

**NESDIS Common Cloud Framework (NCCF)  
Digital Ground Radio Processing  
Broad Agency Announcement**

**1332KP23BNEEG0001**

**December 2022**

**Office of Satellite Ground Services (OSGS)  
National Environmental Satellite, Data, and Information Service (NESDIS)  
National Oceanic and Atmospheric Administration (NOAA)  
Department of Commerce (DOC)**

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# 1. OVERVIEW

This is a Broad Agency Announcement (BAA) posted in accordance with Federal Acquisition Regulation (FAR) Subpart 35.016. The United States Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), Office of Satellite Ground Services (OSGS) is requesting proposal submissions for demonstration of commercially available cloud-based digitized radio processing solutions. NOAA has established the NESDIS Common Cloud Framework (NCCF) and seeks vendors to demonstrate the viability of expanding the NCCF architectural framework to include cloud-based software implementation of core ground radio processing capabilities: direct Radio Frequency (RF) ingest, (de)modulation, (de)coding, and frame and packet processing.

This announcement shall be posted for a total of thirty (30) calendar days, and all submissions are due by 3:00 PM Eastern Daylight Time (EDT), January 24, 2023. Submissions shall consist of proposals for a demonstration meeting the requirements laid out in this BAA. All pre-submission inquiries shall be submitted in writing to both the Contract Specialist and Contracting Officer by 11:00 AM EST, December 15, 2022. The program offices and technical points of contact may not be contacted directly and will refer all inquiries to the Contracting Officer. Additional submission instructions are provided at Section 4.

## GENERAL INFORMATION

### NAICS Code

The NAICS code for this BAA will be 541715 – Research and Development in the Physical, Engineering, and Life Sciences (except Nanotechnology and Biotechnology).

### Agency Name

United States Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Environmental Satellite, Data, and Information Service (NESDIS), Office of Satellite Ground Services (OSGS)

### Development Opportunity Title

NESDIS Common Cloud Framework (NCCF) Digital Ground Radio Processing

### Announcement Type and Date

Broad Agency Announcement (1332KP23BNEEG0001); posted December 5, 2022

### Demonstration CONOP Proposal Due Date

## **Eligible Offerors**

This BAA is open to ALL responsible sources. Offerors may include single entities or teams from private sector organizations, Government laboratories, and academic institutions.

To be eligible for award, a prospective recipient must meet certain minimum standards pertaining to financial resources, ability to comply with the performance schedule, prior record of performance, integrity, organization, experience, operational controls, technical controls, technical skills, facilities, and equipment.

Federally Funded Research and Development Centers (FFRDCs) and Government entities (Government/National laboratories, military educational institutions, etc.) are subject to applicable direct competition limitations and cannot submit a response to this BAA in any capacity unless they address the following conditions:

### **FFRDCs**

1. Must clearly demonstrate that the proposed work is not otherwise available from the private sector.
2. Must provide a letter on letterhead from their sponsoring organization citing the specific authority establishing their eligibility to propose to government solicitations and compete with industry.
3. Must demonstrate compliance with the associated FFRDC sponsor agreement and terms and conditions. This information is required for any FFRDCs proposing to be primes or subcontractors.

### **Government Entities**

1. Government entities must clearly demonstrate that the work is not otherwise available from the private sector and provide written documentation citing the specific statutory authority (as well as, where relevant, contractual authority) establishing their ability to propose to government solicitations. Specific supporting regulatory guidance, together with evidence of agency approval will be required to establish eligibility. NOAA will consider eligibility submissions on a case-by-case basis; however, the burden to prove eligibility for all team members rests solely with the Offeror.

The Government and FFRDC entities are encouraged to consider teaming arrangements with responsible sources from academia and industry. Offerors who propose teaming arrangements must name which organization will operate as the main point-of-contact or lead for the team. The Proposal must be submitted by the team lead organization. A description of each team member's role on the team must be included. In the event of an award to a team proposal, the

award will be made to the team lead (Prime) organization named in the proposal for the purposes of contract administration. The Prime organization will be responsible for putting in place all the sub-contracts and other teaming arrangements.

