the Atmosphere Observing System (AtmOS). There is also interest in ride-sharing capacity/capability for other payloads to be developed by AtmOS partners. In addition, we seek information on the capability of vendors able to provide Ground System and Mission Operation services.

The National Aeronautics and Space Administration (NASA) GSFC is seeking capability statements from all interested parties, including all socioeconomic categories of Small Businesses and Historically Black Colleges and Universities (HBCU)/Minority Institutions (MI), for the purposes of determining the appropriate level of competition and/or small business subcontracting goals for AtmOS Access to Space (ATS). The Government reserves the right to consider a Small, 8(a), Women-owned (WOSB), Service Disabled Veteran (SD-VOSB), Economically Disadvantaged Women-owned Small Business (EDWOSB) or HUBZone business set-aside based on responses received.

No solicitation exists; therefore, do not request a copy of the solicitation. If a solicitation is released, it will be synopsized on SAM.gov. Interested firms are responsible for monitoring this website for the release of any solicitation or synopsis.

Interested firms having the required capabilities necessary to meet the requirements described herein should submit a capability statement of no more than 15 pages indicating the ability to perform all aspects of the effort.

Please advise if the requirement is considered to be a commercial or commercial-type product. A commercial item is defined in FAR 2.101.

This synopsis is for information and planning purposes only and is not to be construed as a commitment by the Government nor will the Government pay for information solicited. Respondents will not be notified of the results of the evaluation.

The AtmOS Project is a funded mission in Pre Phase A. AtmOS grew out of the NASA's ACCP Decadal Study. Information on the ACCP Study is available at the following website:

https://vac.gsfc.nasa.gov/accp/

AtmOS plans to take advantage of the growing commercial rideshare/hosted payload capabilities and launch the AtmOS mid-inclination spacecraft on a single launch vehicle.

Consideration will be given to planned development approaches that deviate from the referenced processes. Information is also sought regarding opportunities for public-private and other partnerships to enable successful development of systems within cost and schedule constraints. Responses should recognize that implementing a system that stays within the allocated budget is an essential programmatic requirement for the U.S. Government. Specifically, three types of responses are sought:

1. Response Option 1: Concepts for spacecraft designs and plans for development of the spacecraft that include integration and test with the payload, through launch and commissioning;

2. Response Option 2: Concepts for hosting a partial or full complement of instrument payloads within the architecture of a current or future system;

3. Response Option 3: Concepts for public-private or other partnership options to develop systems to meet mission objectives.

This RFI is open to all types of organizations, including U.S. industry, universities, nonprofit organizations, NASA Centers, Federally Funded Research and Development Centers, other U. S. Government agencies, and international organizations.

2.0 BACKGROUND

The Atmosphere Observing System (AtmOS) mission team has been established by the NASA Science Mission Directorate Earth Science Division to study mission concepts to meet AtmOS science objectives as part of Pre-Phase A activities leading to a Mission Concept Review (MCR) and Key Decision Point-A (KDP-A) anticipated to occur in 2nd quarter FY2022.

The AtmOS mission will meet the critical observational needs of Earth's atmosphere by employing a multi-satellite architecture sufficient to cover the relevant temporal and spatial scales, thereby transforming our understanding of this critical part of the Earth System. As part of pre-formulation and formulation activities, the AtmOS mission study team is performing trade studies to determine options to make measurements and achieve sampling to meet as many of the science mission objectives as possible within cost and schedule constraints. To maximize science objectives achievable, efficient and effective system concepts for accommodating the instruments are needed. Through this RFI, the study team is seeking information on spacecraft system concepts and innovative approaches, including a range of solutions for dedicated spacecraft and hosted instruments, to develop necessary quantities of systems to meet science objectives. The study team is also seeking information regarding opportunities for public-private and other partnerships. System concepts that may accommodate portions of the instrument payload complement and quantities will be considered.

The study team plans to use the information provided in combination with studies of all mission elements to evaluate overall mission architecture options relative to science objectives and cost and schedule constraints.

3.0 AtmOS SCIENTIFIC GOALS AND OBJECTIVES

Per the ACCP 'Science and Applications Traceability Matrix', the overarching AtmOS goal is: "Understand the processing of water and aerosol through the atmosphere and develop the societal applications enabled from this understanding." AtmOS provides transformative space-based and suborbital observations of essential cloud, precipitation and aerosol processes, leading to improved predictions of weather, air quality, and climate for the benefit of society.

The following are the detailed goal of the AtmOS Mission:

- G1: Cloud Feedbacks – Reduce the uncertainty in low- and high-cloud climate feedbacks by advancing our ability to predict the properties of low and high clouds.
- G2: Storm Dynamics – Improve our physical understanding and model representations of cloud, precipitation and dynamical processes within convective storms.
- G3: Cold Cloud and Precipitation – Improve understanding of cold (supercooled liquid, ice, and mixed phase) cloud processes and associated precipitation and their coupling to the surface at mid to high latitudes and to the cryosphere.
- G4: Aerosol Processes – Reduce uncertainty in key processes that link aerosols to weather, climate and air quality related impacts.
- G5: Aerosol Impacts on Radiation – Reduce the uncertainty in Direct (D) and Indirect (I) aerosol-related radiative forcing of the climate system.

Further details of the AtmOS science goals and objectives can be found in the ACCP Science and Applications Traceability Matrix, which can be found at:

https://vac.gsfc.nasa.gov/accp/docs/accp-satm-rel-f-master.pdf

4.0 REFERENCE PARAMETERS

The following reference parameters should be considered in the responses to this RFI.

4.1 <u>Mission Schedule and Reviews</u>

The current notional AtmOS mission schedule is as follows. This hypothetical schedule may or may not be or become the planned mission schedule and is intended only to enable consistent responses to this RFI.

- Mission Concept Review (MCR): 2/2022
- Mission System Requirements Review (SRR): 12/2022
- Mission Preliminary Design Review (PDR): 6/2024
- Mission Critical Design Review (CDR): 6/2025

- Instruments Delivery Date: 6/2026
- Launch Readiness Date: 3/2028

We intend to initiate multiple study contracts to support Mission Concept Review (MCR) in February 2022. If an Access to Space (ATS) Request for Proposal (RFP) and/or a spacecraft/hosted payload is released, it is anticipated to follow the schedule below:

- ATS Study (Pre-Phase A) RFP Release: 9/2021
- ATS Study (Pre-Phase A) Contract Award: 11/2021
- Spacecraft/ATS RFP Release: 2/2023
- Spacecraft/ATS Contract Award: 11/2023

4.2 Mission Requirements

4.2.1 Orbit Parameters

The planned orbit is 407km circular (+/- 10km), 50-70 degree inclination. Note: the Government is interested in information from the respondent if there are vendor preferences or cost savings enabled by specific orbital choices.

4.2.2 Operational Modes and Fault Detection

The spacecraft should have operational modes that include: operation with instruments in standby, engineering, operation in science mode (instruments operating), safe hold, and load shed capability. The spacecraft should be powered during launch. The spacecraft should provide fault detection and safe action for the instruments.

4.2.3 Mission Lifetime

3 years starting at the completion of 3 months of commissioning, with planned consumables for minimum 5 years of operations, plus disposal.

4.2.4 System Reliability

Each AtmOS spacecraft and instrument payload complement is currently envisioned to be Risk Class C per NPR 8705.4. Concepts that follow alternative approaches will be considered. Related information is requested per 4.6. Information is requested regarding the reliability of the spacecraft for the mission lifetime per 4.2.3. Depending on the orbital debris approach taken, the spacecraft will have a reliability of deorbit per the orbital debris requirements per 4.2.6.

