AtmOS Polarimeter Instrumentation
Solicitation Number: RFI-GSFC-AtmOS-Polarimeter
Agency: National Aeronautics and Space Administration
Office: Goddard Space Flight Center
Location: Office of Procurement

SYNOPSIS

NASA Goddard Space Flight Center is hereby soliciting information from potential sources for flight Polarimeters for potential future AtmOS acquisition.

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 flight Polarimeters for potential future AtmOS acquisition. 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 25 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.

AtmOS BACKGROUND

The Atmosphere Observing System (AtmOS) was established by the NASA Science Mission Directorate Earth Science Division to fulfill the science needs proffered in the 2017 Earth Science Decadal Survey for the combined Designated Observables: Aerosols and Clouds, Convection and Precipitation (ACCP). The AtmOS Constellation Architecture is the result of a 2.5 year ACCP Architecture Study. The ACCP Architecture Study concluded in February 2021 and the mission was authorized to move into Pre-Phase A on May 23, 2021. The respondent may find information on the study results including the Science and Applications Traceability Matrix at the ACCP Architecture Study website: https://vac.gsfc.nasa.gov.

The AtmOS Constellation will make measurements of the aerosol and cloud microphysical properties as well as the measurements of the vertical velocity of convection, aerosol redistribution and precipitation to understand the processes which drive the Earth's atmosphere. By employing a multi-satellite architecture, AtmOS will be able 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 team is performing trade studies to determine options to make measurements and achieve sampling to meet as many of the AtmOS science objectives as possible within cost and schedule constraints. Through this RFI, the AtmOS team seeks information on Polarimeter approaches to further refine the payload assignments, spacecraft needs, and mission concept of operations necessary to meet the science objectives.

The selected AtmOS architecture is illustrated in Figure 1**Error! Reference source not found.**. This architecture encompasses flight assets in two orbit planes: (1) Polar: Sun-Synchronous Orbit, 450 km, and 1330 Ascending Node and (2) Inclined: Nominally 50 to 65 Degree Inclination, 407 km. Within the AtmOS Constellation, Inclined Plane assets will be launched first to achieve earliest possible science with instruments that will make advancements in the understanding aerosol and cloud properties and target the **dynamics** of the cloud processes and precipitation on sub-daily to sub-minute time scales. The polar plane will follow a year or two later with more advanced measurements targeting the seasonal, global scale microphysical properties of clouds and aerosol and their linkage to atmospheric radiation and longer-term climate **change**. The constellation targets understanding the dynamics of the Earth's Atmosphere and the processes that drive change over time.

