National Aeronautics and Space Administration
Request for Information: Spacecraft bus concepts to support the Asteroid Redirect Robotic Mission and In Space Robotic Servicing.

1. Introduction

NASA is formulating the Asteroid Redirect Mission (ARM) to advance technologies and gain operational experience critical for future human spaceflight beyond low Earth orbit. In 2014, NASA released a Broad Agency Announcement (BAA) to study concepts from industry in support of ARM pre-formulation activities. Eighteen study contracts were awarded in five areas: Asteroid Capture Systems, Rendezvous Sensors, Adapting Commercial Spacecraft, Partnerships Opportunities for Secondary Payloads, and Partnerships Opportunities for the Asteroid Redirect Crewed Mission. The robotic segment of ARM has successfully passed its Mission Concept Review (MCR) and baselined the robotic boulder capture options. NASA is now seeking additional information from industry on a range of spacecraft implementation approaches and procurement options that may achieve further cost savings.

ARM consists of three segments. (1) An observation component to identify and characterize potentially viable target asteroids. (2) The Asteroid Redirect Robotic Mission (ARRM) will use advanced Solar Electric Propulsion (SEP) technology, dexterous robotics and six degree of freedom proximity operations control to acquire a multiple ton asteroid boulder from the surface of a near-Earth asteroid (NEA) and redirect the mass into a stable distant retrograde orbit (DRO) in the vicinity of the moon. ARRM using SEP will also conduct a demonstration of one or more planetary defense techniques to inform future hazardous asteroid mitigation concept studies. (3) In the Asteroid Redirect Crewed Mission (ARCM), astronauts arriving on an Orion Multipurpose Crewed Vehicle will dock with the ARRM vehicle. The astronauts will perform extravehicular activities in the DRO to select and acquire samples of asteroid material.

ARRM will demonstrate high power SEP technology in translating to the target asteroid and to the DRO. SEP is a critical technology for future human spaceflight infrastructure. Future SEP vehicles may provide essential logistics and crew transportation capabilities for human and commercial operations in cis-lunar space and eventually Mars.

The ARRM spacecraft capture system and technologies also have synergies with future on-orbit spacecraft servicing capabilities. NASA is studying strategies and developing technologies for on-orbit robotic servicing capabilities for existing and future spacecraft. Such capabilities could be valuable for maintaining existing and growing commercial, governmental, and national security assets, thereby increasing the return on investment. As a demonstration of key technologies and capabilities, NASA is studying an In Space Robotic Servicing (ISRS) mission, Restore-L, which will use dexterous robotics and require six degree of freedom proximity operations control to capture and refuel a U.S. Government owned satellite in low earth orbit (LEO). Restore-L would bring to operational status the technologies needed for future commercial servicing of satellites in geosynchronous Earth orbit and other locations. The notional Restore-L spacecraft utilizes a chemical propulsion-based spacecraft bus. NASA is investigating methods to potentially increase synergy between Restore-L and ARRM leading to reduced overall cost, potentially increased return on investment, and to stimulate potential transition of ARRM and ISRS technologies to commercial use.

This is a Request for Information (RFI) only and does not constitute a commitment, implied or otherwise, that NASA will take procurement action in this matter. Further, neither NASA, nor the U.S. Government will be responsible for any costs incurred in furnishing this information.

2. Objective for Request for Information

NASA seeks information that would assist NASA in developing ARRM acquisition strategies, including increased potential synergy with the Restore-L mission concept. To that end, NASA seeks feedback on the feasibility and viability of the system concepts detailed below, including any suggested revisions. NASA also seeks information on ideas for potential collaboration or partnership.

3. Description of Reference Concepts

Current ARRM Concept:

In the current ARRM concept (shown as drawing 1 in Figure 1), the SEP Module has the following performance characteristics: 10,000 kg of xenon maximum storage, 58 kW of solar array power at beginning of life; 40 kW of electric propulsion (EP) power at 1 AU end-of-life; up to 24 kW of power transfer capability to any docked elements; an EP system using 12.5 kW thrusters, with a maximum specific impulse of 3000 s, a 6 year operational life; and, operability from 0.8 to 1.9AU. The ARRM spacecraft, known as the Asteroid Redirect Vehicle (ARV), also has the capability of being refueled for reuse after completion of joint ARRM/ARCM operations. The reference ARV fits within a 5-meter fairing and can be accommodated on a Space Launch System, Falcon Heavy, or Delta IV Heavy launch vehicle. While the reference configuration is capable of a 10,000 kg xenon propellant load, the actual mission required xenon propellant load would depend on the launch vehicle and the detailed mission design. Missions requiring xenon propellant loads of 5,000 kg or less exist, with a corresponding impact on the returnable mass from the target NEA.