4.2.5 Launch Vehicle

The current plan is to launch all spacecraft needed to fly the instrument payload complement quantities per Section 4.3.1 on a single launch vehicle. Information, configurations, and envelopes for launching the respective quantities of systems is requested. The scope of work for the spacecraft vendor should include the system to deploy the spacecraft from the launch vehicle, including cost. It should be assumed that the launch vehicle will provide the signal to deploy the individual spacecraft. The spacecraft vendor will perform all launch site activities, including pre-launch preparation and testing, in coordination with the launch vehicle provider. The spacecraft vendor should assume the launch will occur on the continental United States. Launch vehicle or launch service costs should not be included in cost estimates. Alternative approaches will be considered. It is envisioned that the Launch Vehicle will be procured separately by the Government, unless a spacecraft and/or spacecraft deployment solution is inherently linked to a launch vehicle by the solution provider. For this RFI, it is only requested that respondents state whether the spacecraft solution is so linked.

4.2.6 Orbital Debris

The proposed spacecraft must plan for orbital debris and spacecraft re-entry requirements per NASA STD-8719.14, Process for Limiting Orbital Debris.

4.2.7 Propulsion and Delta-V

The proposed spacecraft must include a propulsion system that is capable of providing adequate change in velocity (Delta-V) to maintain the spacecraft orbit and meet mission requirements. All maneuvers should be executed in an appropriate timeframe or orientation to meet the spacecraft /availability parameter per 4.2.8. If this is not feasible, please describe the system capability. The available Delta-V should include:

- Launch insertion and orbit maintenance for planned mission life maintaining the 407 +/- 10 km altitude window as measured at the equator.
- Ground track registration of the radar and lidar spacecraft (if on separate spacecraft) should be maintained within +/- 3 km at the equator and all AtmOS inclined spacecraft should maintain their ground track registration to within +/- 10 km as measured at the equator.
- Maintenance of spacecraft temporal separation to within the values specified in Section 4.3.2.
- Cold-side spacecraft view maintenance over the mission life (see Section 4.3.5.
- Momentum unloading, as applicable
- Disposal, based on the orbital debris plan per Section 4.2.6

4.2.8 Spacecraft Availability

The spacecraft should be in an operational mode to support science operations greater than 96% of the time, taking in to account times for maneuvers, momentum unloading, or other operations that cause mission and payload accommodation parameters, such as pointing per 4.3.3, to be violated.

4.2.9 Timing and Position

The spacecraft should use GPS to determine position and provide time at the tone and timing pulses to each instrument. UTC registration accuracy should be within 100 msec. Within a given spacecraft, time tag knowledge between instrument measurements should be within 10 msec.

4.2.10 Data Downlink, Communications, and Mission Operations

The Government solicits responses for a ground system solution in support of a constellation of 2-6 spacecraft in Low Earth Orbit (LEO). The six instruments will be distributed across the constellation of spacecraft. The solution should address the ground system solution for both the pre-launch observatory-level integration and test and the post-launch operational phases of the mission. The solution should be an end-to-end ground system, including the use of antenna ground stations and a terrestrial communication network. Traditional Mission Operations Center (MOC) functions, such as mission planning, trending, flight dynamics, and real-time operations should be addressed from a multi-spacecraft operations standpoint. The response should include an approach to optimize/integrate a separate Science Operations Center (SOC) and multiple Instrument Operation Centers (IOC).

Specifically, the responses should include capabilities to enable low latency transmission of the instrument science data to the ground-based science data processing facilities. While science data latencies of less than 1 hour are highly desirable the Government is interested in solutions with latencies of up to 6 hours. Innovative approaches to data downlink will be considered. If addressed, communication approaches should include downlink, uplink, and commanding concepts.

Reliable and cost-effective solutions should be qualified. The use of industry standards to meet FISMA Medium controls should be addressed, as should any cyber-security solutions. Finally, staffing and automation considerations should be discussed.

4.2.11 Onboard Data Storage

On board data storage should be sufficient to store at least 72 hours of science data and telemetry.

4.2.12 Command Encryption

Commands to the spacecraft should be encrypted.

4.2.13 Environmental Requirements

The spacecraft, including the instrument payload complement, should meet the environmental requirements per General Environmental Verification Standard, GSFC-STD-7000A. This includes atomic oxygen effects, total dose, electronics radiation tolerance, and surface charge mitigation commensurate with the proposed orbit and mission timeframe.

4.3 Payload Accommodation Requirements

The instrument payload complement will be Government Furnished Equipment to the spacecraft vendor. There are several types of instruments planned for inclusion in the inclined orbit project. The instrument payload configuration can be adjusted to fit with the proposed spacecraft capability and overall mission architecture, as part of the study effort to determine the concepts that feasibly meet science objectives at the lowest cost. The payload complement may be split among multiple spacecraft to carry the total quantities of instrument payload complements, depending on spacecraft capability. The final instrument payload complements to be accommodated and the respective quantities of spacecraft will be determined based on total mission cost estimates that fit within constraints and meet science objectives.

For example, there are six AtmOS instruments. There one significant constraint with respect to instrument accommodation: the Tandem Stereographic Camera consists of two units and the two units must be separated on two spacecraft (see the constraints listed below). As such, a vendor could accommodate five instruments on one spacecraft with a camera unit on a second spacecraft or the vendor might accommodate six AtmOS instruments on six different spacecraft.

In our proof-of-concept design study, we developed two copies of a rideshare spacecraft and accommodated three instruments on each spacecraft (see Appendix C for a summary of our design study). Our plan was to minimize the spacecraft cost by building two copies of the same bus and minimize launch costs by flying multiple rideshare spacecraft on the same launch vehicle.

Responses should examine the required instruments, examine their spacecraft capabilities, and suggest the most cost-effective approach to accommodate our six instruments and meet our science requirements (see Appendix A).

4.3.1 Instrument Payloads

For the purposes of this RFI and to garner consistent responses, six notional instruments on multiple spacecraft should be assumed when developing plans and cost estimates to develop, integrate, and test systems to accommodate the instrument payload complement. The notional six instruments are summarized in **Table *1*** and the requirements for each instrument are listed in Appendix B.

Table 1. The Strawman AtmOS Instrument Payload Characteristics

Instrument	Qty	Unit Mass [kg, MEV]	Unit Orbit Avg Power [W, MEV]	Unit Orbit Avg Data [Megabits/sec, MEV]
Radar	1	190	330	5 Mbps
Lidar	1	150	340	4 Mbps
Radiometer	1	55	65	0.2 Mbps
Polarimeter	1	30	55	65 Mbps peak (daylight only)
Tandem Stereographic Camera*	2	10	15	4 Mbps peak (daylight only)

*Camera accommodation resources are per camera unit/spacecraft.

4.3.2 Payload Instrument constraints, requirements, and desires.

The following are the AtmOS instrument requirements (r) and desires (d):

1) The spacecraft carrying the Stereo Camera unit #1 and the spacecraft carrying the Stereo Camera unit #2 must be separated by 45 seconds (+15s / -10s). (r)
2) The six instruments will be integrated on multiple rideshare spacecraft and the rideshare spacecraft will launch on a single launch vehicle (Note: 1, 2) (r)
3) All spacecraft are in the same orbit: 407 km circular (+/- 10km), 50-70° inclination. (d)
4) Spatial co-registration of radar and lidar footprints within 200m cross-track. (d)
5) Data latency of 1 hour or less is desired for the microwave radiometer, from instrument acquisition to the ground data system (GDS). (d)
6) Data latency 3-6 hour is required for all data to be downlinked. (r)
7) The grouping of which instruments on which spacecraft can be optimized for cost, but the following is a desire:
    a. The lidar/radar on the same s/c or the lidar/radar can be maintained less than 60 seconds apart on different s/c, (d)
    b. The lidar/polarimeter on the same s/c or the lidar/polar can be maintained less than 60 seconds apart on different s/c, (d)
    c. The radar/radiometer on the same s/c or the radar/radiometer can be maintained less than 60 seconds apart on different s/c. (d)

Notes:
(1) Rideshare spacecraft (RSC) include (but limited to) ESPA, ESPA Grande, Propulsive ESPA, Propulsive ESPA Grande, or other spacecraft and adaptors that allow multiple spacecraft on a single launch vehicle.

(2) Implementing AtmOS with rideshare spacecraft allow other rideshare spacecraft to ride with AtmOS and it may allow another a spacecraft to fly on top of the AtmOS integrated payload stack (IPS).

