

Introduction

The present generation of space researchers has inherited a bountiful legacy from the exploratory missions and discoveries of earlier decades. Our own success in conducting a robust program of exploration at new scientific frontiers will leave to future generations a similar gift of achievement and inspiration. Because the purpose of exploration is to understand the unknown, the precise benefits of their future space research and their path to success defy detailed prediction. We do know that progress will require constant adaptation to exciting diversions and new directions.

Building on this successful history of exploration, we now seek to transform human understanding of this fascinating system of systems that are so closely connected. The Bastille Day solar storm of 2000 and the Halloween storms of October and November, 2003 first demonstrated the power of gathering measurements of such disturbances from all across the solar system for understanding these linked systems. The totally unprecedented quickness of the onset of the extremely intense particle radiation event on January 20, 2005 demonstrated both the importance of and deficiency in our predictive knowledge. We will not only develop a predictive capability to address hazards to space travelers and important technological assets closer to home, but we will also learn how the interplay of fundamental space processes affects the habitability of other distant environments. The SSSC strategic plan for the future consists of three encompassing scientific and exploration objectives:

Open the Frontier to Space Environment Prediction – *Understand the fundamental physical processes of the space environment – from the Sun to Earth, to other planets, and beyond to the interstellar medium.*

The Sun, our solar system, and the material universe consist primarily of plasma, resulting in a rich set of interacting physical processes and regimes, including intricate exchanges with the neutral environment. We will encounter hazardous conditions on our return to the Moon and our journey to Mars. We must develop a complete understanding of the many processes that occur with such a wide range of parameters and boundary conditions within these systems.

As the foundation for our long-term research program, we plan to develop a complete understanding of the fundamental physical processes of our space environment—from the Sun to the Earth, to other planets, and beyond to the interstellar medium. We will systematically examine similar processes in widely different regimes with a range of diagnostics techniques to both test our developing knowledge and to enhance overall understanding. The universal themes of energy conversion and transfer, cross-scale coupling, turbulence and nonlinear physics have been chosen as priority targets. The fundamental processes that have been identified as the critical immediate steps are: magnetic reconnection, particle acceleration and transport, the generation and variability of magnetic fields, cross-scale coupling across boundaries and large structures, and nonlinear energy and momentum transport and coupling in atmospheres. Both *in situ* and remote sensing observations will be required, providing a three-dimensional large-scale perspective as well as a detailed small-scale microphysics point of view. With our increasingly sophisticated understanding of such basic processes, we will open the frontier of predictive modeling across the solar system.

Understand the Nature of Our Home in Space – *Understand how human society, technological systems, and the habitability of planets are affected by solar variability and planetary magnetic fields.*

Humankind does not live in isolation; we are intimately coupled with the space environment through our climate, our technological needs, the habitability of the planets and the solar system bodies we plan to explore, and ultimately the fate of our Earth itself. We regularly experience how variability in the near-Earth space environment affects the activities that underpin our society.

We plan to better understand our place in the Solar System by investigating the interaction of the space environment with the Earth and the effect of this interaction on humankind. Building on our new knowledge of fundamental processes, we plan to characterize and develop a predictive knowledge of the impact of the space environment on society, technology, and our planet. This will be accomplished both by direct investigation of the local environment and by what can be learned about life on Earth through studying other environments. We must understand the origins and history of solar activity, how disturbances propagate from Sun to Earth, the development of terrestrial responses to space weather, and the climatic response to solar variability. Human life and society provide the context in which these investigations are conducted.

As we extend our robotic and human presence throughout the solar system, we will be increasingly interested in the planetary environments that await us and how the lessons learned can be applied to our home on Earth. A casual scan of the solar system is sufficient to discover that habitability, particularly for humankind, is a rare congruence of many events. At least some of these factors, especially the role of magnetic fields in shielding planetary atmospheres, are a subject of immense interest. We believe we know some of the features that make planets habitable, but there is much more to be understood.

Safeguard Our Outward Journey

The great variety of space environment conditions will have a significant impact on our future space explorers, both robotic and human. We plan to pursue, with all due vigilance, the research necessary to assure the safety and the maximum productivity of our explorers. We plan to develop the capability to predict space environment conditions from low Earth orbit to the Moon and Mars. Addressing space weather issues is necessary for optimizing the design of habitats, spacecraft, and instrumentation, and for planning mission and operations scenarios, ultimately contributing to mission success.

Building on our knowledge of fundamental processes, we plan to understand those aspects of the space environment essential for enabling and securing space travel. Good engineering data is already flowing into exploration-oriented planning and implementation because the Sun-solar system community knows how to explore useful scientific directions. Our space plasma research community is poised to provide the next generation of measurements, simulations and models that will be useful to the implementation of manned and robotic missions to the Moon, Mars, and other planetary

bodies. Such parameterizations of the space environment will be essential inputs for solutions to the challenging engineering problems that must be solved for successful and economical exploration activities.