Historically Black Colleges and Universities (HBCUs), Minority Institutions (MI), Small Business concerns, Small Disadvantaged Business concerns, Women-Owned Small Business concerns, Veteran-Owned Small Business concerns, Service-Disabled Veteran-Owned Small Business concerns, 8(a) Business concerns, and HUB Zone Small Business concerns are encouraged to submit proposals and to join other entities as team members in submitting proposals.

### **Research and Development Areas of Interest**

Development and technical objectives are described in Section 3.

### **Award Information**

The total expected amount of funding for demonstrations is \$750K. NESDIS envisions (1-3) awards for demonstrations under this BAA, with each one having a duration of up to 6 months, with a presentation briefing and technical report as the final deliverable. The government may award zero, one, or multiple contracts under this BAA; dependent on the applicability of the Proposals to the technical need, and congressional appropriations.

In the event the Government awards multiple contracts from this BAA, demonstrations will be conducted sequentially. Following separate kick off meetings each contractor will receive a notice to proceed (NTP) letter which will identify the contractor's POP start date. The Contractor will have up to six (6) months from the NTP date on their letter to meet all the Government's requirements.

This BAA shall not be construed as a commitment or authorization to incur costs in anticipation of a grant, cooperative agreement, other transaction, or contract. Contracts, grants, cooperative agreements, or other transactions may be awarded, as appropriate. At this time, it is anticipated that each award will result in a firm fixed price contract.

The Government is not responsible for any costs incurred in the preparation of a submission in response to this BAA. Note that proposal submissions may be subject to review by experts outside of the civil service such as NOAA contractors, each of whom would sign non-disclosure agreements as required. This exchange of information must be consistent with procurement integrity requirements (See FAR 3.104).

## 2. PROGRAM DESCRIPTION

NESDIS is currently engaged in the developing and transitioning to a Common Service-based Enterprise Ground Architecture that is both supportive of NOAA's next generation satellite observing systems and responsive to new and evolving threats and opportunities. This operating paradigm requires a more efficient, agile and scalable end-to-end information system that can ingest, harmonize and integrate data from any source into easily accessible and usable products.

NESDIS developed characteristics for this Common Ground System described as an architecture that will:

- Maximize infrastructure resource sharing
- Maximize the use of standardized development, integration and operational environments
- Minimize lifecycle costs and streamlining new capability deployment
- Increase automation
- Prioritize tools that enable deployment in Cloud environments

As the first step along this path, NOAA/NESDIS has established the NESDIS Common Cloud Framework (NCCF) supporting ingest, product generation, distribution and access, archive and data stewardship needs. (See reference diagram in Section 2.1)

NESDIS is now seeking to investigate next steps regarding the viability of utilizing commercial sector capabilities for expansion of the NCCF where applicable and has identified the utilization of cloud-based core digital ground capabilities required for enterprise-level support of Space-to-Ground Communications (SCM) in the near-term as an area that warrants further exploration.

Specifically, NESDIS is investigating the feasibility of using enterprise multi-mission RF digitization in combination with Software-Defined Radios (SDRs) and Front-End Processing (FEP), as developed with cloud-based capabilities, in support of telemetry processing for its satellite program(s) of record.

Industry, academic and other interested parties are invited to submit proposals for consideration outlining a vendor conducted demonstration for migration of traditional hardware-based ground radio processing capabilities to cloud-based software applications as Cloud Network Functions (CNFs) within the NCCF.

## 2.1 NESDIS COMMON CLOUD FRAMEWORK (NCCF) REFERENCE ARCHITECTURE

For the purposes of this announcement, NOAA is providing a high-level diagram of the NESDIS Common Cloud Framework. All submitted proposals shall reference this baseline in the development of concept of operations (CONOPS) and proposed solutions.