4.3.3 Science Operations Pointing Requirement

The spacecraft nadir face should be fixed within the control and knowledge parameters below, dictated by the tightest needs of the payload instrumentation (i.e. polarimeter instrument):

Pointing Control:	43 arc-seconds, three sigma
Pointing Knowledge:	18 arc-seconds per axis, three sigma

4.3.4 Instrument Alignment Stability

The spacecraft should maintain instrument pointing stability to within 20 arc sec per axis, three sigma, on-orbit, including effects from environments and other disturbances. It can be assumed that bias errors will be characterized on-orbit during commissioning to determine and apply bias corrections.

4.3.5 Thermal Interface

The thermal interface to the instruments, including instrument electronics, will be thermally regulated with the spacecraft providing temperature sensors and heaters to monitor and maintain each instrument mounting interface within the operational temperature range of -10 to +40 degree C, and a survival temperature range of -20 to +50 degrees C. The amount of allowable heat transfer across the mounting interface will be limited in agreement between the instruments and spacecraft. Other than this thermally-controlled mounting interface, the instruments are responsible for, and will be delivered with, the necessary subsystems for their own thermal management. This includes internal heaters, heat pipes, and radiator surfaces as necessary. The spacecraft surfaces within view of the instruments will be covered with multi-layer insulation (MLI) to minimize radiative coupling with the spacecraft. The instruments are designed with the assumption of a cold-sky field-of-view available during their operations. As such, the spacecraft will ensure each instrument a view to the cold sky for instrument heat rejection. In addition, the spacecraft will need to ensure a 'cold-side' to the spacecraft throughout the annual cycle. In the design exercises conducted by NASA for a 65-degree inclination, this entailed approximately nine 180-degree spacecraft yaw maneuvers per year to maintain the cold-side to the spacecraft. Note: the science instruments are able to perform in both ram orientations.

4.3.6 Contamination Control

Some of the instruments are sensitive to contamination by both particles and hydrocarbons. Adequate precautions must be taken during spacecraft Integration & Testing (I&T) to assure the on-orbit performance of the instrument. Materials used in the spacecraft must be selected to be consistent with meeting low outgassing rates. During integration and up until launch, some instruments will require continuous purging with dry nitrogen, although brief interruptions on the scale of a few hours in controlled environments are acceptable. Surface cleanliness levels will be monitored through witness samples particle fall-out plates, direct surface cleanliness testing, and UV and white light inspection. Cleaning operations will be performed as necessary. At a minimum, a class 10,000 environment will be required whenever AtmOS is unbagged for integration and test operations.

4.3.7 Electronics and Interfaces

The spacecraft should provide the following electrical interfaces to each instrument:

1. +28 V primary power services sized for instrument power
2. RS-422 communication services or similar for instrument command and telemetry
3. High-speed data interface sized for instrument data rate
4. Pulse Per Second (1 PPS) services for time synchronization

Plans to develop the appropriate spacecraft simulator GSE should be included to enable functional test of integrated payloads in parallel with spacecraft development. Costs associated with either option should be included.

4.4 Hosted Payload Approach

The instruments could be hosted on a spacecraft that is part of another system architecture. The highest science value is obtained by instruments at the orbit specified above. Information is requested for capabilities and opportunities to host payloads at the orbits above, broken down by instrument mass, area, volume, and FOV accommodation capabilities. The mission requirements in Section 4.2 do not necessarily apply to systems that are proposed to host instruments. When developing the Phase A-D cost estimate for hosted payloads (HP), the cost should include the instrument accommodation cost, the launch cost, and any hosting fees, in a single fixed price cost. The Phase E-F cost estimate should include the price per month/year for the ground data system and the mission ops costs.

4.5 Development Approach

The development approach reference parameters described in this section have been defined as a point of departure, based upon processes used to develop similar NASA missions in the past. Proposed development approaches that deviate from these reference parameters will be considered. To appropriately evaluate various approaches and relative risks, it is important for the study team to understand how proposed approaches adhere to, and/or differ from, the reference approaches.

4.5.1 Systems Engineering

The spacecraft vendor should perform the necessary systems engineering (SE) required to ensure that the spacecraft meets all of the performance, interface, and implementation requirements of the mission, including the analyses, flow-down of technical requirements, allocation of system budgets, verifications for the spacecraft, definitions of interfaces, technical risk evaluations, system design tradeoff analyses, requirements for GSE, orbital performance analysis, flight software requirements analysis, and lower level requirements (eg. subsystem, components, assemblies, parts). This includes documenting all information from the design, qualification testing, acceptance testing, and compatibility testing of the hardware and software, together with analysis and assessment of the data with respect to expected performance.

4.5.1.1 Reviews

As part of the development approach, the spacecraft vendor should conduct and provide technical and programmatic data for the following reviews:

- Spacecraft System Requirements Review (SRR)
- Spacecraft Preliminary Design Review (PDR)
- Spacecraft Critical Design Review (CDR)
- Instrument Integration Readiness Review (IIRR), one per spacecraft
- Full System (Observatory) Pre-Environmental Review (PER), one per spacecraft
- Full System (Observatory) Pre-Shipment Review (PSR), one per spacecraft
- Observatory Acceptance Review (OAR), one per spacecraft

These reviews should meet the NASA/GSFC Criteria for Flight and Flight Support System Lifecycle Reviews, GSFC-STD-1001A.

After each review, the spacecraft vendor will provide formal responses to all request for actions (RFAs) to the Government for approval

In addition to the above reviews, the spacecraft vendor will provide support to these mission reviews:

- Mission Preliminary Design Review (MPDR)
- Mission Critical Design Review (MCDR)
- Mission System Integration Review (MSIR)
- Mission Operations Review (MOR)
- Flight Operations Review (FOR)
- Flight Readiness Review (FRR)
- Launch Readiness Review (LRR)

The spacecraft vendor will also conduct monthly status reviews (MSRs) at the Contractor's facility to review the technical, schedule and programmatic activities. At a minimum, these reviews should include the status of work being performed (e.g., schedule and milestone progress), changes to design parameters and technical performance metrics, and description and status of technical issues, including anomalies and mishaps.

In addition to the meetings and reviews described above, the vendor will support periodic, informal meetings and telecons with the Government.

4.5.1.2 Analysis

Appropriate analyses should be performed to validate the design will meet requirements with appropriate margins, or verify requirements, including:

- Structural and dynamic analysis
- Functional performance analysis
- Analysis necessary to demonstrate margins to GOLD rules per Section 4.5.3

4.5.1.3 Documentation

The spacecraft vendor will develop, deliver, and maintain all documentation for the observatory and its interfaces, including, but not limited to:

- Spacecraft Performance Specification
- Spacecraft Design and Verification Analyses
- System Performance Verification Plan
- Instrument Interface Control Document (IICD)
- Telemetry and Command Requirements Documentation and Procedures
- FSW Documentation and Procedures
- Test Plans and Procedures
- External Interfaces, Models and Analysis
- Flight Operations Ground System Interface Documentation (Ops ICD)
- Observatory-to-Launch Vehicle Interface Control Documents (LV-ICD) and Launch Vehicle Analysis
- Observatory and GSE Storage, Transportation and Handling Plan
- Observatory Launch Site Operations and Test Plan
- Observatory Launch Site Operations and Test Procedures
- Flight Operations Support Plan and Training
- Spacecraft Operations Description Manual
- Engineering Change Proposals, Deviations and Waivers

4.5.2 Development Units

The development approach for the spacecraft subsystems should include the use of Breadboard Units, Engineering Units, Engineering Test Units, and Qualification Units to reduce the development risk associated with each subsystem depending on the maturity of the design.

These units can also be used to create a ground test bed to enable functional testing without the need for the Flight unit.

The spacecraft vendor will provide a spacecraft interface simulator of appropriate level of fidelity to enable effective use by mission elements for interface verification, including instruments.

4.5.3 Design Rules

The design of the spacecraft and its subsystems should meet the NASA/GSFC Rules for the Design, Development, Verification, and Operation of Flight Systems (GOLD Rules), GSFC-STD-1000G.