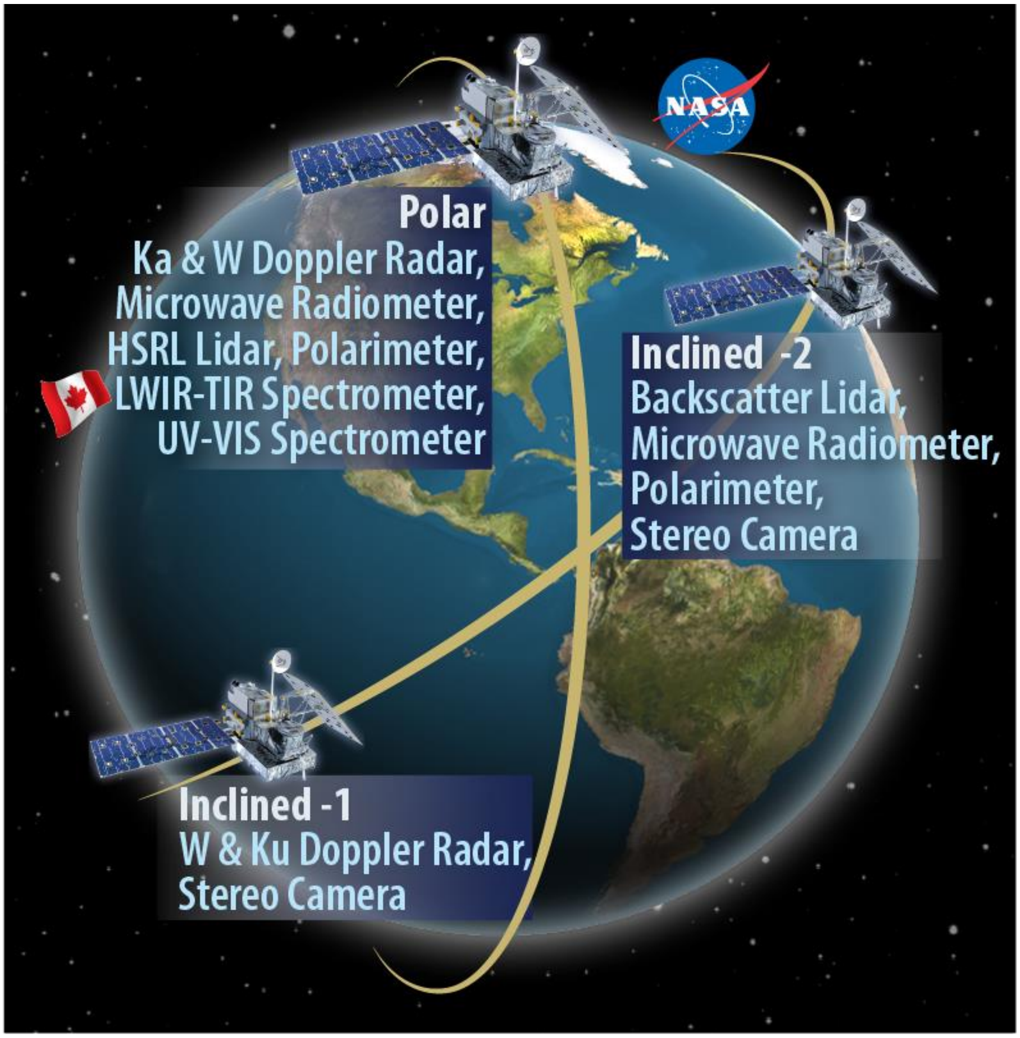

Figure 1 Preferred AtmOS Architecture Concept

While the concept illustrated in Figure 1**Error! Reference source not found.** accurately reflects the AtmOS intent, the number of spacecraft in the two orbit planes and the specific instrumentation assignment on the spacecraft remains under study during the pre-Phase A period.

The anticipated instrumentation suite for the AtmOS Constellation as assigned to the Inclined Orbit and the Polar Orbit is shown in Table 1. Note that some passive instrumentation/sensors (i.e. Polarimeter, Microwave Radiometer) are found in both orbit planes but their performance and spacecraft allocation needs may differ depending upon the assigned orbit plane.

Table 1 Anticipated AtmOS Science Instrumentation

Polar Orbit Plane Instrumentation	Inclined Orbit Plane Instrumentation	Acquisition Comment for Passive Instruments
---	W/Ku Band Doppler Radar	---
W/Ka Band Doppler Radar	---	---
---	Backscatter Lidar	---
High Spectral Resolution Lidar	---	---
LWIR-TIR Spectrometer	---	Proposed CSA Contribution
Microwave Radiometer	Microwave Radiometer	Subject of a separate AtmOS RFI
Polarimeter	Polarimeter	Subject of this AtmOS RFI
UV-VIS Spectrometer	---	Subject of a separate AtmOS RFI
---	Stereo Camera (Tandem Stereographic Cameras)	Subject of a separate AtmOS RFI

