Story - Technology (text only)

Innovation is the engine that drives scientific progress, through development of new theories, formulation of new mission scenarios, and invention of new technologies that lead to improved measurements or new mission capabilities. NASA is therefore intimately connected with technology, both in terms of enabling and enhancing technologies that are at the heart of mission concepts, and because of the impact of space weather on mission safety and the global technological infrastructure. Space weather affects manned and unmanned exploratory missions both within and beyond the solar system.

Continuing the study of the Sun-Solar System Connection (SSSC) will require technological development in a number of key areas. Future SSSC technology needs are driven by the requirement to sample space plasmas at multiple points simultaneously (with missions such as MMS and Magcon), to improve measurement resolution and coverage in order to answer specific scientific questions, to achieve high delta-V orbits (for example, to escape from the solar system or to enter a polar heliocentric orbit), and to develop and/or incorporate relevant new technologies into instrumentation, data visualization, communication, and analysis systems. These steps are necessary in order to obtain, analyze, assimilate, and visualize complex data sets, which in turn lead to more sophisticated and accurate predictive models. For these reasons, technology development that enables or enhances our efforts to study the Sun-Solar System Connection is an important part of our strategic plan.

Future SSSC technology needs can be broken down into several focus areas:
1. High delta-V propulsion;
2. Development of compact, low-cost spacecraft and launch systems;
3. Visualization, analysis, and modeling of solar system environments;
4. Designing, building, testing, and validating the next generation of SSSC instrumentation;
5. Returning and assimilating large data sets from throughout the solar system.

Examples that demonstrate how progress in these areas contributes to furthering key SSSC objectives are provided below.

High Delta-V Propulsion

A number of SSSC missions will study solar system plasmas from unique vantage points. For example, missions have been planned to examine the sun from a polar perspective, and to leave the heliosphere to study the interaction between plasmas in the solar system and the interstellar medium. Propulsion systems that can supply a larger delta-V than conventional rocket engines are required to carry out such missions. Studies have shown that for the combination of low payload mass and orbit requirements being considered, solar sails are an ideal choice. Ground based demonstrations of solar sail subsystems have taken place over the last few years, and plans are being made to undertake a flight demonstration of a 40 meter solar sail system that would provide all the necessary data to enable solar sails to be used operationally. Following this flight demonstration the first science missions (e.g. Heliostorm and Solar Polar Imager) would require sails in the 100-150 meter class. It is interesting to note that Japanese sounding rocket experiments carried out in 2004 have already demonstrated some aspects of this promising sail technology with smaller class sails.

*Solar sail discussion goes here.

Development of Compact Low-Cost Spacecraft and Launch Systems

Because of the complexity and large scale of solar system plasmas it is often necessary to study them with clusters or constellations of spacecraft making simultaneous multi-point measurements (e.g., Inner Heliospheric Sentinals, MMS, Magcon, and GEC). For multi-spacecraft missions enabling and enhancing technologies include the development of low mass, power, and volume (MPV) instrumentation as well as low mass, economical spacecraft. These two developments are linked in the sense that smaller, better integrated spaceflight instrumentation packages (perhaps developed from the outset using a systems approach rather than a PI-driven approach) could be accommodated on smaller, less expensive launch platforms.

Well over half of most mission costs are associated with launch vehicle procurement and launch operations, and little pressure has been brought to bear to curtail these costs. This trend is particularly alarming given the prospect of flat or declining budgets for space exploration, because the combination of fixed price programs and rising launch costs effectively stifles the innovation that fuels scientific progress.

*There is much more to be said here - anyone care to contribute a specific example to help make the case? For example, if large mission launch and operational costs could be reduced by 15%, how many more millions would become available per year to fly other missions, or to improve existing measurements? I don't know these numbers, but I suspect they are large.

Visualization, Analysis, and Modeling of Solar System Environments

One of the most exciting recent technological advances is in the field of advanced supercomputing for model development and innovative new technologies for data analysis and visualization. Examples include NASA's Information Power Grid, a joint effort between government, academia, and industry to provide large scale, distributed computing resources to the scientific and engineering communities. Another noteworthy example, the Columbia supercomputer, uses 10,240 Intel Itanium 2 processors and provides an order of magnitude increase in NASA's computing capability.

One of the great challenges faced by current and future NASA missions is visualization of multiple vector and scalar quantities measured by many spacecraft in a simultaneous, coherent fashion. The VisBARD project, funded by NASA's Applied Information Systems Research Program, was developed to meet this need.

Space science data are displayed three-dimensionally along the orbits which may be presented as either connected lines or as individual points. The data display allows the rapid determination of vector configurations, correlations between many measurements at multiple point, and global relationships. Events such as vector field rotation and dozens of simultaneous variables that are difficult to see in traditional time-series line-plots are easily visualized with this tool.

Insert Neil's figures

An example of this is shown in the figure with data from the Helios 2 spacecraft orbiting the Sun. The symbols on the orbit show that the plasma becomes colder (smaller symbols) and denser (blue and green) where the wind slows (colored arrows) and the magnetic field changes direction (blue arrows) The change in the field direction in this sector boundary region is quite complex, and is very difficult to visualize using line plots.

Designing, Building, Testing, and Validating the Next Generation of SSSC Instrumentation
Many of the missions needed to pursue future SSSC goals will require the development of new scientific instrumentation. While most required measurements can currently be made by existing flight instruments, these instruments are often larger and more power-hungry than can be easily accommodated by future missions. There are also important advances needed in specific areas. Examples include large focal plane arrays, large scale adaptive optics, true solar-blind energetic particle detectors, and instruments capable of directly measuring plasma neutral interactions (e.g., collision frequencies).

Spaceflight instrumentation can only be developed through complex processes that include formulation of new designs (perhaps based on technologies developed in other fields), fabrication of engineering test models, laboratory testing, and finally flight validation. Of these steps the last two are the most costly and time consuming, largely because of the specialized equipment required. In order to continue to lead the world in space science research, NASA must support the development and maintenance of space-quality test facilities, including those capable of simulating the particle and radiation environments encountered during spaceflight missions. For some of these applications, NASA's low-cost access to space (LCAS) program provides an ideal avenue for testing and validation. A prime example of this paradigm is the development of top-hat style energetic particle detectors. These were first conceived for studies of the Earth's auroral regions, and were first flown on sounding rockets. Their successes in this area led directly to the instruments flown on the highly successful FAST mission. Radiation test facilities will become particularly important as ongoing technological innovations and the push to develop more power efficient instruments results in smaller electronic instrumentation.

A wealth of new technologies have been developed in the last decade, some of which may have applications in the development of newer and better space science instrumentation. For example, the incredible shear strength and impressive electronic properties of carbon nanotubes may lead to the development of stronger, lighter materials and more power efficient ionization sources. The continuing development of conductive polymers and other exotic new materials and coatings may well pave the way for the development of sorely needed new instruments like solar blind particle detectors, new and better cometary dust analyzers, and miniature mass spectrometer systems. Such systems are crucial for measuring, understanding, and assessing the impacts of the solar system environment on future manned and unmanned exploratory missions, but they cannot be developed without strong support for technological innovation and assimilation.

Returning and Assimilating Large Data Sets from Throughout the Solar System
* We need help here.!