Strategic RFA #10: Interdisciplinary Studies in Support of the Vision for Space Exploration

Overview. Interplanetary space is a dangerous place for humans, and for sensitive technology and other assets, primarily because of dynamic events originating at the Sun. Coronal Mass Ejections, or CMEs, are the best-known and most dramatic of these, ejecting large clouds of magnetized plasma and producing high energy particles and radiation. In the near-Earth environment these interact with the Earth's own magnetic field, producing what has been called "space weather," a term that does not do justice to the violence and danger of the phenomenon. Solar eruptions likewise propagate these dangers into the space between planets.

A human presence in space requires both an ability to predict the occurrence of these dangerous events and to take protective measures in response. Some progress in detection has been made in recent years, primarily from instrumentation in space that detects events when they occur and that measures them as they approach the Earth. Satellites such as SOHO and TRACE have shown that understanding the global magnetic configuration is key to any predictive capability for eruptive events. The next round of solar satellites – Solar-B, STEREO and SDO – will greatly improve our detection capabilities, and will help us to understand the large-scale global properties of the solar atmosphere which lead to these eruptions.

What is missing in NASA's current planning is a mission designed to reach an understanding of the energy release process itself. The solar corona is dynamic because it is a hot magnetized plasma rooted in a turbulent solar surface. We now know that eruptions such as CMEs are driven by both the large-scale configuration in the corona and by a highly localized small-scale process that allows the energy stored in the corona to be released. Improved forecasting depends on an understanding of this energy release mechanism, and this requires that we observe the fundamental scale at which magnetic fields energize matter in the solar atmosphere. None of the presently planned missions has the capability to observe the Sun at these scales.

The Driver of CMEs. The technology exists to attack the problem of resolving the genesis of the Sun's explosive activity. The Reconnection and Microscale (RAM) Solar-Terrestrial Probe, resolves the energy release sites in the corona and includes an ability to locate the source of high energy radiation and particles in the Sun's atmosphere. RAM is designed to understand the drivers of coronal dynamics leading to flares, coronal mass ejections and high-energy particles in the interplanetary medium. This is accomplished via an interdisciplinary combination of cutting-edge instrumentation, coordination with other heliospheric and geoterrestrial missions and highly advanced modeling of both hot (solar corona) and cool (terrestrial magnetosphere) magnetized plasmas. Ideally, the results of this intensive research would be the discovery of standardized indicators – for instance, a localized reconnection process that precedes an eruptive event – that could be deployed in an operational manner for routine forecasting.

RAM attacks the problem of coronal energy release head-on, with a bold advance in both detection and analysis capabilities. By utilizing recent cutting-edge advances in soft X-ray imaging and detection technology, it is now possible to propose a mission that images coronal dynamics at a spatial resolution approaching 0.01 arcsec – 25 times better than any coronal observations to date – and also to detect X-rays with imaging arrays which provide high resolution spectra at each pixel. The combination of instruments planned for the RAM Probe provides a breakthrough in observational capability that enlarges the discovery space for studies of coronal dynamics by orders of magnitude.

The Strawman payload for RAM consists of: an ultra-high resolution X-ray imager (HRI) with 0.02 arcsec resolution and 8Kx8K detector; a context imager (ISI) with 0.1 arcsec pixels and moderate-sized field of view; a high-throughput UV/EUV imaging spectrograph with 0.1 arcsec pixels and ISI field of view; an X-ray calorimeter array (XRC) with 100X100 elements, and a hard X-ray imaging telescope to detect the presence of flare energetic particles. Continuous contact from a geostationary orbit provides the required data rate to the ground, and a substantial data analysis and modeling plan permits the crucial interactions between observation and theory which will produce the major advances in understanding and predicting dynamic events in the solar atmosphere.

The Broader Context. The RAM Probe is complementary to missions designed to study the cooler magnetized plasma around the Earth. Together with missions such as MMS, we will comprehend the dynamics of the plasmas most directly relevant to life on Earth and in near-Earth space. The RAM Probe additionally provides a tremendous breakthrough in our understanding of fundamental astrophysical processes. Magnetized plasmas are implicated in many of the most energetic and dynamic phenomena that have been observed, from the solar corona and the Earth's magnetosphere, to active galactic nuclei and black hole binaries. Particles are accelerated to high energies by shock waves and magnetic reconnection, and both processes involve the small spatial scales that RAM will detect. Insights obtained from high resolution studies of the solar corona are directly relevant to the interpretation of high energy phenomena in the broader astrophysical context. We study the Sun because it is the driver of space weather near the Earth and also because models developed in the solar context are prototypes for explaining magnetic activity throughout the universe.

Submitted by: Drs. L. Golub and E. DeLuca, Smithsonian Astrophysical Observatory
Dr. P. Martens, Montana State University
Dr. S. Antiochos, Naval Research Laboratory