CHALLENGE AREA 2: INNOVATIVE EXPLORATION APPROACHES

HUMMINGBIRD: DRAMATICALLY REDUCING INTERPLANETARY MISSION COST.

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System Summary: Microcosm, Inc. and NASA Ames Research Center (ARC) are working jointly on the development of a new class of very-low-cost, rapidly built interplanetary spacecraft, called Hummingbird. After the initial system design and development at a total cost of less than $8 million, subsequent Hummingbird spacecraft can be built in a few months for approximately $2 million each and new payloads or electronics can be introduced even after the spacecraft has been built.

The short time and low cost of fielding systems also allows the introduction of new technology much faster and at less cost and risk than would otherwise be possible and provides the opportunity to flight test the technology in Earth orbit, prior to committing to interplanetary flight. The key characteristics of Hummingbird are as follows:

- Resolution of approximately 30 cm from 100 km using an existing telescope
- Available in 2 configurations: (A) 75 kg spacecraft with 3 km/sec of delta V and (B) 130 kg spacecraft with 4 km/sec of delta V (other sizes also possible)
- 50 W (Config. A) or 75 W (Config. B) worst case orbit average power available (out to distance of Mars); bus uses <20 W
- Scan mirror available that can move FOV in pitch at 60 deg/sec
- Spacecraft roll by up to 180 deg in 6 sec (30 deg/sec)
- Several low-cost communications options available
- Attitude knowledge to 0.01 deg and pointing to 0.03 deg
- Can accommodate payload mass of up to approximately 30 kg and 40-50 cm diameter (heavier payloads result in lower total delta V available)
- Total recurring spacecraft cost, including visible light telescope payload, of approximately $2 million (depending on configuration)

The mission concept is especially applicable to Mars orbit missions and missions to Phobos and Deimos. Reducing the payload mass to 3-4 kg, Hummingbird has sufficient delta V capability for Mars rendezvous and for maneuvering around Phobos and vous and for maneuvering around Phobos and Deimos to gather science.

Hummingbird allows the potential to create a new type of rapid, very-low-cost interplanetary mission that responds to the global need for much lower cost space exploration. Multiple types of light-weight payloads can be accommodated, such as a visible light 9.25 inch aperture telescope, a near-IR spectrometer for gathering surface coposition information, a mid-IR camera for thermal investigation and to correlate features observed in visible bands, and a UV-visible spectrometer for dust and debris monitoring near the surface of the moons. Surface measurement payloads could include surface probes, such as cubesats and small sensors, such as temperature probes, cameras, antennas, and Langmuir probes to obtain mechanical and electrical properties. Multiple spacecraft configurations (with differing delta V, power, and communications) can be supported.

Hummingbird can be launched on a dedicated small launcher, as a secondary payload, or as a secondary payload on a host spacecraft. Moreover the low-cost design and development can allow multiple "scouts" equipped with complementary payloads on a single mission. Each spacecraft could gather independent science and engineering data to be processed on Earth. Rapid development and testing in Earth or near-Earth orbit allows for continuous, incremental improvement in our knowledge of the solar system and for the development of truly innovative approaches to interplanetary exploration.

Technical Approach: As shown in Figures 1 and 2, the Hummingbird spacecraft is a follow-on to the NanoEye very-low-cost Earth-orbiting spacecraft being developed by Microcosm for the U.S. Army. The spacecraft dry mass is 20 kg and it contains 50 kg of hydrazine propellant. (A larger version is also available.) A version using green propellant with a somewhat higher Isp will be available in the future. The Hummingbird optical payload is based on a 9.25-inch diffraction-limited telescope that weighs 2.95 kg and has been built and tested by ITT/Exelis, a leading manufacturer of precision space optics. The spacecraft bus components are rad-hard versions of cubesat electronics being developed by Innoflight. The propulsion system, which supports large delta V maneuvers, autonomous orbit control in Earth or planetary orbits

(previously flown and validated in LEO by Microcosm), and rapid attitude maneuvers, is based on 1 lbf thrusters that weigh 5.4 gm each and have been previously built and flown by Aerojet for the LEAP program. The 1-piece, all-composite unibody propellant tank and structure is built by Microcosm, and a structural model has been built and vibration tested to 10 g's on a prior SBIR Phase II. Several low-cost communications approaches are currently being evaluated. Thus, nearly all of the key components have been built and either flown in space or have been space-qualified, such that the performance, mass, and cost are well established.

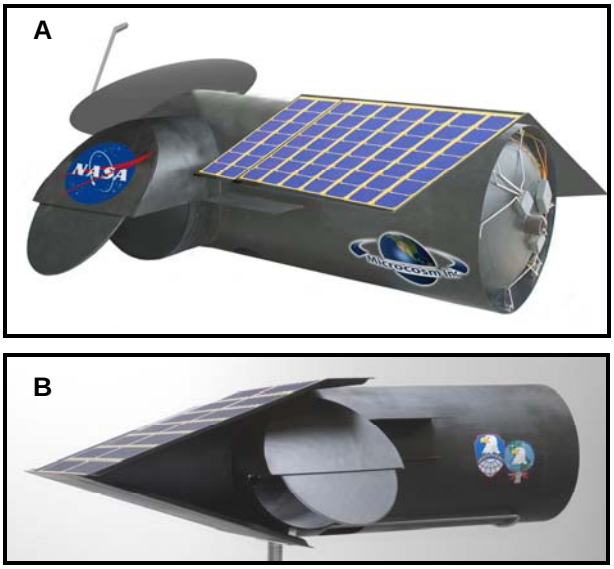

Fig. 1. Hummingbird and NanoEye Spacecraft. A. Hummingbird spacecraft configuration. B. Full-scale model of the Earth-orbiting NanoEye spacecraft on which Hummingbird is based.

The prime contractor for the program is Microcosm, a recognized leader in space mission and systems engineering with specific expertise in reducing mission cost and one of the principal originators of the "Reinventing Space" movement. Additional systems engineering and validation has been provided by NASA Ames Research Center. The baseline visible light payload is provided by ITT Exelis, although many different payloads can be accommodated. The spacecraft bus components are primarily from Innoflight and the propulsion system from AeroJet. The advanced unibody bus construction is provided by Scorpius Space Launch Company, a sister corporation to Microcosm and a world leader in advanced composite systems for launch vehicle and space applications. Low-cost approaches to ground control and data dissemination are also available, leveraging the current mission operations center at ARC developed for the LCROSS, Kepler, IRIS, and LADEE missions. This team has both the experience and the expertise to create spacecraft that meet the needs of the interplanetary science community at dramatically reduced cost. Hummingbird has the potential to significantly change the way we do business in space and responds directly to the national need to significantly reduce interplanetary mission cost in the near term.

Fig. 2. The NanoEye structural test model, successfully vibration tested by ITT Exelis.