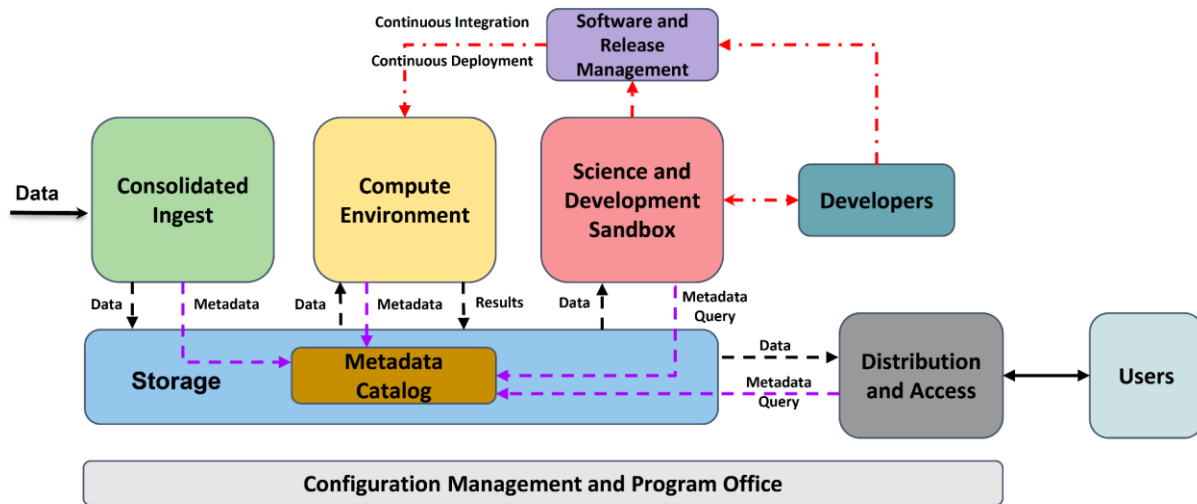


Figure 1-1: NCCF Architecture Diagram

### **3. RESEARCH AND DEVELOPMENT AREA OF INTEREST**

#### **3.1 DIGITAL GROUND RADIO**

This BAA is soliciting proposals for demonstrations from commercial, government, and academic sources for tools, services, and capabilities that support a future NOAA/NESDIS transition from mission-specific hardware-based telemetry to a cloud-based telemetry processing paradigm conformant with its established NCCF architecture. The Government seeks to conduct demonstrations to gain further market research on current industry and academic technical solutions in order to develop a technical roadmap, understand cost tradeoffs and risks associated with transitioning cloud based radio processing capabilities to the NESDIS Ground Enterprise architecture. The Government is not intending to prescribe nor preclude specific technical solutions in response to this submission call. The following NOAA long-term objectives/priorities should be considered in responses to this BAA's identified scope.

The responses should address the following desired characteristics:

- Capability to adapt and scale to new missions
- Advances in adaptation of Agile Methodologies
- Performance, cost, and ease of implementation
- Promotes modularity with open standards-based interfaces
- Cloud-based Software
- Mission/Spacecraft-Agnostic
- Cloud Service Provider-Agnostic
- FEP and Encryption Interface Capabilities
- Security Compliance Approach
  - FedRAMP status (mandatory)
  - Requirements for monitoring, vulnerability scanning, and remediation
  - FISMA compliance approach (mandatory)
  - Compliance with DOC IT Security Program Policy (CAR 1352.239-72)
  - Other security frameworks, e.g. ISO 27001 and others

##### **3.1.1 Technical Requirements**

The Government would like to hear from both academia and industry on potential technical solutions to best support the development and transition to cloud-based SCM processing as aligned with the above identified NOAA long-term Enterprise objectives and priorities. Sources submitting proposals for consideration should thoroughly review the aforementioned and submit detailed responses including the following information:

- Plan of what the proposal will demonstrate:
  - Outline of phased approach, milestone schedule, entrance/exit criteria