Future Exploration Concepts:

It is critical that the ARRM design provide a cost-effective extensibility path to the spacecraft needed for future human spaceflight architectures. Extensibility may be accomplished at various levels from components to spacecraft. Spacecraft needed for future human exploration architectures to support human mission to the Mars system are envisioned to have 190 kW beginning of life solar array power (at 1 A.U.) of which 150 kW is allocated for EP, and about 16,000 kg of xenon propellant. The same xenon tanks, thrusters, power processing units, and solar array designs are envisioned to be used in both the ARV design and the future exploration design. The extension from the ARRM design to the future exploration concept comprises an increase in the number of units in these components. The design of the primary structure (and possibly the xenon tanks) may need to be different but it is the desire of the Government to establish a cost effective growth path to the future exploration concept vehicle.

Reduced Xenon Capacity ARRM Concept:

The reduced xenon capacity ARRM concept (depicted as drawing 2 in Figure 1) emerged from the recent ARM BAA work, and while it involves less propellant mass for the ARRM spacecraft, it retains substantial extensibility at a potentially lower cost. The reduced xenon capacity ARRM concept includes the same power, power processing and other capabilities as the reference concept, but with a reduced xenon propellant storage capacity. For example, as compared to the reference ARV design, the reduced xenon capacity alternative would still have a 58 kW solar array and a 40 kW EP system; the same type and number of solar arrays, thrusters, and power processing units; and the same reaction control subsystem. However, the xenon storage capacity for the alternative concept would be reduced to a maximum of 5,000 kg. The reduced xenon capacity alternative ARRM spacecraft would also be capable of being refueled for reuse after completion of ARRM/ARCM operations. Refueling may be accomplished by fluid transfer, addition/replacement of modular tank modules or through other means, and may allow extension toward a future exploration spacecraft.

Separable Spacecraft Architecture ARRM Concept:

NASA may also consider a separable spacecraft architecture ARRM concept (depicted as drawing 3 in Figure 1) if it can be cost effectively implemented for ARRM and Restore-L. As distinguished from the monolithic ARRM spacecraft concepts described above, the separable spacecraft architecture ARRM concept would consist of a two-spacecraft configuration, partitioning the spacecraft into a dedicated SEP vehicle or “tug” and a smaller Asteroid Capture Vehicle (ACV). This concept is envisioned to utilize the same EP elements (thrusters, power processing, and solar arrays) as the reference ARV and reduced xenon capacity concepts while providing flexibility in systems architecture and acquisition.

The following describes a notional operational timeline for a separable spacecraft architecture ARRM concept:

- The SEP vehicle and ACV mated and launched together
- The SEP tug transports the ACV to the target asteroid
- The ACV separates from the SEP tug, descends to the surface of the asteroid, collects a boulder, and ascends off the surface of the asteroid
- After the boulder collection, the ground commands the SEP tug to autonomously re-mate with the ACV. The SEP tug must be capable of returning to the lunar DRO without the ACV, if necessary.
- The SEP tug transports the ACV and asteroid boulder back to Lunar DRO
- The ACV separates again from the SEP tug
- The ARCM Orion spacecraft docks with the ACV and begins exploration of the boulder

System designs that permit the implementation of this timeline or other compatible mission architectures and operational approaches are desired for this RFI.

The ACV and the Restore-L servicing vehicle may be designed to have significant commonality, allowing for increased efficiency and cost savings in the development of the two vehicles.

Restore-L Dedicated Spacecraft Concept:

NASA has invested in development of on-orbit robotic servicing capabilities and conducted several studies which included prior market research to assess the feasibility, practicality, and cost of servicing satellites using elements of currently planned and future NASA human spaceflight systems and/or robotic technologies. Additional information on NASA's on-orbit satellite servicing capabilities can be found at http://ssco.gsfc.nasa.gov.

The proposed Restore-L Mission would use the Restore Servicing Vehicle (RSV), which consists of the government provided Servicing Payload (SP) and a commercial Spacecraft Bus (SB) to service a LEO polar-orbiting government owned satellite. The Restore-L SP and ARRM Capture Module exhibit a significant amount of commonality. Like the ARRM Capture Module, the Restore-L SP includes two 7-DOF robot arms, rendezvous and proximity operations sensors, and avionics. The SP also includes refueling tools and a Propellant Transfer Subsystem responsible for gaining access to the client propellant fill and drain valves and transferring hydrazine into the client satellite's propellant tanks which are not present in the ARRM Capture Module design. The ARRM Capture Module also contains the Contact and Restraint Subsystem (CRS) "legs" which are not present in the Restore-L SP concept design.