POLARIMETER PERFORMANCE

Polarimeter Introduction

Multi-wavelength and multi-viewing-angle photopolarimetric measurements make better use of the information content of scattered solar radiation in comparison to single-viewing measurements (Hasekamp and Landgraf, 2007; Mishchenko and Travis, 1997), providing the information necessary to obtain accurate aerosol microphysical and optical properties. This was recognized in the 2017 Decadal Survey (DS) which recommended the use of a multi-angle, multi-spectral polarimeter, to achieve the science goals of the Aerosols Designated Observable. The NASA study for the combined Aerosols and Clouds, Convection, and Precipitation (ACCP) Designated Observables subsequently showed that polarimetric observations could provide many of the geophysical variables associated with aerosols that were identified as necessary to meet ACCP mission objectives. In addition, polarized hyper-angular observations of clouds offer a unique ability to characterize water cloud droplet size distributions (Alexandrov et. al. 2012) and the shape of ice-particles in order to constrain their asymmetry parameter (Van Diedenhoven et al., 2012) and polarimetric observations in absorbing bands allow for the determination of cloud droplet number concentrations (Sinclair et al. 2019) with fewer assumptions than current approaches (Grosvenor et al. 2018).

Polarimeter Definition

The primary characteristics that allow the information content in polarimetric observations to be accessed are the spectral range, the multi-viewing-angle range and the accuracy of the polarimetric and radiometric observations. Ideally the spectral range should be from the deep blue/ultra-violet to the short-wave infrared (Wu et al. 2015), the angular range that is viewed should encompass a wide scattering angle range (Hasekamp and Landgraf, 2007), there should be at least five viewing angles over that scattering angle range (Wu et al. 2015, Xu et al., 2017) and the polarimetric accuracy should be better than 0.5% (Hasekamp and Landgraf, 2007, Knobelspiesse et al., 2012). We note that the studies of both Wu et al. and Xu et al. are for a limited number of cases over the western United States and that longer wavelength measurements may be valuable for detailed characterization of dust and more viewing angles would allow for the use of neutral points and ocean glint (Ottaviani et al. 2013) in retrieval algorithms. Polarization measurements that meet the requirements described above allow for aerosol retrievals that provide the following geophysical variables: Aerosol Optical Depth (AOD), Aerosol Absorption Optical Depth, Aerosol Vertical Extent, Aerosol Fine Mode Optical Depth, Aerosol Angstrom Exponent, Aerosol Real Index of Refraction, Aerosol Asymmetry Parameter and Aerosol Non-Spherical AOD Fraction with an accuracy that allows for the quantification of the aerosol radiative forcing (Mishchenko et al. 2004, Da Silva et al. 2020). Optimal estimation schemes are used in the retrieval of the aerosol geophysical variables (GVs) and it is not generally possible to associate any particular retrieved variable with a particular spectral band or viewing geometry (Stamnes et al. 2018).

Table 2 provides a minimum set of target performance/capability values that would allow the GVs to be retrieved with sufficient accuracy to allow the AtmOS objectives to be met for performance/capabilities that apply to both orbital planes. The intent of these target values is to ensure that responses to this RFI provide a sensor that would allow AtmOS objectives to be met but does not attempt to prescribe a particular solution. Table 3 is provided as a source of information regarding potential spectral bands that might be used by an instrument vendor and defines the dynamic range appropriate for those bands together with a rationale for the suggested dynamic range parameters.

Table 2 Summary of Key Instrument Performance Targets for an AtmOS Polarimeter

Description	Target Value	Rationale
Wavelength Range[1]	360-2260 nm	Full range analyzed in literature
Spectral Sampling[2]	At least 6 bands within the full wavelength range. At least one band between 360-410 nm; at least three bands between 440-870 nm and at least two bands within the 1000-2260 nm range.	Minimum number of bands used to meet requirements in published literature.
Radiometric Accuracy	≤ 3%	Literature
Stokes Parameters Measured	I, Q, U	Literature
DoLP Accuracy	≤ 0.005	Literature
Cross-track Swath (km)	≥ 100	Synergy with spectrometer/adequate cloud detection and clearing
Nadir Spatial Resolution (km)	≤ 1.0	Avoid cloud contamination
Along Track Viewing Angle Range	±55° at spacecraft	Provides required scattering angle range
Number of Viewing Angles over Range[3]	At least 5 viewing angles within angular range	Literature
Calibration Approach[4]	TBD	
Noise Effective Delta Reflectance at 865 nm	≤ 0.001	Assumes 5 viewing angles, could be increased if more angles used.
Polarimetric Precision	≤ 0.003	
Long Term Stability[5]	1%/year	Performance maintained over life