- Technology Readiness Level (TRL) of demonstrated technologies
- Technical limitations of solutions and capabilities demonstrated (Frequency digitization ranges, modulation schemes, and data rates)
- Associated risks and advantages of the proposed demonstration approach
- Demonstration achievement objectives and deliverables
- How does the proposed demonstration align with NOAA stated transition goals (common services, network security implementation)?
- Proposed Reference Architecture and Concept of Operations for cloud-based SCM processing, including details pertaining to software applications, network topologies, requested cloud services and/or physical equipment or facilities.
  - Describe if or how the proposed solution met or has the potential to meet through modifications, commercial items as defined in the Federal Acquisition Regulation (FAR) 2.101, Describe if or how a solution can be met with a commercial item or if modifications are required, and discuss the time frame involved.
- Security Implementation
  - How will each component of the demonstrated solution support current NESDIS security hardening, monitoring, channelization and data integrity requirements?  
Note: NIST 800-53 Rev 5 and NIST IR 8401 IPD
  - Does the plan support an evolutionary path for implementation of NESDIS Enterprise level security for digital ground radio components across diverse mission sets?
  - How will the implemented architecture support and foster resilient operations?
  - Is the proposal compliant with all current NESDIS security requirements for networked systems? (Add pertinent reference materials)
- Identification of any requested Government Furnished Property (GFP) and any expected modifications required to support the Vendor's Reference Architecture and Concept of Operations
  - How would interfaces to Government-provided Encryption solutions be handled?
  - Do vendor solutions exist that could provide comparable NIST 140-2 Encryption capabilities natively within their own SCM products?
- Processes as well as assumptions for transition from the existing legacy HW based SDR/FEP processing to a vendor-provided solution and the associated timeframe.
- Potential risks and or issues for the Government to consider, including but not limited to, Information Technology (IT) Security or programmatic considerations

- Recommended approaches to reduce or otherwise mitigate risk for the Government's consideration
- Initial ROM cost estimate for implementation of the proposed Reference Architecture to include Non-recurring engineering (NRE), HW/SW procurement, installation and integration, and licensing costs. For streamlining purposes, Offeror's are required to use Attachment BAA - 1, SDR ROM template.
  - The estimate shall include any assumptions and should highlight major cost drivers and opportunities for cost savings such as trade-offs between development costs for automation, hardware reductions and operations costs/staffing.
  - Please detail any published catalog pricing, as applicable.

### **3.1.2 Demonstration Requirements**

This section describes the requirements for the demonstration. It is included to aid the Offerors in developing their estimates for the demonstration, as required in Section 4.

#### **3.1.2.1 Demonstration Coordination Requirements**

**Kick-Off Meeting:** A kick-off meeting will be held (Face to face, WebEx/telecom, or a combination). Its objective is to ensure the demonstration plans, schedule, and deliverables are understood, and to answer any questions that may arise as part of the process.

**Phased Checkpoint Status Meeting(s):** The phased checkpoint status meeting is intended to provide current project status, present evidence of conformance to phased entrance/exit criteria, discuss technical hurdles, and mutual agreement on any adjustments to the work to be completed during the remainder of the demonstration.

#### **3.1.2.2 Demonstration Communication Requirements**

The Offeror shall maintain proactive, open, and responsive communication with the Government. Regular communication shall include support of programmatic and technical interchanges taking the form of email, recurring teleconferences, etc., as required. The Offeror shall support in-person reviews at the customer location or Offeror's facilities, as required.

Teleconferences shall take place at least once every month to discuss status and interchange information.

#### **3.1.2.3 Demonstration Period of Performance**

The period of performance will be specified by the Offeror, but not to exceed seven (7) months from Authorization to Proceed (ATP). This period of performance includes up to six (6) months to perform the demonstration and produce the deliverables, plus one month for follow up questions and/or clarifications.

#### **3.1.2.4 Government Furnished Equipment (GFE)/Government Furnished Services (GFS)**

The Government will provide access to Government sites, specialized test equipment and IT systems on a pre-coordinated case-by-case basis, subject to work site-location availability, mission priority and cost considerations.

#### **3.1.2.5 Place of Performance**

The demonstration shall be conducted out of the following Government locations:

Wallops Command and Data Acquisition Station (WCDAS)  
33699 Chincoteague Rd  
Wallops Island, VA 23337

NOAA Satellite Operations Facility (NSOF)  
4231 Suitland Rd  
Suitland, MD 20746

#### **3.1.2.6 Security**

The Contractor shall comply with the IT Security requirements of the Department of Commerce (DOC) as outlined in Commerce Acquisition Regulation (CAR):

- CAR 1352.239-72, Security Requirements for Information Technology Resources (April 2010).
- CAR 1352.239-72, section (d) includes the DOC IT Security Program Plan, the NOAA IT Security Manual NESDIS IT Security Handbook.
- The Contractor shall also comply with FAR Clauses 52.204-21, 52.224-1, 52.224-2 and 52.239-1.