4.5.4 Performance and Environmental Verification

The full system, after integration of the instrument payload (observatory), test program should include the following tests at a minimum:

- EMI/EMC
- Vibration
- Acoustics
- Shock, both launch vehicle shock environments and self-induced shocks
- Thermal Balance with three thermal cases (hot operational, cold operational, and cold survival)
- Thermal Vacuum testing, 4 thermal cycles
- Comprehensive performance testing (one before any environmental testing, one at hot plateau in TV, one at cold plateau in TV, and one after all environmental testing has been completed)
- Functional tests between all major tests, at the launch site after arrival, and then every two months and on the pad
- Alignment between the spacecraft master cube and the instruments before and after mechanical environments and after thermal vacuum testing
- Deployment testing of any mechanisms before and after mechanical environments
- RF compatibility (NEN and SN)
- Spacecraft or Observatory to Mission Operations Center (MOC) compatibility
- End-to-End testing - There will be two levels of end-to-end testing.
    - One level will include all mission elements (e.g., instruments, spacecraft, communication and ground system, MOC, and the Science Operations Center).
        - This test will demonstrate that data collected by the instruments can be sent through all mission elements and be processed by the SOC.
        - The preferred environment for this test is thermal vacuum.
        - The test will last approximately 2 days (not including setup time).

- The other level will include these mission elements: instruments (may not be included in every test), spacecraft, communication and ground system, and MOC.
  - There will be approximately 3 of these tests.
  - This testing will occur at ambient.
  - The testing will last approximately 3 days each (not including setup time).

All tests should be in accordance with the General Environmental Verification Standards (GEVS), GSFC-STD-7000A, proto-flight test program. Considerations for possibly reducing tests given the quantities of systems are welcome.

4.6 Safety and Mission Assurance Processes

The Government is interested in information on how the vendor would implement Safety and Mission Assurance, whether through a conventional approach with Government-levied Safety and Mission Assurance requirements or through alternative approaches that still guarantee mission life requirements and satisfy mission Risk Class C.

4.7 Access to Space (ATS) Insurance

Given the perceived risk of rideshare and hosted payload missions and given the dependence of mission success on multiple rideshare/hosted spacecraft, commercial insurance may help mitigate the mission's risk. The insurance market for the commercial space industry is global with approximately 40 insurers worldwide including four markets in the US. Within the space insurance market there are many different types of coverage available addressing all aspects of satellite and vehicle manufacture, transportation, launch and in-orbit operation. Typical coverages commence at lift-off and extend for one year in orbit and cover the loss of a satellite during launch and early operation. At the end of this period insurance can be purchased to cover in-orbit technical issues. Pre-launch and third-party liability coverages are also available. Insurance can also be limited to certain aspects of the satellite such as bus or platform only, payload only, launch only etc.

The process of purchasing insurance requires the involvement of spacecraft manufacturers, launch services providers, insurance brokers, underwriters, financial institutions, reinsurers, and government agents cooperating in order to coordinate an insurance for any given commercial satellite launch. This process provides the insurance company with a level of oversight and technical understanding of the underlying risks associated with the satellite and/or launch vehicle.

4.7.1 Insurance for the Traditional Spacecraft Development Approach (Option-1)

The perceived rideshare risk could be transferred to the spacecraft manufacturer by procuring the bus with a replacement guarantee in the event of failure. The on-orbit delivery of the spacecraft would occur following the successful completion of on orbit testing. If the spacecraft manufacturer is unable to deliver the spacecraft or meet agreed performance milestones due to loss or serious anomaly, then they would be required to build a replacement spacecraft. The replacement guarantee could be amended in the procurement contracts to become NASA credits in the event NASA elected not to have the mission repeated. The satellite manufacturer will be responsible for procuring insurance to cover the contractual replacement obligations. The cost of the insurance will increase the cost of the procurement to NASA; however this cost impact will be significantly less than the cost of NASA replacing the spacecraft.

4.7.2 Insurance for the Hosted Payload Approach (Option-2)

The hosted payload (HP) risk can be transferred to the HP service provider by procuring the hosted payload service with a re-launch guarantee in the event of failure. Like Option-1, the on-orbit delivery of the HP would occur following the successful completion of on orbit testing. If the hosted payload provider is unable to deliver the payload to orbit or meet agreed performance milestones due to loss or serious anomaly, then they would be required to provide a replacement hosted payload opportunity. The replacement guarantee could be amended in the procurement contracts to become NASA credits in the event NASA elected not to have the mission repeated.

4.8 References

The following files are references for, and posted with, this RFI

- GSFC-STD-1001A
- GOLD Rules, GSFC-STD-1000G
- GEVS, GSFC-STD-7000A

5.0 INFORMATION REQUESTED

5.1 Disclaimers:

This is a request for information and is for planning and information purposes only. This is not a request for proposal or quotation, nor is this a solicitation for a contract or grant award. This RFI does not obligate the Government in any way. The Government will not reimburse the respondents for any costs associated with the information submitted in response to this request. No solicitation exists; therefore, do not request a copy of the solicitation. If a solicitation is released, it will be synopsized on beta.sam.gov (https://www.beta.sam.gov/) or the NASA/GSFC Rapid Spacecraft Development Office (RSDO) internet site. It is the interested party's responsibility to monitor these sites for the release of any solicitation or synopsis.

The information is requested for planning purposes only, subject to FAR Clause 52.215-3, entitled "Solicitation for Information for Planning Purposes." As part of the study and review process, the study team intends on using material provided to evaluate concept feasibility, which includes distribution and presentation of material as part of review processes. Care should be taken if providing and marking material provided per the RFI as other than suitable for full and open distribution, such as proprietary or sensitive material as it will limit the study team's ability to use appropriate material to evaluate concept feasibility. Neither export controlled nor classified material should be submitted and will be destroyed upon receipt without further consideration. To the full extent that it is protected pursuant to the Freedom of Information Act and other laws and regulations, information identified by a respondent as "Proprietary or Confidential" will be kept confidential. The Government will treat cost information in confidence.

As part of its assessment of industry capabilities, NASA may contact respondents to this RFI for clarifications or further information.

5.2 <u>The Response</u>

Interested parties should submit a response to one or more of the following response options with a written statement of interest or capability and discussion per the requested information and structure per the respective response option. Respondents do not have to respond to all of the options. Interested parties or organizations may respond to more than one option. Each response should be separate from responses to other options and limited to 15 pages per response option, not including the appendices. Responses should be in Microsoft Word (.doc or docx) or Portable Document Format (.pdf). The appendices should follow the templates provided and should be in Microsoft Excel format (.xls or .xlsx). Responses should be submitted via electronic mail (e-mail) to both points of contact below by 5 pm Eastern Time on the date listed on page-1. The subject line of the submission should be "RFI for AtmOS Access to Space (ATS) Study".

Respondents are encouraged to submit any questions regarding this request to both points of contact below within one week of release of this RFI to allow the Government time to develop responses prior to the due date for submissions. The subject line of questions should be "Questions regarding RFI for AtmOS Spacecraft Study." As practicable, questions and any responses provided will be posted to the same location as the RFI prior to the response due date to assist all potential respondents. The Government reserves the discretion to determine which questions are practical to respond to and post.

5.3 <u>AtmOS RFI Briefings</u>

Based on your RFI response, we may ask you to brief your RFI response to our team in a virtual meeting, 2-4 weeks after your RFI response is submitted. The briefing will provide an opportunity for you to discuss your mission concept and for us to ask questions about your implementation approach. We will contact you with the details of the vendor presentations.

