**REQUEST FOR PROPOSAL:**
Design of An Autonomous Coulomb Vehicle for Interplanetary Missions

## I. OPPORTUNITY DESCRIPTION

As the national focus now shifts to returning to the moon, and going beyond to Mars, *performing fuel and power efficient* routine inspections of the inter-planetary spacecraft is of increasing importance. The cost of every extra pound of required propellant increases rapidly with the distance of the mission target. Similar free-flying autonomous robots to the AER-Cam[i] and mini-AerCam[ii] are envisioned that could perform various tasks in support of the crew and spacecraft. For example, routine external craft inspections can be performed during long missions if the devices have cameras and other sensors aboard. Further, these devices can support crew during EVA by either autonomously monitoring the activity or being remotely controlled by another crewmember. Current concepts of free-flying robots such as the AERCam and the mini-AERCam typically use cold gas jets to move the craft and control its orientation. This propulsion and control concept is mechanically very simple and reliable. However, it does consume a proportionally large amount of propellant. Cold gas thrusters have a specific impulse (fuel efficiency measure) ranging between 50–75 seconds. A novel propulsion concept called Coulomb propulsion exploits electrostatic forces between vehicles to control the relative motion. The electrostatic (Coulomb) forces can have specific impulses as high as $10^{10}$–$10^{13}$ seconds, many orders of magnitude better than cold gas thrusters. As a comparison, ion engines have fuel efficiencies ranging between 2000–10000 seconds. The Coulomb propulsion concept is a very clean method of generating inter-spacecraft forces because no ion-engine-like caustic plumes are generated, and thus is a very promising concept for tight relative motion control.

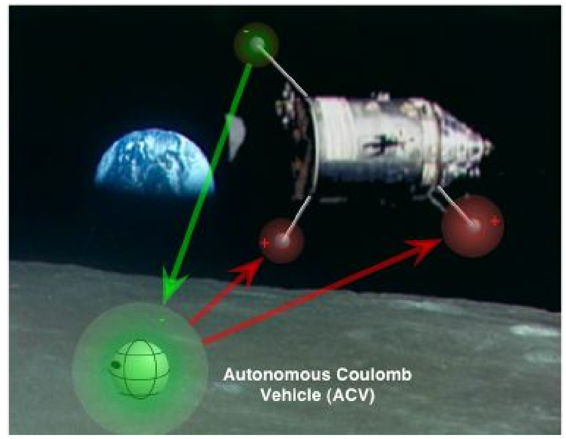


**Figure 1: Illustration of the ACV Concept**

The Autonomous Coulomb Vehicle (ACV) concept consists of a small, free-flying craft that is released from the mother-craft. The main craft has electric field generators extended out to strategic locations on booms. The extension boom will need to have specific dielectric properties to minimize differential charging levels across the structure and avoid arcing. By charging the ACV to a known voltage, the main craft charging devices can control the *relative motion* of the ACV as shown in Figure 1. The positive and negative charging devices on the mother-craft are controlled to attract and/or repel the ACV, thus controlling its relative motion. The magnitude of the resulting forces have been shown to be sufficient for relative motion control with separation distances ranging to at least 100 meters.[iii] Note that the Coulomb force generation is not viable in low Earth orbits due to the local space plasma environment properties. Electrostatic forces are absorbed by this plasma within a meter or two. However, for missions to the moon, orbiting about the moon, or under-way to

Mars, this mode of relative motion propulsion is feasible.

## II. PROJECT OBJECTIVE

The objective of this project is to produce a complete system concept design for an Autonomous Coulomb Vehicle (ACV). The design must provide, at a minimum, the complete spacecraft design, a spacecraft charging mechanism design for both ACV and the mother-craft, any sensors and internal actuators for attitude control, a docking system design, a power system, a metrology system, a communications system, and a command and data handling system. Design of the radio systems is not required for this project, but sizing the RF equipment and the required support subsystems (antennas, power, *etc*.) is required. The spacecraft charging behavior need not be described in detail; however, maximum required charge and voltage levels must be determined for the described maneuvers. If such system is feasible and valuable, there is a possibility that NASA could adopt it for autonomous spacecraft inspection missions. In any case, this project serves as a sound basis for investigating a variety of technologies associated with creating a Coulomb-thrusting based spacecraft.

## III. REQUIREMENTS AND CONSTRAINTS

The fundamental requirement is to develop a feasible system and to design the necessary hardware to enable the mission described in Section I.

The ACV must be deployable and retrievable from an inter-planetary spacecraft without using conventional thrusting.

Differential charging across the vehicle must be minimized to avoid arcing.

The ACV must be designed for a minimum three-year lifetime, long enough for a round trip mission to Mars.

## IV. DATA REQUIREMENTS

The proposal should

a) describe the system architecture;

b) explain from first principles how the design was chosen;

c) explain the launch vehicle selection process;

d) describe the type of attitude and relative motion control mechanisms to be used;

e) describe how the system will be deployed, including any deployment mechanisms to be used;

f) describe the power requirements and the power system design, including load, solar arrays, batteries, etc.;

g) describe how a typical mother-craft inspection mission will be operated;

h) describe the command and data handling system, including telemetry and data storage requirements;

i) include performance predictions;

j) describe the end-of-life disposal procedures; and

k) include cost estimates for production, deployment, and operations.

## VI. REFERENCES

[i] Fredrickson, S., "AERCam Sprint," http://vesuvius.jsc.nasa.gov/er_er/html/sprint/.

[ii] Fredrickson, S., "Mini AERCam," http://aercam. nasa.gov/.

[iii] Schaub, H., Parker, G. G., and King, L. B., "Challenges and Prospect of Coulomb Formations," AAS John L. Junkins Astrodynamics Symposium, College Station, TX, May 23-24 2003, Paper No. AAS-03-278.

These and additional references will be made available on course website.