Contractor personnel shall be screened in accordance with the requirements for Moderate Risk contracts as specified by Commerce Acquisition Manual (CAM) 1337.70 section 2.2 (Oct 2015); specifically, in accordance with CAR 1352.237-70, Security Processing Requirements High or Moderate Risk Contracts (April 2010). Any access by contract personnel who are Foreign Nationals shall be in accordance with the requirements of CAR 1352.237-73, Foreign National Visitor and Guest Access to Departmental Resources (APR 2010).

#### **3.1.2.7 Deliverables**

The Offeror shall provide the following reports and deliverables.

##### **3.1.2.7.1 Reports**

A final briefing and report of the demonstration and deliverables shall be provided approximately two weeks after the completion of the demonstration. The report shall include a risk profile, lessons learned, security recommendations, technical limitations, cost/price profile (revised ROM) and a Concept of Operations based on the demonstration.

At the completion of each phase of the demonstration, the Contractor shall provide a short briefing and report outlining accomplishments and conformance with entrance/exit criteria. Prior to the contractor proceeding to the next demonstration phase, the Government will review and provide approval.

Additional demonstration specific deliverables may be required under the RFP.

#### **3.1.2.7.2 Deliverables**

Deliverable #	Name	Deliver to	Delivery Method	Delivery Date
0001	Kick-Off Meeting	COR	Virtual presentation	Within ten business days of award
0002	Phased Checkpoint Status Meetings	COR	Virtual presentation	Five days prior to conclusion of each phased milestone
0003	Digital Ground Radio Processing Final Report	COR	Electronic submission and virtual presentation	Ten days after conclusion of demonstration

#### **4. Proposal Guidelines:**

##### **Special Notice:**

Contractor Participation - The Government may utilize Contractors to support the evaluation of proposals. Additional information has been provided in Section L paragraph L.5 of the BAA Provisions and Clauses.

##### **4.1 Submission Preparation:**

Interested Offerors shall submit a proposal, offering tools, services, and/or capabilities that support a future NOAA/NESDIS transition from mission-specific hardware-based telemetry to a cloud-based telemetry processing paradigm conformant with the currently implemented NCCF architecture that meets the mission criteria described in section 3. The proposal submission

shall not exceed 17 pages (including a cover page, technical proposal and small business participation plan). If submissions exceed the limitations, only those pages defined in the table below will be reviewed. Tables, figures and diagrams are not included in the page limit.

For each distinct proposal submission, the Offeror shall follow the table in paragraph 4.2 Proposal Submission.

The document must be submitted in accordance with the preparation guidance below. The document should describe the effort in sufficient detail to allow evaluation of the technical merit and its potential contribution to the NOAA mission.

Proposal submissions must remain valid for six months from the submission deadline.

Offerors will be notified via e-mail if their submission has been selected for a funded demonstration under this BAA.

Electronic Submission, due 3:00 PM, January 24, 2022 EST. Late submissions will not be considered. All submissions shall be submitted electronically to both:

- Contract Specialist: Andrea Chiodi, [andrea.chiodi@noaa.gov](mailto:andrea.chiodi@noaa.gov)
- Contracting Officer: Lori Smith, [lori.smith@noaa.gov](mailto:lori.smith@noaa.gov)

The Government reserves the right to open additional rounds of proposal submissions. Additional requests, if applicable, will be posted on SAM.gov as an amendment to this posting no later than June 30, 2023.

**IMPORTANT:** The subject line of the email shall consist of the RFP number, BAA title and the name of the Offeror, (e.g., 1332KP23BNEEG0001- BAA Digital Ground Radio Processing - <OFFEROR NAME> -), . Proposals must be submitted in the following format:

- Page Size: 8 ½ x 11" with 1" Margins
- Spacing – single
- Font – Times New Roman size 12 font or equivalent; charts, tables, and graphics may use a Times New Roman size 10 font

The files shall not exceed 10 Megabytes of storage space. Video and sound file attachments, URL Links, or other additional files, will not be accepted.

Classification: All proposal submissions must be UNCLASSIFIED.