The current Restore-L dedicated spacecraft (shown as drawing A in Figure 1) concept has a chemical propulsion system only with no SEP. Addition of a reduced-performance version of the ARRM SEP system (shown as drawing B in Figure 1) could enhance the Restore-L mission (potentially allowing servicing of more client satellites), and introduce increased synergy between the two mission concepts, provided it does not significantly increase the combined cost of the two missions.

Summary of Reference Concepts:

Figure 1 shows comparisons of notional ARRM and Restore spacecraft options. The first column shows Restore-L configurations including a single-client chemical-only propulsion options (A), and a multiple client option with solar electric propulsion (B). The second column shows the alternative ARRM configurations.

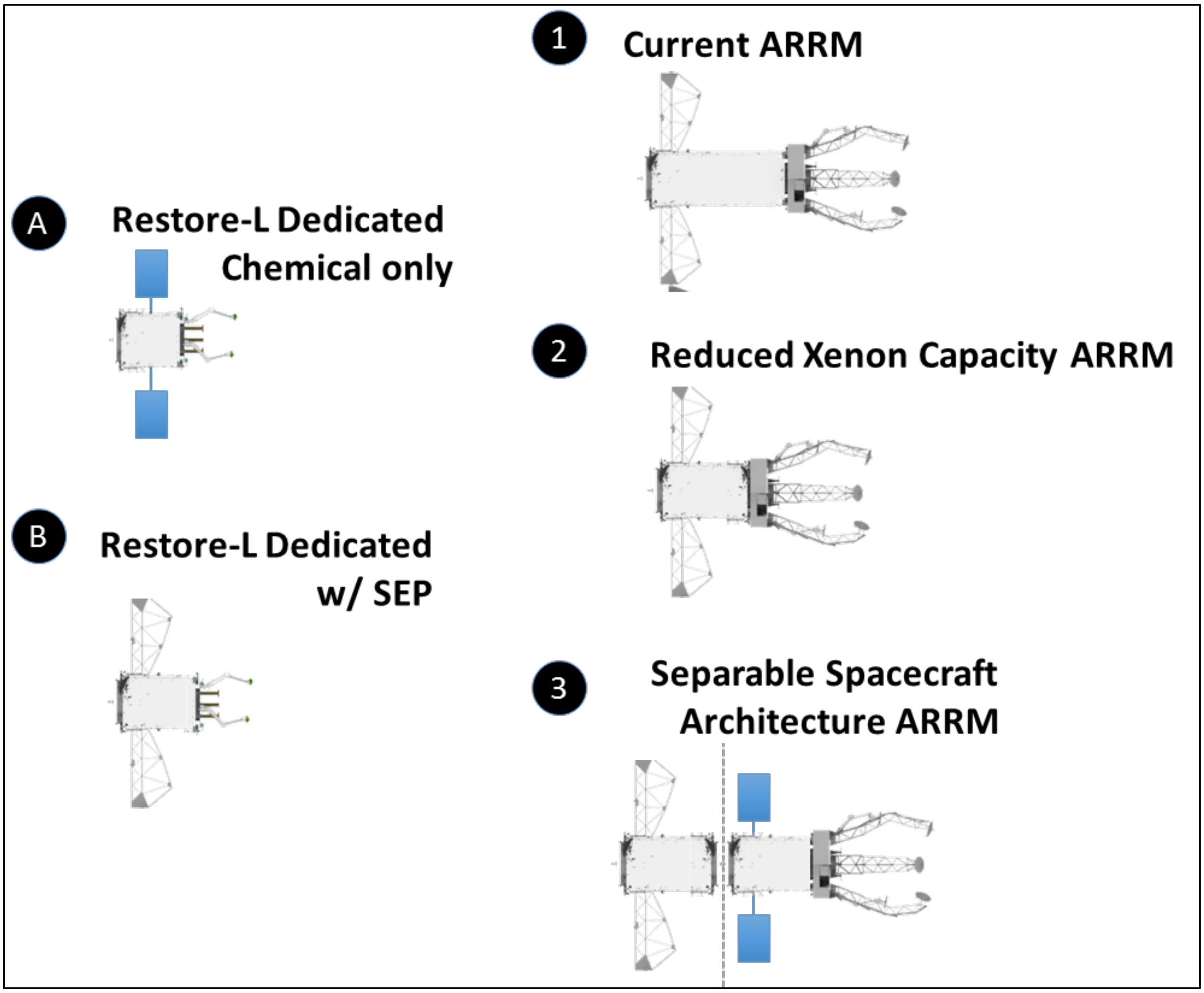

Figure 1 - Notional Restore-L and ARRM spacecraft configuration concepts

4. Description of Information Requested

RFI responses must include:

1. Respondent Information
   a. Name of Respondent;
   b. Respondent's address;
   c. Name and contact information for primary Respondent Point of Contact (POC), including POC's name, title (or affiliation with Respondent entity), email address, and phone number; and

d. General description of Respondent's capabilities and experience in the subject matter of this RFI.