Footnotes for Table 2:

1. It is not the intent of this statement of spectral range to prescribe that instruments should have spectral bands that cover the full spectral range, but rather that bands over this range are of interest and have been used to obtain the GVs that allow AtmOS objectives to be met.
2. A band at 670 nm similar to that used for the ATMOS Tandem Stereographic Camera is desirable. A band at 940 nm that can be used for water vapor retrieval and correction would be beneficial. The literature suggests that it is sufficient to have the longest wavelength band in the 1600 nm window region (Wu et al. 2015). The spectral bandwidths are not specified, but it is expected that the bandwidth will not be so wide that it precludes the effective use of the measurements in retrievals of GVs.
3. A minimum of 5 angles has been identified as sufficient for aerosol GVs. As noted in the introduction hyper-angular measurements that allow droplet size distribution retrievals are also of interest.
4. Note that if the calibration approach requires spacecraft maneuvers, that information should be included in the response to this RFI.
5. Note that if stability tracking is based on lunar views, or other spacecraft maneuvers, that information should be included in the response to this RFI.

Dynamic range targets for an AtmOS Polarimeter are given in Table 3. Generally, the focus of the polarimeter is on aerosol GVs and the dynamic range requirements reflect this both in the typical and maximum radiance levels. However, in order to use the bi-spectral method for the retrieval of cloud particle size and optical depth it is necessary that the bands commonly used at 670 and 860 nm do not saturate and the maximum reflectance required for these bands reflects this desire. Reflectance values for 1380 and 1880 nm bands reflect their use for detection and characterization of thin cirrus clouds. Bandwidths are not specified, but it is expected that they would be chosen to allow for the use of the observations without excessive degradation by gaseous absorption in those bands focused on aerosol GVs.

Table 3 Dynamic Range Targets for an AtmOS Polarimeter

Band Center (nm)	Reflectances			Solar Irradiance ($W/m^2/\mu m$)	Radiances ($W/m^2/\mu m/sterad$)		
	Rmin	Rtyp	Rmax		Lmin	Ltyp	Lmax
360	0.12531	0.13619	1	966.8	38.5620	41.91	307.73
380	0.10180	0.11064	1	1084.6	35.1458	38.20	345.24
410	0.07602	0.08263	1	1745.1	42.2285	45.90	555.47
440	0.05795	0.06320	1	1864.4	34.3939	37.51	593.46
550	0.02459	0.04255	1	1902.7	14.8903	25.77	605.64
650	0.01294	0.02919	1.1	1586.7	6.5350	14.74	555.58
750	0.00747	0.02522	1	1268.7	3.0149	10.18	403.83
870	0.00422	0.02125	1.1	931.4	1.2513	6.30	326.13
940	0.00249	0.02282	1	817.9	0.6489	5.94	260.36
1050	0.00339	0.02047	1	656.3	0.7078	4.28	208.92
1230	0.00249	0.01971	1	460.4	0.3643	2.89	146.55
1380	0.00027	0.00885	0.6	355.4	0.0300	1.00	67.87
1550	0.00088	0.01835	0.8	267.7	0.0752	1.56	68.18
1650	0.00056	0.01788	0.8	223.3	0.0399	1.27	56.86
1880	0.00027	0.00885	0.6	135.9	0.0115	0.38	25.95
2130	0.00031	0.01531	0.8	91.7	0.0091	0.45	23.36
2260	0.00025	0.01461	0.8	73.6	0.0058	0.34	18.74