5.4 Points of Contact

Craig Keish, Contracting Officer
craig.f.keish@nasa.gov
NASA/Goddard Space Flight Center, Code 210.Y
Greenbelt, Maryland 20771
United States

Technical Point of Contact:
Steve Bidwell, Mission Systems Engineer
NASA/Goddard Space Flight Center, Code 599
steven.w.bidwell@nasa.gov
Greenbelt, Maryland 20771
United States

5.5 Response Option 1

Describe your concepts for multiple spacecraft designs that can accommodate the six instrument payloads with development approaches that follow, or explicitly deviate from, the reference development, design, verification, and mission assurance processes, and result in full system integration and test with payloads, launch processing and commissioning, including:

1. Spacecraft design and development
2. Integration of instrument payloads to the spacecraft
3. Integrated system performance and environmental test
4. Launch site, Launch, and Commissioning activities
5. Challenges and solutions to developing multiple spacecraft
6. Schedule estimate for spacecraft development, integration, test, and activities through commissioning
7. Cost estimates for the spacecraft development and planned work

Please provide the following information that addresses the requested concept and plan for this response option relative to the reference parameters in Section 4.0:

1. Organization information: Organization name and address, point-of-contact name, E-mail address, phone number
2. Abstract: Provide a brief summary of the system concept and approach
3. System Concept: Description of the design and capabilities of proposed spacecraft and how it addresses the mission reference parameters in Section 4.2, and its heritage and maturity (Technology Readiness Level) both at present and projected with maturation plan at the time of implementation (if for a future capability). Include explanations of how the spacecraft addresses: maneuvers to maintain availability, breakdown of delta-V budget, and approaches to survive the atomic oxygen, and radiation environments. Design description should include: dry mass; wet mass; total power allocation, including instruments; mission life; propulsion type; max and min thrust; drag area; delta-V

capability; solar array type (body mounted, fixed deployed, articulating deployed); solar array size; battery capacity; Launch Vehicle adapter type/size; system envelope dimensions; ACS actuator type; attitude determination sensors; and, ODAR approach.

4. Payload Accommodation: Description of the instrument payload complement accommodation assessment on the spacecraft relative to the payload reference parameters in Section 4.3, including instrument interface description and sketches of instrument mounting configuration and fields of view. Include discussion of payload mass capability, payload area and volume capability for sensors and electronics, ram area for payload, concepts for deployed instruments, approaches to meet electrostatic and magnetic cleanliness, pointing and alignment capability, and plan for electrical interfaces
5. Launch Configuration: Description of the launch vehicle mounting and envelope, including concepts for launching the quantities systems needed to fly the instrument payload complement quantities and the system to be used to deploy the spacecraft from the launch vehicle.
6. Development Approach: Discuss the planned development approach, including how it relates to the reference parameters in Section 4.5. Discuss any planned development units, including tests planned for those units and any plan for a ground test bed. Discuss considerations and plans for developing quantities of spacecraft related to section 4.3.1
7. System Integration and Test: Describe the planned or recommended process to integrate and functionally test the individual instruments in parallel with the spacecraft development and plans to integrate the payload to the spacecraft, consistent with Section 4.1. Discuss plans to test the fully integrated spacecraft and payload systems. Include discussion of available facilities and processes to handle the quantities of systems. Describe how cleanliness levels will be maintained for the instruments per 4.3.6. Provide a simple block diagram depicting the performance and environmental test flow for the spacecraft and fully integrated systems relative to the reference parameters in Section 4.5.4. Include a description of how subsequent units will be tested
8. Safety and Mission Assurance Processes: Describe plans relative to the safety and mission assurance reference parameters in Section 4.6. Discuss reliability of the proposed spacecraft concept, mission life expectations, and the features in the concept and development plans intended to improve reliability.
9. Organization Capabilities and Experience: Description of organization capabilities and experience performing spacecraft developments, integration and test, launch support, and support of mission operations similar to this mission. Include capacity and processes to handle quantities of spacecraft, instrument payloads, and fully integrated systems. Include any proposed partnerships that could benefit the execution of the plan.
10. Appendix A: Spacecraft Capabilities vs. Instrument Requirements (workshet 1 of n). Complete this worksheet to compare your spacecraft capabilities to your suggested payload configuration (the instrument payloads listed in Appendix B). Complete a worksheet for each of your suggested spacecraft configurations (observatories).
11. Cost and Schedule Estimate: For each observatory suggested in Appendix A, provide a Rough Order of Magnitude (ROM) cost estimate in fiscal year 2021 dollars (FY21$). Break the cost estimates down into: spacecraft design and development, including all effort to design, develop, build, and test the spacecraft, including development units and ground test sets; full system integration, test, launch, and commissioning activities, including all effort to integrate the instrument payload to the spacecraft, perform full

system performance and environmental test, launch site activities, and commissioning; sparing philosophy and costs to implement this philosophy; and, costs for the system to deploy the spacecraft from the launch vehicle. Include Management, Mission Assurance, Systems Engineering, and review support in these estimates. Discuss the estimated schedule to complete planned activities.

12. Commercial Insurance: Describe the pros and cons of the spacecraft manufacturer procuring commercial insurance, as described in Section 4.7.
13. Drivers: Description of key technical, schedule and cost drivers. Identify options for mitigating cost drivers, including technical trades.
14. Reference Document Review – The following documents will be included in a future Access to Space (ATS) Study RFP and the Spacecraft RFP. Provide any comments, questions, or concerns with the following documents in your RFI response:
    a) GSFC-STD-1001A
    b) GOLD Rules, GSFC-STD-1000G
    c) GEVS, GSFC-STD-7000A

5.6 Response Option 2

Concepts for hosting all six instrument payloads within the architecture of a current or future system, including:

1. Integration and system level test of instrument payload with system
2. Challenges and solutions to hosting the range of instrument payload quantities
3. Cost and schedule estimate for hosting opportunity and planned work.
4. The Phase A-D costs should be a fixed-price that includes:
    a. The instrument accommodation costs,
    b. the launch costs, and
    c. any hosting fees, in a single fixed price cost.
5. The Phase E-F cost estimate should include the price per month/year for the ground data system and the mission ops costs.

Please provide the following information that addresses the requested concept and plan for this response option relative to the reference parameters in Section 4.0:

1. Organization information: Organization name and address, point-of-contact name, E-mail address, phone number
2. Abstract: Provide a brief summary of the system concept and approach
3. System Concept: Description of the design and capabilities of the proposed spacecraft or system that will host the payload, including the concept of operations for the hosted payload, orbit parameters, expected environments, and timeframe of operations as related to the mission reference parameters in Section 4.2. All of the mission requirements in Section 4.2 do not necessarily apply to systems that are proposed to host instruments, including launch vehicle, availability, environments, delta-V, etc. Descriptions of capability are requested.

4. Payload Accommodation: Description of the instrument payload the host spacecraft can accommodate relative to the payload reference parameters in Section 4.4 and 4.3, including how the hosted payload will be accommodated, environmental requirements that must be levied on the instrument(s), instrument interface description, and sketches of instrument mounting configuration and fields of view. Describe nadir instrument mass, area, volume, and FOV accommodation capabilities.
5. Launch Configuration: Description of the launch vehicle mounting and envelope for the host spacecraft
6. Development Approach: Discuss the development and verification approach used for the host spacecraft. Discuss considerations and plans for integrating the hosted payload in to the proposed spacecraft or system, including the quantities related to Section 4.3.1. Provide a simple block diagram depicting the performance and environmental test flow for the spacecraft after the hosted payload is integrated relative to the reference parameters in Section 4.5.4. Include a description of how subsequent units will be tested
7. Safety and Mission Assurance Processes: Discuss reliability of the proposed spacecraft concept, mission life expectations, and the features in the concept and development plans intended to improve reliability.
8. Organization Capabilities and Experience: Description of organization capabilities and experience performing spacecraft developments and hosting payloads, integration and test, launch support, and support of mission operations similar to this mission. Include capacity and processes to handle quantities of spacecraft.
9. Cost and Schedule Estimate: Rough Order of Magnitude (ROM) cost estimate in fiscal year 2021 dollars (FY21$) for the cost of the hosted payload opportunity for the instrument payload. Discuss the estimated schedule to complete planned activities.
10. Commercial Insurance: Describe the pros and cons of the hosted payload provider procuring commercial insurance, as described in Section 4.7.
11. Drivers: Description of key technical, schedule and cost drivers. Identify options for mitigating cost drivers, including technical trades

5.7 Response Option 3

Concepts for public-private or other partnership options to develop systems to meet mission objectives, including:

