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Fully Autonomous Navigation for the NASA Cargo Transfer Vehicle

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ABSTRACT

A great deal of attention has been paid to navigation during the close approach (≤ 1 km) phase of spacecraft rendezvous. However, most spacecraft also require a navigation system which provides the necessary accuracy for placing both satellites within the range of the docking sensors. The Microcosm Autonomous Navigation Systems (MANS) is an on-board system which uses Earth-referenced attitude sensing hardware to provide precision orbit and attitude determination. The system is capable of functioning from LEO to GEO and beyond. Performance depends on the number of available sensors as well as mission geometry; however, extensive simulations have shown that MANS will provide 100 m to 400 m (3σ) position accuracy and 0.03° to 0.07° (3σ) attitude accuracy in low Earth orbit. The system is independent of any external source, including GPS. MANS is expected to have a significant impact on ground operations costs, mission definition and design, survivability, and the potential development of very low-cost, fully autonomous spacecraft.

Because MANS uses on-board attitude sensing hardware, the additional cost for achieving autonomous navigation will be quite low. A single sensor measures the spacecraft attitude as well as the range to the Earth and the relative positions in the spacecraft sky of the Sun and Moon, thus eliminating or reducing many of the principal bias terms which drive attitude and orbit sensing accuracy. MANS is also capable of accepting data from a range of other sensor types (star sensor, GPS receiver, gyros, and accelerometers) and using this data to further enhance its performance. The sensor data is used to provide position and velocity (orbit) data as well as Earth-referenced attitude. MANS outputs the following data at 250 msec intervals:

- Position and velocity
- Attitude and attitude rate (Earth referenced or inertial)
- Sun vector in spacecraft coordinates
- Ground lookpoint of any spacecraft sensor
- Vector in spacecraft coordinates to another satellite whose orbit is known (requires implementation of minor upgrade)

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MANS incorporates a high-fidelity force model which includes high-order geopotential effects, solar/lunar gravitational disturbances, solar radiation pressure, and atmospheric drag. Multiple data checks are executed to ensure the integrity of the output solutions. The software is written entirely in Ada and can reside in either the sensor processor or a flight computer.

The Microcosm Autonomous Navigation System was developed under contract and both flight hardware and software have been delivered. Flight system development began in mid-1989 and was completed in August, 1991, with on-orbit testing expected in late 1992. A ground-based simulation of MANS was developed concurrently and tests are being made to evaluate system performance in a variety of orbit conditions.

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