#### **4.2 Proposal Submission:**

The Offeror proposal shall consist of all the Volumes as set forth in the table below:

Volume Number	Volume Title	Page Limit	Copies
1	Technical <ul style="list-style-type: none"> <li>• Cover Page</li> <li>• Technical Merit Proposal</li> <li>• Small Business Participation Plan</li> </ul>	Cover Page: 1 page limit  Technical Merit Proposal: 15 page limit  Small Business participation Plan: 1 page	Electronic copy (Searchable PDF format)
2	Past Performance	1 page per past performance example	Electronic copy (Searchable PDF format)
3	Price	No Page Limit	Electronic copy (Excel format)
4	Business	No Page Limit	Electronic copy (Searchable PDF format)

#### **4.2.1 Technical Proposal (Factor 1)**

**The technical factor consists of 2 subfactors listed in descending order of importance, technical merit and small business participation.**

##### **4.2.1.1 Technical Merit (Subfactor 1):**

The Technical Merit Proposal shall describe the Offeror's concept's ability to address the need and requirements detailed in the appropriate part of Section 3. Merely restating the minimum objectives is not sufficient. The core components of the Technical Merit Proposal include a detailed explanation of the concepts being proposed including definitions of how the Offeror plans to meet the requirements for that given concept including but not limited to:

1. What capabilities they are proposing to demonstrate
2. What they plan to accomplish in the demonstration timeframe
3. What they plan to deliver at the end of the demonstration

4. How their concept contributes to the requirements laid out in Section 3 regarding NESDIS's need for a more efficient, agile and scalable end-to-end information system that can ingest, harmonize and integrate data from any source into easily accessible and usable products.
5. Include a detailed schedule to include phasing and milestones.
6. Provide an initial ROM for the migration as described in paragraph 3.1.1 Technical Requirements.

Additionally, the Offeror must supply sufficient data to justify the proposed Technology Readiness Level (TRL) maturity of the solution.

#### 4.2.1.2 Small Business Participation (Subfactor 2):

Other than small businesses shall advise the Government how they intend to provide small businesses an opportunity to subcontract.

#### **4.2.2 Past Performance Proposal**

The Offeror shall provide a summary of past performance information of up to two (2) projects/studies/demonstrations performed in the last three (3) years to demonstrate the relevance to the task in the BAA. Offerors shall provide a description of the work performed and explain how it is relevant to this BAA.

#### **4.2.3 Price Proposal**

The price proposal shall include labor categories, number of hours per labor category, hourly rates, subtotal and total amounts associated with design and execution of the proposed demonstration. The price proposal shall also include the costs for shipping, installation, integration and testing for any hardware included in the proposal.

#### **4.2.4 Business Proposal**

The purpose of this volume is for the Offeror to provide all information necessary for the Government to make an award. The Offeror shall include the following:

- Proposal Form - The Offeror shall submit a vendor-signed version of the Standard Form (SF) 33 with blocks 13-18 filled out.
- Exceptions and Deviations - The Offeror shall identify and explain any exceptions or deviations taken to any part of the BAA or conditional assumptions, including BAA provisions and clauses. Offerors should note that taking exceptions to the Government's requirements may indicate an unwillingness or inability to perform the contract, and the proposal may be evaluated as such.

- Potential Organizational Conflict of Interest (OCI) – The Offeror shall identify potential OCIs as required by CAR 1352.209-70. Any potential OCI that is not adequately identified, addressed, or mitigated in the proposal may prevent an Offeror from receiving the award.
- Offeror Representations and Certifications – The Offeror shall include all required representations and certifications or certify that the required representations and certifications are available at SAM.gov.
- Offeror shall provide their Unique Entity ID and Commercial and Government Entity (CAGE) code.

## **5 EVALUATION INFORMATION**

### **5.1 Evaluation Criteria**

The evaluation is based on three (3) factors which are listed below in descending order of importance: Technical, Past Performance and Price. Technical and Past Performance, will be evaluated independent of price. It is cautioned that the award may not necessarily be made to the lowest priced proposal.

The Government will evaluate proposals in accordance with the following evaluation criteria:

#### **A. Factor 1 Technical:**

Technical, which is the most important factor, will be evaluated based on the following criteria in descending order of importance.