1. Options for Government design spinoff to industry, and/or ideas or input on how partnerships might benefit mission development
2. Benefits of partnership to developing the range of system quantities
3. Cost and schedule estimate for planned work

Please provide the following information for the proposed partnership approach that facilitates the development of a system relative to the reference parameters in Section 4.0:

1. Organization information: Organization name and address, point-of-contact name, E-mail address, phone number
2. Abstract: Provide a brief summary of the proposed approach

3. Partnership: Describe potential partnership arrangement to develop the mission by spinning off a Government, or a joint Government and partner, spacecraft design to the partner for fabrication and test of the possible flight unit quantities, including development unit build strategies and full system level (spacecraft with instruments) integration, and/or describe ideas or input on partnership approaches that could be implemented to enable mission development
4. Teaming Strategy: Describe teaming considerations relevant to the proposed partnership approach, including knowledge transfer, if applicable
5. Development Approach: Discuss the development approach, I&T considerations, planned verification tests for any hardware development as part of the proposed partnership. Include discussion of how the proposed approach compares to the reference parameters in Section 4.0. All of the parameters in 4.0 do not necessarily apply to partnership arrangements, including launch vehicle, availability, environments, delta-V, etc. Descriptions of capability and proposed approaches are requested.
6. Safety and Mission Assurance Processes: Describe the safety and mission assurance processes that would be followed in the implementation of the proposed partnership arrangement, relative to the safety and mission assurance reference parameters in Section 4.6
7. Organization Capabilities and Experience: Discuss the capabilities and experience of the organization in performing the necessary activities to implement the proposed partnership. Include capacity and processes to handle quantities of spacecraft, if applicable
8. Cost and Schedule Estimate: Rough Order of Magnitude (ROM) cost estimate in fiscal year 2021 dollars (FY21$) for the cost to implement the proposed partnership. Adjust the cost category as necessary to fit with the proposed approach. Discuss the estimated schedule to complete planned activities.
9. Drivers: Describe key technical, schedule and cost drivers. Identify options for mitigating cost drivers, including technical or programmatic trades
10. Reference Document Review – The following documents may be included in our future Access to Space (ATS) Study RFP and our Spacecraft RFP. Provide any comments, questions, or concerns with the following documents in your RFI response:
    d) GSFC-STD-1001A
    e) GOLD Rules, GSFC-STD-1000G
    f) GEVS, GSFC-STD-7000A

5.8 Response to Rideshare Spacecraft Market Survey

The Air Force Rideshare Users Guide (RUG) defines the rideshare standard services (RSS) of the standard rideshare spacecraft adaptors (or carriers). This RFI/market survey asks the vendors to provide a summary of the following rideshare-class of spacecraft:

1) ESPA – This spacecraft is accommodated on a standard 6-port ESPA ring.
2) ESPA Grande – This spacecraft is accommodated on a 4- or 5-port ESPA Grande ring.
3) A-Deck/Aquila – This spacecraft sits on a flat plate inside a structure/series of ESPA rings.

4) Propulsive ESPA – This spacecraft uses an ESPA ring as its primary structure.
5) Propulsive ESPA Grande – This spacecraft uses an ESPA Grande ring as its structure.

For each rideshare-class spacecraft, complete the Table in Appendix D, the Spacecraft Capabilities Table. We will use this data when we explore rideshare options for future instruments and future missions. For planning purposes: a) provide a ROM cost estimate to develop and deliver an environmentally qualified bus (in $XX.XM, FY21$) and b) provide a development period in years (YY.Y), assuming GSFC integrate the payloads after delivery.

Appendix A-1 - Spacecraft Capabilities vs. Instrument Assumptions (worksheet 1 of n)

Spacecraft Capabilities: Worksheet 1 of n

S/C No.	Spacecraft Class / Rideshare Adaptor	Bus Name / Number	P/L Mass Capability	P/L Power (OAP/Peak)	Pointing Control (arcsec)	Pointing Knowledge (arcsec)	Pointing Stability (arcsec/sec)	Mounting Area Avail.	Data Storage (Mbytes)	Data Downlink (Mbps)	Spacecraft Design Life	Spacecraft Dimensions	Delta V / Prop System
1 of n													

Instrument Requirements:

No.	Instrument Type	Instrument Name	P/L Mass	P/L Power (OAP/Peak)	Pointing Control (arcsec)	Pointing Knowledge (arcsec)	Pointing Stability (arcsec/sec)	Mounting Area Req.	Data Storage (Mbytes)	Data Downlink (Mbps)	Instrument Design Life	Instrument Dimensions	Notes (#)
1													
2													
…													
m													
Total													
Delta													

Appendix A-2 - Spacecraft Capabilities vs. Instrument Assumptions (worksheet 2 of n)

Spacecraft Capabilities: Worksheet 2 of n

S/C No.	Spacecraft Class / Rideshare Adaptor	Bus Name / Number	P/L Mass Capability	P/L Power (OAP/Peak)	Pointing Control (arcsec)	Pointing Knowledge (arcsec)	Pointing Stability (arcsec/sec)	Mounting Area Avail.	Data Storage (Mbytes)	Data Downlink (Mbps)	Spacecraft Design Life	Spacecraft Dimensions	Delta V / Prop System
2 of n													

Instrument Requirements:

No.	Instrument Type	Instrument Name	P/L Mass	P/L Power (OAP/Peak)	Pointing Control (arcsec)	Pointing Knowledge (arcsec)	Pointing Stability (arcsec/sec)	Mounting Area Req.	Data Storage (Mbytes)	Data Downlink (Mbps)	Instrument Design Life	Instrument Dimensions	Notes (#)
Total													
Delta													

Appendix B – AtmOS Strawman Instrument Assumptions Summary.

Appendix B.1 – Notional Radar Instrument Assumptions

Assumption Type	**Value**
Dimensions (cm) L x W x H	Electronics Box A: 30 cm x 30 cm x 30 cm Electronics Box B: 30 cm x 15 cm x 15 cm Solid Antenna: Diameter: 210 cm, Height: 70 cm Deployed Mesh Antenna: Diameter: 210 cm, Height including fixed feed horn: 180 cm
Mass Properties (kg) CBE	120 kg Box A: 30 kg Box B: 10 kg Solid Dish: 50 kg Mesh Dish: 30 kg
Data latency	< 1 hour
Data interface(s) (kbps)	4 Mbps
Timing	1 pps signal
Pointing Accuracy/Knowledge	Changing off-nadir pointing to match cross-track location of lidar beam (other spacecraft) to within 0.025 degrees (90 arcsec), maintaining 2 degree off-nadir along-track pointing angle. Co-aligned with Lidar-09R (scene registration, not temporal)
Pointing Stability	0.01 degree (36 arcsec) RMS 3 sigma over 2 seconds
Jitter	0.01 degree (36 arc sec) RMS 3 sigma over 0.2 seconds
Horizontal Spatial Resolution	5 km Ku-band, 1 Km W-band
Field of Regard	No mechanical scanning, +/- 6 degrees cross-track and +/- 6 degrees along-track.
Field of View	Near-nadir, single beam, 0.1 degree (W-band, fixed antenna), and 0.7 degree (Ku-band, both antennas).
Viewing Restrictions	W-band beam nominally points 2-5 degrees forward 0 cross-track
Operational Temp	-10 to 45 deg C
Survival Temp	
Thermal Stability	N/A
Thermal Gradients	N/A
Power (W, CBE)	230W CBE Box A 220 W Box B 10 W

Appendix B.2 – Notional Lidar Instrument Draft Assumptions

Assumption Type	**Value**
Dimensions (cm) L x W x H	100 cm x 90 cm x 90 cm
Mass Properties (kg, CBE)	120 kg
Data latency	3-6 hours
Data interface(s) (kbps)	3 Mbps
Timing	1 PPS with 0.005 ms accuracy
Pointing	< 45 arcsec
Pointing Stability	< 20 arcsec
Jitter	Jitter < 20 arcsec max, < 0.33 arcsec/second
Field of Regard	50 degrees
Field of View	0.004 degrees half angle
Viewing Restrictions	2-5 degrees off-Nadir, pointed with W-band of radar; sunshield around Ø60cm receiver
Operational Temp	-10 to +30 C
Survival Temp	-20 to +60 C
Thermal Stability	N/A
Thermal Gradients	N/A
Power (W, CBE)	300 W CBE; 140 W standby; 90W survival heater power