POLARIMETER RESOURCE ALLOCATION TARGETS

The AtmOS team has developed target spacecraft resource allocations for the Polarimeter based on information gathered during the ACCP Architecture Study Phase, including information gathered from an instrumentation Request for Information submitted during that period. From this information the mission systems team developed spacecraft concepts commensurate with allocations as found in Table 4. The respondent should provide both their Current Best Estimate and Maximum Expected Value resource needs in the attached spreadsheet under tab labeled 'Spacecraft Accommodation.' Note: The values in the table below are not requirements but rather for informational purposes to provide the respondent with the notional resources needs currently envisioned by the AtmOS team. Exceedance of these values are acceptable and expected, especially in the event of enhanced performance capability.

Table 4 Polarimeter Target Resource Allocations

Resource	**Units**	**Target Allocation (Current Best Estimate)****
Mass	kg	35

Operational Power (Orbit Average)	W	50
Envelope Dimensions in Operational Configuration (L x W x H)	cm	60 x 40 x 45
Data Rate (Peak*)	bits/second	1.0 x10^8
*Peak data rate is the nominal rate while the instrument is in its acquisition mode.		**Please provide both the Current Best Estimate (CBE) and the Maximum Expected Value (MEV) for these resources. MEV = [(100 + XX)/100] CBE where XX is contingency in percent.

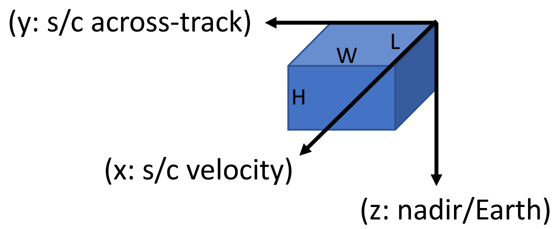

Figure 2 Instrument reference coordinate system.

INSTRUMENT MATURITY

The respondent is encouraged to use the narrative section of the response to describe the technical maturity and supporting basis for the instrument use in spaceflight. In addition to the narrative, the respondent should address the itemized requests within the spreadsheet on technology readiness assessment.

Suitable instrument candidates must be no less than Technology Readiness Level (TRL) 6 by the Polarimeter Preliminary Design Review (PDR), see Table 5. TRL definitions can be found in the NASA Systems Engineering Handbook, and they apply to the relevant, intended environment (e.g. airborne instrument demonstrated in that environment would be considered TRL 6, but would not be considered TRL 6 if they were intended for a spaceflight environment for AtmOS).

If the candidate instrument is not currently at TRL 6 for the intended environment, the response should include the following:

a) An estimate of current TRL, using the TRL definitions in Appendix G of the NASA Systems Engineering Handbook (NASA SP-2016-6105 Rev. 2, 2016).
b) A technology maturation plan that outlines the approach and timeline to achieve TRL 6
c) Identification of the external funding source(s) supporting the effort to achieve TRL 6 and qualify the hardware for the intended environment

COST ESTIMATE

The AtmOS Constellation is cost-constrained. The AtmOS team requests a rough-order-of-magnitude estimate on the total cost in 2021 dollars for the Polarimeter. For purposes of cost estimation and planning, the respondent should consider award of the instrument Phase A contract NET March 2022. Award of an instrument delivery contract should occur sometime in Phase B for Phase C-E. Phase B is expected to start NET March 2023. The respondent should assume that the instrument is delivered to a spacecraft provider for integration and testing at observatory-level and for delivery to the launch site for launch and a follow-on period of on-orbit checkout. For purposes of developing the Cost Estimate, the respondent should assume the following draft AtmOS milestone schedule found in Table 5.

