Deorbit Maneuver Strategy For The Three THEMIS Probes

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Keywords: Multi-spacecraft mission, automated orbit design, THEMIS, deorbit maneuver

The *Time History of Events and Macroscale Interactions during Substorms (THEMIS),* a NASA Medium Explorer (MIDEX) mission, was launched in February 2007 as a scientific magnetospheric constellation of originally five spacecraft, called *probes*. Probes carry an identical suite of particle and field instruments as well as a hydrazine based propulsion system. In 2009 the mission was split into two missions by transferring two probes (P1,P2) into lunar orbits forming the new *Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS) mission*. Both missions are operated from the Mission Operations Center of the University of California at Berkeley in principal investigator mode. Subject of this paper is our deorbit strategy for the three THEMIS probes (P3, P4, P5) orbiting Earth near the equatorial plane. The mandatory deorbit maneuvers have always been integrated in the orbit design and are estimated by taking advantage of luni-solar perturbations.

As previously reported, THEMIS has utilized its fuel reserves to greatly enhance its science return by frequently redesigning the orbits based on most recent observations. Provided future extended mission phases past 2020 are granted the anticipated plans are ambitious and the mission will finally expedite its onboard propellant while fulfilling the reentry requirement. For our long term planning it is essential to design a reentry maneuver that is a robust estimate regardless of varying orbit redesigns.

By 2020 the three probes will align in a highly elliptical orbit with apogee at 13.2 Re and perigee at 1.18 ±0.11 Re. and remain there in a close string-of-pearls formation for unspecified time. Reentry from such an orbit is ensured by lowering perigee. In order to integrate a reentry maneuver into our automated mission design we analyze the evolution of past and predicted perigee altitudes of the THEMIS probes and relative positions to Sun and Moon. The dynamic of the perigee altitude profile is the result of the combined effects of luni-solar and drag forces as well as the Earth's oblateness and thus significantly varies with different orbit redesign scenarios. In this paper we present results from our analysis which vary for each probe even on similar orbits. As our solution of a robust reentry maneuver, we demonstrate that a maneuver of fixed size can be executed any time in order to initiate reentry later. We describe how the size of this maneuver can be derived from the minima of perigee altitudes which occur on these orbits approximately once every five to six years.

It is our believe our analysis contributes to studies of the luni-solar effects proposing their exploitation to either avoid premature reentry or to optimize deorbit maneuvers, and its implementation into our automated mission design supports the trend towards operating swarms of satellites on a low budget.