Appendix B.3 – Notional Polarimeter Instrument Draft Assumptions

Assumption Type	Value
Dimensions (cm) L x W x H	50 cm x 25 cm x 50 cm
Mass Properties (kg, CBE)	25 kg
Data latency	3-6 hours
Data interface(s) (kbps)	50 Mbps nominal, 0 during eclipse
Timing	1 PPS (1 ms accuracy) via spacewire
Pointing	43 arc-sec (0.012 degrees) Accuracy; 18 arc sec (0.005 degrees) Knowledge - all 3 axes
Pointing Stability	10 arc-sec (3 sigma)
Jitter	226.8 arcsec (0.063 degrees) /sec jitter
Field of Regard	144 degrees
Field of View	Along track 114 degrees; cross track 94 degrees
Viewing Restrictions	Nadir at center of FOR
Operational Temp	-20 to +35 C
Survival Temp	-40 to +70 C
Thermal Stability	N/A
Thermal Gradients	N/A
Power (W, CBE)	40W peak, 23W OA *needs to be calculated; survival power 20W

Appendix B.4 – Notional Radiometer Instrument Draft Assumptions

Assumption Type	**Value**
Dimensions (cm) L x W x H	80 cm x 45 cm x 45 cm
Mass Properties (kg, CBE)	40 kg Note: Contains spinning mirror that rotates up to 150 RPM
Data latency	<1 hour
Data interface(s) (kbps)	0.2 Mbps
Timing	TBD – future work
Pointing	Nadir, (cross-track scanning), 0.1 degree accuracy (360 arc sec) Knowledge, 0.05 degree (180 arc sec)
Pointing Stability	TBD – future work
Jitter	144 arcsec within 1 ms
Field of Regard	Nadir (along-track), +/- 43 degree cross-track., 72-88 degree off-nadir crosstrack (cold sky calibration – instrument has a scan mirror & view port to accommodate – radiator is on this face)
Field of View	TBD – future work
Viewing Restrictions	Cold view for radiator (decoupled from S/C)
Operational Temp	-10 to 45 deg C
Survival Temp	TBD – future work
Thermal Stability	N/A
Thermal Gradients	N/A
Power (W, CBE)	50 W CBE peak; 15W survival heater power

Appendix B.5 – Notional Stereo Camera Draft Assumptions

Assumption Type	Value
Dimensions (cm) L x W x H	50 cm x 30 cm x 20 cm
Mass Properties (kg)	6 kg
Data latency	< 6 hours
Data interface(s) (kbps)	Peak rate 3.5 Mbps CBE
Timing	1 ms accuracy
Pointing	0.25 degrees accuracy (900 arc sec)
Pointing Stability	100 arcsec (3 sigma) over 30 sec
Jitter	5 arcsec over 0.5 sec RSS of all three axes
Field of Regard	Cross track 15 degrees; Along track 15 degrees
Field of View	15 deg full angle per camera head cross track; 12.5 degrees along track
Viewing Restrictions	One camera at nadir; second camera head: 38 deg aft, third camera: 38 deg forward
Operational Temp	-20 to +55 C
Survival Temp	-30 to +85 C
Thermal Stability	N/A
Thermal Gradients	N/A
Power (W, CBE)	15 W; safehold survival heater power 4W

Appendix C – A Summary of the Goddard Proof of Concept Design Study

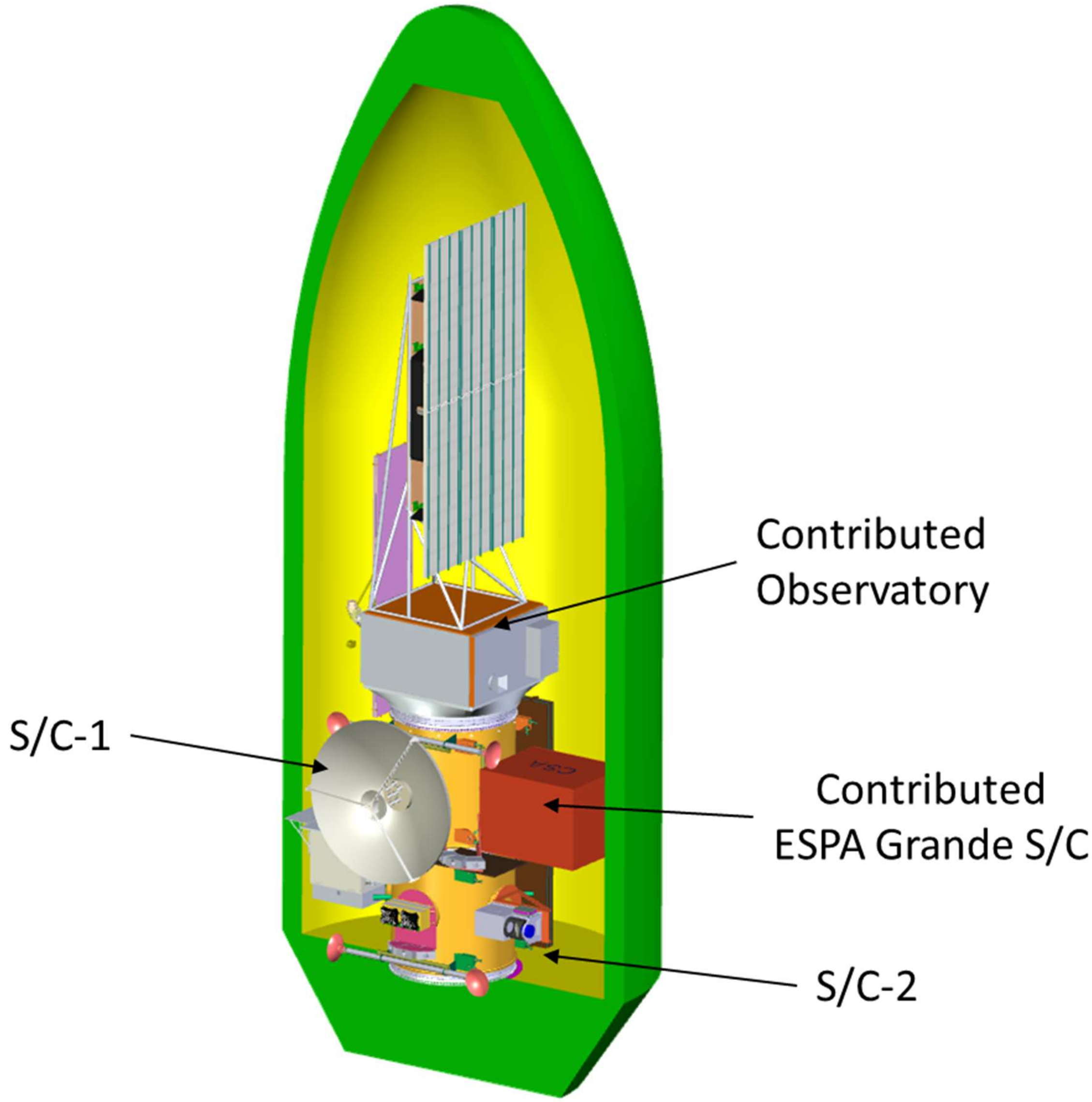
Appendix C.1 – Proof of Concept: Mission and Observatory Assumptions