Table 5 Draft AtmOS Milestone Schedule

Milestone	Date
Mission Concept Review	2/1/22
Polarimeter System Requirements Review	10/1/22
Mission Systems Requirements Review	12/1/22
Polarimeter Preliminary Design Review	4/1/24
Mission Preliminary Design Review	6/1/24
Polarimeter Critical Design Review	4/1/25
Mission Critical Design Review	6/1/25
Inclined Orbit Plane Systems Integration Review	6/1/26
Polar Orbit Plane Integration Review	6/1/27
Inclined Systems Integration Review	6/1/26
Polar Systems Integration Review	6/1/27
Inclined Launch	3/1/28
Inclined On-Obit Checkout Complete/Operations Commence	6/1/28
Polar Launch	3/1/29
Polar On-Obit Checkout Complete/Operations Commence	6/1/29

MISSION ASSUMPTIONS AND SPACECRAFT INTERFACE ASSUMPTIONS

When developing their response, the respondent should consider the following Mission and Spacecraft Interface assumptions detailed in Table 6.

Table 6 Mission and Spacecraft (MSC) Interface Assumptions

Identifier	Category	Polar, Inclined, or Common	Mission Parameters and Spacecraft Interface: Driving/Key Assumptions
MSC1	Orbit	Polar	450 km +/-10 km altitude, Sun Synchronous Polar Orbit, Ascending Node: 1330
MSC2	Orbit	Inclined	407 km +/- 10 km altitude, 50 to 65 degree inclination
MSC3	Orbit and Thermal Interface	Inclined	For thermal purposes, the Inclined Spacecraft will perform approximately 9 to 12 180-degree yaw maneuvers per year to maintain a consistent 'cold side' to the spacecraft. The responder should note any instrument performance or functional concerns with this inclined ConOps assumption.
MSC4	Launch Date	Inclined	See Table
MSC5	Launch Date	Polar	See Table
MSC6	Instrument Design Life	Polar	Minimum 3 Years, accommodate 5 years for any consumable.
MSC7	Instrument Design Life	Inclined	Minimum 3 Years, accommodate 5 years for any consumable.
MSC8	Instrument Risk Classification	Common	Risk Class C per NASA 8705.4A
MSC9	Launch Vehicle	Common	Assume environment envelope of the following launch vehicles: Falcon 9, Blue Origin New Glenn, and ULA Vulcan Centaur.

Identifier	Category	Polar, Inclined, or Common	Mission Parameters and Spacecraft Interface: Driving/Key Assumptions
MSC10	Deployments	Common	Deployments for initial instrument configuration are acceptable. and should be noted by the vendor. For example, this might include protective aperture covers or release mechanisms for a system locked during launch.
MSC11	Orbital Debris Reduction	Common	The instrument should retain with the instrument any deployed hardware. No hardware is to be released into orbit.
MSC12	Thermal Interface	Common	Instrument is responsible for its own thermal management, including any cryocoolers, operational heaters, thermal radiators, thermal straps, and heat pipes. Assume that spacecraft will accommodate field of view for instrument radiators with view to a 'cold side' of the spacecraft. Conductive heat transfer between instrument and mounting interface will be restricted.
MSC13	Survival Power	Common	Spacecraft will provide dedicated power feed for survival heaters from nominal 28 V DC power service. Instrument is responsible for its own survival heaters and control (e.g. thermostats).
MSC14	Operational Power Service	Common	Assume nominal 28 V DC power service from spacecraft battery system, notionally 23 V to 32 V DC range of variation.
MSC15	Spacecraft Attitude Control System	Common	The spacecraft will maintain a nadir-pointing attitude during operations.
MSC16	Science Data Management	Common	Instrument need not provide its own data storage system. Assume spacecraft will provide adequately sized data recorder to store instrument science, telemetry, housekeeping for periodic spacecraft downlinking.
MSC17	Science Data Management	Common	Data Rate values provided in the targeted resource allocation are for uncompressed data. Assume that the spacecraft will not implement any data compression on the instrument science data. The instruments may wish to implement data compression (lossy or lossless) algorithms prior to transfer to the spacecraft.

