ON-BOARD ORBIT PROPAGATOR USING KUSTAANHEIMO-STIEFEL ELEMENTS FOR MARS MICRO ORBITERS

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Introduction: Economization of the small satellite systems becomes essential especially for planetary and small body orbiters. The quality of the payload and the dimensions of the spacecraft subsystems including Attitude and Orbit Control (AOCS), Power, Thermal Control and Communications are mutually dependent. Mars orbiting missions have long phases of non-communication with Earth and use non-GPS orbit navigation. A competent level of autonomy should be achieved in the on-board navigation and guidance software which eventually affects the performance and quality of the AOCS subsytem. The integral part of the navigation and guidance software is the on-board orbit propagation algorithm. Although widely used, numerical integration algorithms for orbit propagators with complex force models are expensive in terms of memory allocation and power consumption, and not suitable for implementation in small and low-cost spacecrafts. In view of the stringent memory and power budget, a simple and robust propagation flight software becomes essential and analytical methods come handy with closed-form solution which can be evaluated to high accuracy comparable to numerical integration algorithms.

KS Element Orbit Propagator: The major perturbing forces affecting the motion of the satellites around Mars are the oblateness, atmospheric drag, and third-body attraction from its satellites and the Sun. The main perturbations outside the low altitude atmosphere of Mars are the solar gravity and the planetary oblateness effects. Due to the non-linear nature of the classical Newtonian equations of motion, during spacecraft close approaches to the central body, they exhibit singularities and are unstable for long-term orbit propagation. Using regularization method due to Kustaanheimo and Stiefel (KS), linear differential equations of a harmonic oscillator with constant frequency is obtained and extended to perturbed motion. KS regular equations of motion can be used to produce singularity-free analytical solutions. The equations are smoothed for eccentric orbits and generalized eccentric anomaly is the independent variable. In the present study, a new analytical solution concurrently with numerical integration algorithm is developed in terms of KS regular elements with solar gravity perturbation and oblateness of the Mars. The algorithm utilizes an analytically computed areocentric solar coordinates and second zonal harmonics (J_2) of Mars.

Conclusion: The analytical solutions will be compared with the numerically integrated values. The elegance of the analytical solution is the existence of symmetry between the equations of motion which allows solving of only two out of nine equations while the rest are solved by altering the initial conditions, instead of six. The symmetric characteristics of the KS element equations will reduce the computational time, and the on-board memory requirement is minimized considerably due to simple transcendental function addition and subtraction operations. The major applications include development of on-board orbit propagation algorithms, and mission analysis for small spacecraft missions about Mars.