REQUEST FOR PROPOSAL:

$2DM^2S^2$: Two-Dimensional Mass Motion Spacecraft Simulator

I. OPPORTUNITY DESCRIPTION

Research related to spacecraft formation flying has been of great interest to both NASA and the DOD over the past decade. Having several spacecraft flying together in formation can be useful in several applications, including interferometry, stereoscopic imaging, and distributed aperture systems. An important constraint for such systems is the precision determination and control of relative position of spacecraft within the formation.

One interesting concept for precision relative position control is described in Ref. 1. The author envisions using precise control of the motion of internal masses to change the position of the spacecraft mass center. Precise control of the internal masses can lead to extremely precise control of the spacecraft motion. For example, as the author notes, "if we move a particle of mass as large as 1% [of the spacecraft mass] over a distance of 1 cm, the motion of [the spacecraft in inertial space] is as small as a 1/10 of a millimeter." This type of control mechanism has not been used in spacecraft, and needs to be demonstrated in ground-based experiments. A two-dimensional simulator is sufficient to provide a meaningful demonstration

II. PROJECT OBJECTIVE

The objective of this project is to produce a complete system design that will serve as the basis for building an experimental apparatus to investigate the proposed control mechanism. The new simulator design, hereafter referred to simply as "2DS," must be as compatible as possible with the existing facilities in the Space Systems Simulation Lab (SSSL)[1] in Hancock 214. The primary relevant apparatus in the SSSL is the Distributed Spacecraft Attitude Control System Simulator (DSACSS). The DSACSS is described in some detail in Ref. 2, and Ref. 2 provides an historical background for simulators in general.

III. REQUIREMENTS AND CONSTRAINTS

The fundamental requirement is to develop a detailed design of a two-dimensional spacecraft simulator system with the following features.

- Three or more "spacecraft" must be able to move in the horizontal plane with minimal friction. The design should characterize the expected friction force and demonstrate that the friction forces have been minimized.
- Each spacecraft must have one rotational degree of freedom (about its vertical axis) and two translational degrees of freedom (*x* and *y* directions in the horizontal plane).
- The spacecraft must be able to move at least two meters in both horizontal directions and have be unrestricted in rotational freedom.
- The spacecraft must have sensors sufficient to determine absolute and relative position accuracy with a 2σ precision of < 1 mm.
- The spacecraft must have sensors sufficient to determine absolute and rela-

[1] The SSSL website includes extensive documentation of the lab facilities: http://www.aoe.vt.edu/research/groups/sssl/

tive attitude accuracy with a 2σ precision of < 0.1°.

- The spacecraft must have actuators sufficient to control the absolute and relative position accuracy with a 2σ precision of < 1 mm.

- The spacecraft must be able to communicate with each other as well as with a control computer.

- The entire 2DS shall have a footprint no larger than 4 m × 4 m.

- The 2DS shall include safety features such that the spacecraft cannot depart from the controlled space allocated for the spacecraft.

- The spacecraft shall include proof mass actuators capable of controlling the mass center location.

- The spacecraft shall include sufficient power and any other expendables to perform a one-hour experiment.

- The 2DS system shall meet all physical requirements for installation in Hancock 214 and be able to operate in normal indoor conditions.

- The 2DS system shall be as compatible as is reasonable with the existing Distributed Spacecraft Attitude Control System Simulator (DSACSS) in the Space Systems Simulation Lab in Hancock 214.

V. DATA REQUIREMENTS

The proposal should

a) describe in detail the system architecture;

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

c) define all mechanisms to be used, and give the basis for the belief that the chosen mechanisms will work;

d) describe how the experimental apparatus will be built;

e) describe the power requirements and the power system design, including load, chargers, batteries, and any required power electronics;

f) describe how a typical experiment will be conducted;

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

h) list the metrics that will be used to establish that the experiment was successful;

i) include performance predictions;

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

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

VI. REFERENCES

1. I. M. Ross, "Mechanism for Precision Orbit Control with Applications to Formation Keeping," *Journal of Guidance, Control and Dynamics*, Vol. 25, No. 4, 2002, pp. 818–820 (available at: http://www.aoe.vt.edu/~cdhall/courses/aoe4065/RossNote.pdf)

2. J. L. Schwartz and C. D. Hall, "The Distributed Spacecraft Attitude Control System Simulator: Development, Progress, Plans," 2003 Flight Mechanics Symposium, NASA Goddard Space Flight

Center, Greenbelt, Maryland, October 28–30, 2003 (available at: http://www.aoe.vt.edu/~cdhall/papers/FMS03.pdf)

3. J. L. Schwartz, M. A. Peck, and C. D. Hall, "Historical Review of Air-Bearing Spacecraft Simulators," *Journal of Guidance, Control and Dynamics*, Vol. 26, No. 4, 2003, pp. 513–522 (available at: http://www.aoe.vt.edu/~cdhall/papers/schwartzpeckjgcd.pdf)