RFI Questions:

The Government requests responses to the following questions:

1. Reduced Xenon Capacity ARRM concept:
   a. Describe your suggested approach to achieving the reduced xenon capacity alternative spacecraft bus concept, including the potential extensibility to NASA's goals. Include a rough order-of-magnitude (ROM) cost estimate, milestone schedule and list of benefits and technical challenges consistent with a December 2020 ARRM launch readiness date.
   b. Describe your suggested approach to evolving the reduced xenon capacity ARRM concept to the current ARRM concept and future exploration architecture concepts including ROM cost estimates.
   c. Discuss potential markets and alternative uses of this reduced xenon capacity ARRM concept beyond ARRM including commercial adaptation.
   d. Discuss procurement approach options, including potential for commercial partnership and cost sharing.
   e. Discuss, if applicable, any relevant, cost-effective system or subsystem-level technology demonstrations that should potentially be conducted in advance of the ARRM capability demonstration that might reduce technical risk for that mission or accelerate development of capabilities for future exploration architectures or commercial applications.

2. Reduced Xenon Capacity ARRM spacecraft common with Restore-L dedicated spacecraft:

a. Describe your approach toward utilizing a common SEP spacecraft for ARRM and Restore-L considering the reduced xenon capacity ARRM concept. Include OM cost estimates, milestone schedules and list of benefits and technical challenges consistent with a December 2020 ARRM launch readiness date.
b. Discuss the potential for a joint ARRM and Restore-L spacecraft procurement.

3. Separable Spacecraft Architecture ARRM concept:
   a. Describe your suggested approach to achieving a separable spacecraft architecture ARRM concept, including your suggested SEP tug and ACV approach. Include a ROM cost estimate, milestone schedule and list of benefits and technical challenges consistent with a December 2020 ARRM launch readiness date.
   b. Describe your suggested approach to evolving your SEP vehicle concept design to achieve the goals of the current ARRM concept and future exploration architecture concepts including ROM cost estimates.
   c. Discuss potential markets and alternative uses of the separable spacecraft architecture ARRM concept or any of its elements including commercial adaptation.
   d. Discuss the potential for partnership and cost sharing in development of the separable spacecraft architecture ARRM concept or any of its elements.
   e. Describe your approach for utilizing a common ACV and Restore-L dedicated spacecraft and the potential for a joint ACV and Restore-L spacecraft procurement.

Requests for Clarifications

The Government may or may not request follow-on discussion with one or more respondents, at the Government's discretion, to obtain clarification or additional detail of the material submitted.

Disclaimer

It is not NASA's intent to publicly disclose Respondents' proprietary information obtained in response to this RFI. 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.

It is emphasized that this RFI is NOT a Request for Proposal, Quotation, or Invitation for Bid. This RFI is for information and planning purposes only, subject to FAR Clause 52.215-3 titled "Solicitation for Information or Planning Purposes," and is NOT to be construed as a commitment by the Government to enter into a contractual and/or binding agreement. The Government will not pay for information submitted in response to this RFI. No solicitation exists; therefore, do not request a copy of the solicitation. If a solicitation is released, it will be synopsized in the FedBizOpps and/or NASA Acquisition Internet Service websites. It is the responsibility of any potential offerors/bidders to monitor these sites for the release of any solicitation or synopsis.

NASA may or may not contact respondents to this RFI, if clarifications are needed.

Responding to this RFI

An entity responding to this RFI must be a U.S. domestic entity.

How to Respond

All responses shall be submitted via e-mail to HQ-ARM-ISRS@mail.nasa.gov no later than forty (40) calendar days from the date of this RFI posting. Submissions must be received by 5:00 PM EDT on that date.

Files may be submitted in MS Word, PDF, or RTF format. Paper submissions will not be accepted. All responses shall be no more than seventy (70) pages including graphs, charts tables, illustrations, and other figures. A page is defined as one (1) sheet 8 ½ x 11 inches using a minimum of 12-point font size for text.

NO CLASSIFIED INFORMATION SHOULD BE INCLUDED IN THIS RFI RESPONSE.

Virtual Industry Day

NASA plans to host a teleconference on May 22 to answer questions and provide additional information about the RFI. Please see this page for details:
http://www.nasa.gov/feature/arm-spacecraft-bus-request-for-information

Point of Contact

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