SOLICITATION

The AtmOS team will conduct a Pre-Acquisition Strategy Meeting with NASA Headquarters and Earth Science Division (ESD) in late Summer 2021 and a final Acquisition Strategy Meeting during Phase A. The purpose of this solicitation is to help inform the AtmOS team in preparation for those Acquisition Strategy meetings. NASA Headquarters Earth Science Division (ESD) will make the final determination as to the acquisition approach including a determination if the Polarimeter will be commercially competed.

The Key Decision Point (KDP) A for AtmOS is expected to be no earlier than 3/2022. If solicited, the Polarimeter solicitation will be posted no earlier than first quarter CY 2022.

DATA SECURITY

The information provided will be maintained on GSFC-maintained secure servers, and accessed only by civil servants, or contractors that have signed Non-Disclosure Agreements (NDAs) that preserve vendor proprietary and competition sensitive data.

It is not NASA's intent to publicly disclose vendor proprietary information obtained during this solicitation, including any cost estimates provided. 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 North American Industry Classification System (NAICS) code for this procurement is 336419, Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Manufacturing, with a size standard of 1,000 employees.

RESPONSE CONTENT REQUIREMENTS

This RFI is to solicit specific capability information from any experienced source and promote collaboration and competition. The RFI seeks responses that provide the technical resource footprint, science performance, and vendor capability statements for the Polarimeter. The description of the Polarimeter should include any relevant laboratory, sub-orbital, or spaceflight information regarding the hardware configuration as previously demonstrated and the science returned, as well as the instrument calibration and data validation methods.

Interested offerors/vendors having the required specialized capabilities to meet the intended application should submit a capability statement indicating the ability to perform all aspects of the effort described herein. Responders are invited to submit a narrative and to fill out the attached Polarimeter spreadsheet. The narrative should not exceed 25 pages. Science publications and other relevant information can be referenced in the narrative to provide examples of the source's expertise, facilities, and prior work, especially regarding hardware and/or test results for the Polarimeter. The respondent should include within the narrative a description of the Polarimeter operating principles within the larger AtmOS operational concept including any measurement synergies enabled by the instrument. The respondent is encouraged to use the narrative to include an instrument functional block diagram, technology readiness assessment basis, identification of any long-lead components or subsystems, and any potential risks (cost, technology, or schedule) envisioned for the Polarimeter based on the AtmOS schedule and flight architecture.

The attached AtmOS Polarimeter spreadsheet offers a convenient and concise means of addressing the anticipated Polarimeter performance, spacecraft resource, and mission operational concept needs. The spreadsheet includes the technical information necessary to support Mission Concept development/pre-formulation. The spreadsheet includes separate tabs for General Information, Polarimeter Performance, Supplemental Information, Spacecraft Accommodation, Orbit and Attitude, and TRL. Please complete one spreadsheet for each candidate instrument submitted.

Responses must also include the following: name and address of firm, size of business; average annual revenue for past 3 years and number of employees; ownership; whether they are large, small, small disadvantaged, 8(a), Woman-owned, Veteran Owned, Service-Disabled Veteran Owned, Historically Underutilized Business Zone and Historically Black Colleges and Universities/Minority Institutions and number of years in business. Also include affiliate information: parent company, joint venture partners, potential teaming partners, prime contractor (if potential sub) or subcontractors (if potential prime), list of customers covering the past five years (highlight relevant work performed, contract numbers, contract type, dollar value of each procurement; and point of contact - address and phone number).

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Technical questions should be directed to: Vickie Moran at Vickie.E.Moran@nasa.gov.

Procurement related questions should be directed to: Craig Keish at craig.f.keish@nasa.gov.

Interested offerors should respond to this RFI in written format as described in the previous paragraphs by electronic mail to: Vickie Moran at Vickie.E.Moran@nasa.gov by July 21, 2021. Responses can be submitted via email. The subject line of the submission should be "RFI for AtmOS Polarimeter," and attachments should be in Microsoft WORD, POWERPOINT, EXCEL or PDF format. The email text must give a point-of-contact and provide his/her name, address, telephone/fax numbers, and email address.

Contracting Office Address:
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Primary Point of Contact:
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