Owner	Assumption
Mission	LRD July 25 2028 (ATP ~ now)
Mission	2 year mission life, 5 years consumables
Mission	Mission Class C
Mission	407 km orbit (+/- 10 km), 65 degree inclination
Mission	S/C-1 & S/C-2 separated by 45 seconds (+/- 15s), S/C-1 trails.
Mission	Constellation alignment 3km cross-track
Mission	Cameras co-registered temporally between the 30s and 60s spacing (simultaneous overlap); spatial co-registration of radar and lidar footprints within 100m cross-track. Three cameras used on the S/C to account for yaw flips.
Mission	End of Mission disposal required
Mission	ELV-Class LV
Mission	The L/V accommodates two contributed s/c: one ESPA Grande S/C and one s/c on top the integrated P/L stack (IPS).
Observatory	3 axis stabilized (+Z points to Nadir, +Y cold, +/- X RAM depending on yaw flips)
Observatory	Mission Phase based Modes (See Modes Table; MEL)
Observatory	On-board propulsion
Observatory	Pointing: 43 arc-sec (0.012 degrees) Accuracy; 18 arc sec (0.005 degrees) Knowledge - all 3 axes: Stability: 20 arcsec (3 sigma) all 3 axes Jitter: 10 arcsec/10 msec all 3 axes
Observatory	Absolute timing 1 PPS with 0.005 ms accuracy
Observatory	Accommodate 54 Mpbs CBE science data from SSG-2 and 6.8 Mbps CBE science data from SSG-1
Observatory	1 hour data latency
Observatory	28V service to payloads
Observatory	72 hours onboard storage
Observatory	Accommodate payload door and other deployments

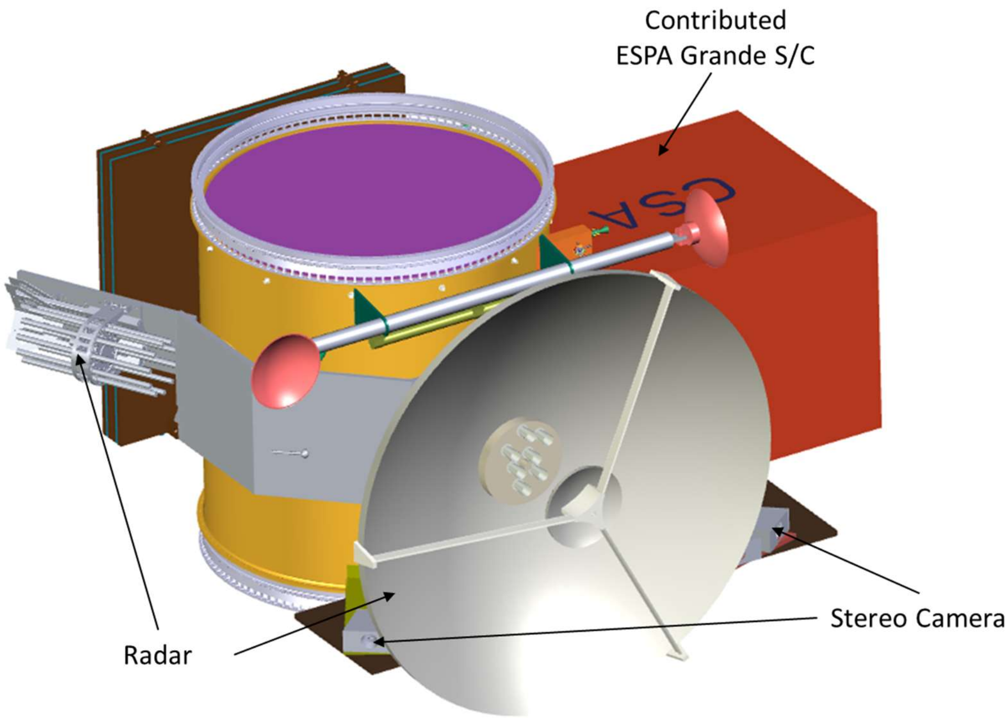
Appendix C.2 – Proof of Concept: Ground Systems and Operations Assumptions

Owner	Assumption
Ground Systems	Provide support for 2 observatories simultaneously
Ground Systems	Receive house-keeping & science data telemetry
Ground Systems	Record/Archive science data
Ground Systems	Provide critical event telecom coverage: Launch Sep, S/A Deployment, Instrument Deployments
Operations	Provide an operations environment compliant with NPR 7120.5, Sections 4.8 & 4.9, for the appropriate mission class
Operations	Provide an IT Security plan for the MOC
Operations	Provide an FOT Staffing Profile supporting Operations Concept
Operations	Develop Ground Data Systems Architecture
Operations	Develop Communication links that support MOC Architecture
Operations	Provide Operations & other required tests & simulations
Operations	Provide any required Instrument Calibration support
Operations	Develop Activity Scheduling protocols
Operations	MOC/SOC acquire Level 0 data, process to Level 1 and Level 2. Perform science data trending.

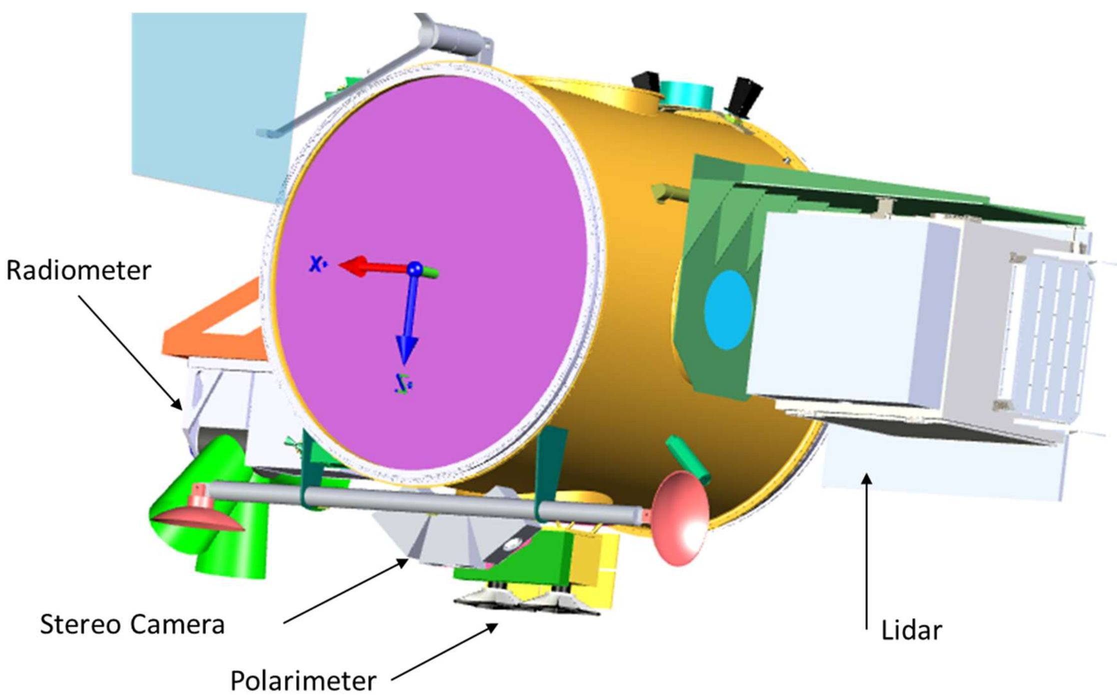
Appendix C.3 – Proof of Concept: Instruments on a Notional S/C in a Notional L/V



Appendix C.4 – Proof of Concept: S/C-1 Instrument Layout



Appendix C.5 – Proof of Concept: S/C-2 Instrument Layout



Appendix D - Rideshare Spacecraft Options and Capabilities

No.	Rideshare Adaptor/Carrier	Vendor / Bus	P/L Mass Capability	P/L Power (OAP/Peak)	Pointing Control (arcsec)	Pointing Knowledge (arcsec)	Pointing Stability (arcsec/sec)	Mounting Area Avail.	Data Storage (Mbytes)	Data Downlink (Mbps)
1	ESPA Class S/C									
2	ESPA Grande Class S/C									
3	A-Deck Class S/C									
4	Propulsive ESPA Class S/C									
5	Propulsive ESPA Grande									

No.	Rideshare Adaptor/Carrier	Vendor / Bus	Spacecraft Design Life	Spacecraft Dimensions	Delta V / Prop System	Available Orbits	Number on Orbit	Comments
1	ESPA Class S/C							
2	ESPA Grande Class S/C							
3	A-Deck Class S/C							
4	Propulsive ESPA Class S/C							
5	Propulsive ESPA Grande							