INNOVATIVE THEMIS EXTENDED MISSION DESIGN AND IMPLEMENTATION TO ACHIEVE CROSS-SCALE MAGNETOSPHERIC CONSTELLATION

S. Frey [(1)], V. Angelopoulos [(2)], M. Bester [(3)]

[(1)(3)] *Space Sciences Laboratory, University of California, 7 Gauss Way, Berkeley, CA 94720-7450, (1) phone: 510-643-9880, email: sfrey@ssl.berkeley.edu,(3) phone: 510-643-1014, email: mbester@ssl.berkeley.edu*

[(2)] *ESS/IGPP, University of California, Los Angeles, 405 Hilgard Avenue, Los Angeles, CA 90095-1567 Phone: (310) 794-7090, Email: vassilis@ucla.edu*

Keywords: *Mission design, THEMIS, magnetospheric constellation, maneuver planning*

ABSTRACT

The *Time History of Events and Macroscale Interactions during Substorms (THEMIS),* a NASA Medium Explorer (MIDEX) mission, was launched in February 2007, and is a magnetospheric constellation of originally five spacecraft, called *probes*. Three of these probes (P3, P4, P5) are currently still operating in Earth orbit while the other two probes (P1, P2) have been transferred into lunar orbits forming the new *Acceleration, Reconnection, Turbulence and Electrodynamics of the Moon's Interaction with the Sun (ARTEMIS)* mission.The combined THEMIS/ARTEMIS mission has been an important component of the Heliophysics Observatory, a global constellation of multiple international missions to study the space environment of the Earth and its dynamical response to external and internal influences. Currently underway are simultaneous measurements of electric and magnetic field and plasma parameters from the three well-spaced THEMIS probes, the four spread CLUSTER satellites and the pair of the Van Allen Probes with the goal to develop empirical models of the geoelectric field and the radiation belts in particular. At the same time measurements of the solar wind by WIND, ACE, and ARTEMIS provide the global scale of the geomagnetic impact of solar activity.

In the near future, the Magnetospheric Multiscale (MMS) NASA mission will join in to use Earth's magnetosphere as a laboratory to study the microphysics of three fundamental plasma processes: magnetic reconnection, energetic particle acceleration, and turbulence. These processes occur in all astrophysical plasma systems but can be studied in situ only in our solar system and most efficiently only in Earth's magnetosphere, where they control the dynamics of the geospace environment and play an important role in the processes known as "space weather. The four identically instrumented MMS spacecraft will be separated by rather small inter-spacecraft distances. The launch of MMS is currently scheduled for late 2014. Combining these spacecraft with the THEMIS probes in a tetrahedral alignment at small to meso-scale separations will create excellent opportunities to conduct magnetospheric studies within an unprecedented constellation.

In this paper we like to report on our recent efforts to contribute to the Heliophysics observatory by using our significant remaining fuel resources while maintaining the ability to fulfill the end-of-mission requirement. We will describe the variations of the relative positioning of the three THEMIS probes to support measurements in coordination with the Van Allen Probes to study radiation belt physics, and we will outline our long term strategy to optimize the very unique opportunity of the cross-scale THEMIS-MMS conjunctions (Figure 1). In 2016 and 2017 the THEMIS orbits will be again crossing the magnetotail during the northern hemisphere winter time while again in conjunction with the Ground Based Observatories in the North American

polar region. The challenge here is to leave room for adjustments to the eventual launch of MMS in order to preserve good quality lineups.

The THEMIS probes are equipped with onboard propulsion systems that are utilized to perform orbital changes and to maintain attitude as well as spin rate within the science requirements. With the mission progressing into its 7th year the fuel reserve and exciting science opportunities become more and more a particular challenge to the orbit design as we also have to ensure re-entry at the end-of-mission. The future plans call for large orbit raises of multiple Earth radii and maneuvers have to be planned carefully to mitigate arc losses by properly timing of the intended orbit change. In this paper we will describe how we address conservative fuel consumption by combining long term goals with near term requests.

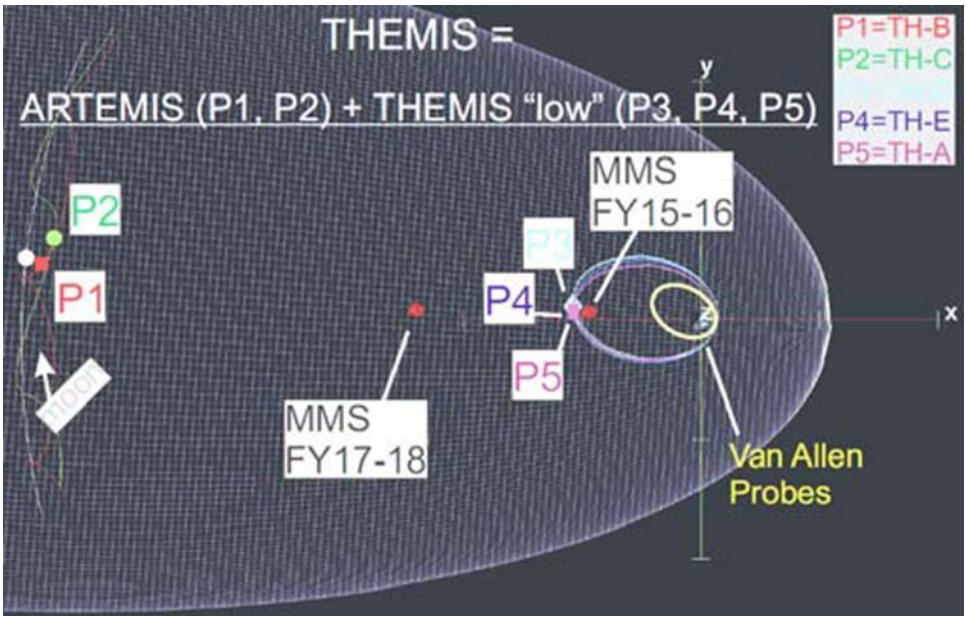

Figure 1: *THEMIS (P3-P5), ARTEMIS (P1,P2), and Van Allen Probes shown in their projected orbits in 2015-16 along with MMS, and in 2016-17-18 with apogees raised further for MMS to25 RE and for THEMIS to13-16RE (not shown) to create resonant orbits with MMS.*