1. Subfactor 1 Technical Merit will be evaluated based on the following criteria
  - i. Unique and innovative approach proposed to accomplish the technical objectives. New and creative solutions and/or advances in knowledge, understanding, technology, and state of the art.
  - ii. The offeror's understanding of the scope of the technical effort.
  - iii. Soundness of the offeror's technical approach including whether the proposal identifies major technical risks, clearly defines feasible mitigation efforts, and demonstrates related experience.
  - iv. The potential to transition the research and development deliverables to future Government needs. Any proposed restriction on technical data or computer software will be considered.

2. Small business Participation:

Small business participation is encouraged. The Government will evaluate if the Offeror has demonstrated that they have given maximum practicable opportunity for small business participation.

B. Factor 2 Past Performance:

- a. Offerors need to have an acceptable level of past performance for similar types of studies to be considered.

C. Factor 3 Price:

- a. Is the least important factor and will be evaluated for Price Reasonableness.

**5.2. Selection Process**

- a. **Categories:** Based on the Peer or Scientific Review, proposals will be categorized as Selectable or Not Selectable (see definitions below). The selection of one or more sources for award will be based on the Peer or Scientific Review, as well as importance to agency programs and funding availability.
  - i. **Selectable:** Proposals are recommended for acceptance if sufficient funding is available.
  - ii. **Not Selectable:** Even if sufficient funding existed, the proposal should not be funded.

Note: The Government reserves the right to award some, all, or none of proposals. When the Government elects to award only a part of a proposal, the selected part may be categorized as Selectable, though the proposal as a whole may not merit such a categorization.

- b. No other criteria will be used.

- c. Prior to award of a potentially successful offer, the Contracting Officer will make a determination regarding price reasonableness.

The Government intends to make its selection without conducting exchanges. The Government reserves the right to conduct exchanges with only the proposal(s) that is most advantageous to the Government.

### **5.3 Contractor Responsibility Determination**

The Government will determine contractor responsibility in accordance with FAR 9.104-3 prior to making an award.

## APPENDIX 1 Definition of Technology Readiness Levels

**TRL 1 Basic principles observed and reported:** Transition from scientific research to applied research. Essential characteristics and behaviors of systems and architectures. Descriptive tools are mathematical formulations or algorithms.

**TRL 2 Technology concept and/or application formulated:** Applied research. Theory and scientific principles are focused on specific application area to define the concept. Characteristics of the application are described. Analytical tools are developed for simulation or analysis of the application.

**TRL 3 Analytical and experimental critical function and/or characteristic proof-of- concept:** Proof of concept validation. Active Research and Development (R&D) is initiated with analytical and laboratory studies. Demonstration of technical feasibility using breadboard or brass-board implementations that are exercised with representative data.

**TRL 4 Component/subsystem validation in laboratory environment:** Standalone prototyping implementation and test. Integration of technology elements. Experiments with full-scale problems or data sets.

**TRL 5 System/subsystem/component validation in relevant environment:** Thorough testing of prototyping in representative environment. Basic technology elements integrated with reasonably realistic supporting elements. Prototyping implementations conform to target environment and interfaces.

**TRL 6 System/subsystem model or prototyping demonstration in a relevant end-to-end environment (ground or space):** Prototyping implementations on full-scale realistic problems. Partially integrated with existing systems. Limited documentation available. Engineering feasibility fully demonstrated in actual system application.

**TRL 7 System prototyping demonstration in an operational environment (ground or space):** System prototyping demonstration in operational environment. System is at or near scale of the operational system, with most functions available for demonstration and test. Well integrated with collateral and ancillary systems. Limited documentation available.

**TRL 8 Actual system completed and "mission qualified" through test and demonstration in an operational environment (ground or space):** End of system development. Fully integrated with operational hardware and software systems. Most user documentation, training documentation, and maintenance documentation completed. All functionality tested in simulated and operational scenarios. Verification and Validation (V&V) completed.

**TRL 9 Actual system "mission proven" through successful mission operations (ground or space):** Fully integrated with operational hardware/software systems. Actual system has been thoroughly demonstrated and tested in its operational environment. All documentation completed. Successful operational experience. Sustaining engineering support in place.