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ROADMAP OF SOLAR-TERRESTRIAL PROGRAMS IN THE USA

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ABSTRACT

During the past decade the world solar physics community has made significant progress in understanding the Sun and its interaction with the heliosphere and Earth's magnetosphere. NASA in coordination and cooperation with many other countries has had impressive results with the SOHO, YOHKOH, POLAR, GEOTAIL, etc spacecraft. These successes have given us a sound foundation to proceed into the new century. The two current main efforts in the U.S. are the Solar Terrestrial Probes (STP) and Living With A Star (LWS) programs. The STP program is basically science driven with new missions being selected on the basis of basic science discovery. The LWS program is focused on understanding the basic physics of solar variability and its effects on Earth systems. The current plans for these two programs are discussed.

Key words : Sun: instrumentation — Solar-terrestrial relation

I. INTRODUCTION

This paper is atypical in that it presents the current status of parts of the U.S. space effort. In a short period of time, many of what is discussed here will become obsolete. The objective of this paper is to present some of the current goals and status of the Sun Earth Connections division within the Space Sciences office of NASA. Current information can be found at the NASA web site http://lws.gsfc.nasa.gov. The two main programs within the division are the Solar Terrestrial Probes (STP) and Living With a Star (LWS) programs. These programs will be discussed in this paper.

II. SOLAR TERRESTRIAL PROBES

The missions under the STP program are chosen purely on the basis of their scientific merit. The objective is pure scientific quality and objective. The missions are planned on the basis of community input and chosen for flight by peer review.

The first mission to be flown within this program is the Solar-B mission, which is well on its way through the development phase. This is primarily a Japanese mission with contributions from other countries, including the U.S. The primary science goals of this mission are achieved primarily through a high spatial resolution telescope. The basic science questions to be addressed by Solar-B are:

- Probing solar magnetic variability
- How is magnetic energy stored and explosively released to cause flares and coronal mass ejections?
- How are solar magnetic fields created and destroyed?

The three primary instruments on Solar-B are a 0.5m visible light telescope (SOT), an X-ray telescope (XRT), and an EUV Imaging Spectrometer (EIS).

The second mission is called STEREO which is also well on its way through the development phase. This is a set of two spacecraft that will go into orbit around the Sun in opposite directions from the Earth. Their goals are:

- Solar origins and development of coronal mass ejections
- Propagation of ejections and disturbances from the Sun to Earth
- Mechanisms of solar energetic particle acceleration
- 3-D structure and dynamics of the corona and heliosphere

The instruments on STEREO are: Sun Earth Connection Coronal and Heliospheric Investigation (SECCHI), which will have four instruments: an Extreme Ultraviolet Imager, two white-light coronagraphs and a Heliospheric Imager.

STEREO/WAVES (SWAVES) is an interplanetary radio burst tracker that will trace the generation and evolution of traveling radio disturbances from the Sun to the orbit of Earth.

In situ Measurements of Particles and CME Transients (IMPACT) investigation will sample the 3-D distribution and provide plasma characteristics of solar energetic particles and the local vector magnetic field.

PLAsma and SupraThermal Ion and Composition (PLASTIC) experiment will provide plasma characteristics of protons, alpha particles and heavy ions. This experiment will provide key diagnostic measurements of the form of mass and charge state composition of heavy ions and characterize the CME plasma from the ambient coronal plasma.

The next mission planned for the STP line is called Magnetospheric Multiscale, but is only in the study

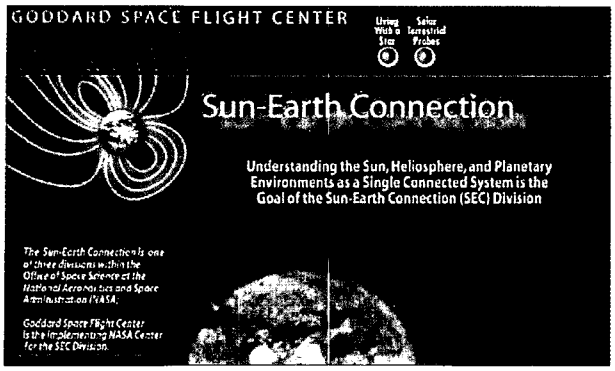

Fig. 1.— SEC home page from the Web

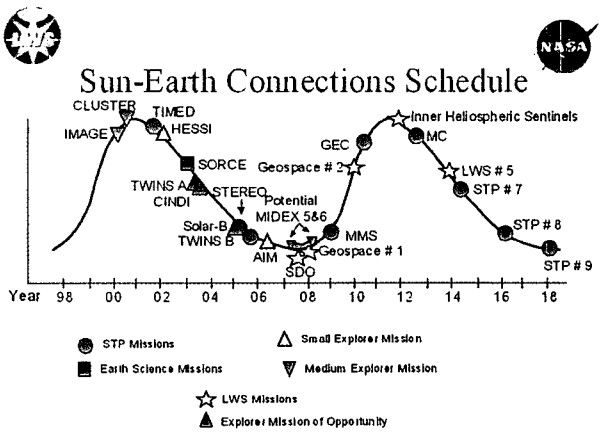

Fig. 2.— Sun/Earth Connection Launch Schedule

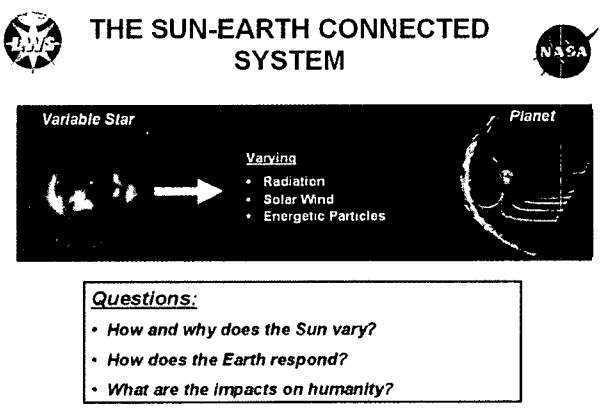

Fig. 3.— LWS Science Questions

phase. Its objective will be to understand how small-scale processes control large-scale phenomenology, such as the magnetotail, plasma entry into the magnetosphere, substorm initiation. The questions to be answered include:

- What are the processes that permit and control the reconnection of magnetic field lines across collisionless plasma boundaries?
- How do energy conversion processes accelerate particles at these boundaries, and what role do parallel electric fields play?
- How are electric currents, which connect distant regions of the magnetosphere, generated, controlled, and disrupted at boundaries?
- What is the importance and character of the coupling across scales (micro- to mesoscales) in all of these processes?
- What is the spatial and temporal structure of collisionless shocks?

Instruments for this mission have not yet been selected.

The fourth mission in this line is called Geospace Electrodynamic Connections (GEC), and it is also in the study phase. The objective of this mission is to study the transition region between the magnetosphere and dense atmosphere, i.e., the ionosphere-thermosphere. The science objective of this mission is to establish the role of the ionosphere/thermosphere in the electrodynamic environment of near-Earth space. Within this context the GEC science objectives are:

- To observe the magnetospheric energy transfer to the ionosphere and thermosphere by making space-time resolved observations in the transfer region.
- To determine the key processes and their space-time scales for coupling between the ionosphere-thermosphere as magnetospheric energy is dissipated.

No instruments have been chosen yet for this mission.

The final mission that is currently planned for this program is the Magnetospheric Constellation, which is also still in the study phase. The fundamental question to be answered by this mission is, "How does the magnetotail store, transport, and release matter and energy?". The science objectives of this mission are:

- Determine the equilibria of the magnetotail.
- Understand the responses of the magnetotail to the solar wind.
- Reveal the instabilities of the magnetotail.
- Map the linkages between local and global processes.

Instruments have not been chosen for this mission either.

Launches for future missions in this line are expected every two years. The approximate expected launch schedule can be seen in Figure 2.

III. LIVING WITH A STAR

The Living With a Star program is different than STP in that it's focus is to improve our ability to predict space weather, and solar effect on human endeavors. This includes solar effects on climate change. An architecture has been laid out by scientists and engineers to determine how best to solve this problem. The science philosophy is shown in Figure 3.

The focus is not to produce an operating space weather network, but to systematically develop the understanding needed to obtain such a capability in the future. The missions in this program have been chosen based on the scientific need, system needs, and the available funds.

The societal objectives of the LWS program are:

- Solar Influences on Global Change
  - Global change (GC) is the single most important environmental problem facing humanity.
  - Affects major national/international policies due to economic impact of GC
- Space environmental "climate" data (e.g., what is the local environment at various places in space?)
  - Needed for design of cost-effective systems with minimal or no sensitivity to space weather.
- Nowcasting Space Environment
  - For rapid anomaly resolution for space and communication / navigation systems; astronaut safety
- Prediction of:
  - Solar Proton Events (astronaut safety, especially for deep space)
  - Geomagnetic storms for applications where effective mitigation is possible (e.g. electric power grid)
  - Space environment for operation and utilization of space systems

The first mission to be flown under this program is the Solar Dynamics Observatory (SDO). The goal of this mission is to determine, observe and understand the dynamic state of the Sun on the multiple temporal and spatial scales which influence life and technology on Earth. The phenomena which influence Earth include:

- Solar irradiance
- Transient events (coronal mass ejections, flares)
- The Sun's evolving structure and its interaction with and influence on transient phenomena
- The extension of the Sun's atmosphere to Earth: the Solar Wind and Heliosphere
- The ultimate source and driver of these phenomena: the Sun's Interior

The instrument complement selected for this mission include:

- The Helioseismic and Magnetic Imager (HMI). This instrument images the Sun's helioseismic, longitudinal and vector magnetic fields to understand the Sun's interior and magnetic activity.
- The EUV Variability Experiment (EVE) measures the solar extreme ultraviolet (EUV) spectral irradiance to understand variations on the time scales which influence Earth's climate and near-Earth space.
- The Solar Heliospheric Activity Research Prediction Program (SHARPP) which images the solar atmosphere in multiple wavelengths and corona to 15 solar radii to link changes to surface and interior changes.

The instruments for this mission have been chosen and are now in their preliminary design phase. Once this is done, the final designs will be accepted and building will commence.

The next set of missions to be developed under the LWS program are designed to study "Geospace". Their scientific goal is to understand how geospace responds to solar changes and to understand and characterize those geospace phenomena that most affect life and society. These missions are currently in the definition phase. The Geospace Missions Definition Team has completed its work and defined a program with four components: The Geospace Missions Network, Missions of Opportunity, Leveraged Programs, and an Instrument Development Program. NASA is currently assessing the estimated costs for these components and will soon issue an Announcement of Opportunity for the community to propose investigations for these missions.

The "Solar Sentinels" missions will be designed to understand the transition and evolution of eruptions and flares from the Sun to the Earth's magnetosphere. The status of these missions is such that they need further definition and their architecture is under study with International Living with a Star (ILWS - see below) partners. A strategy panel has been formed to evaluate progress that can be made with current assets and what additional resources are needed.

Another component of the LWS program is the Space Environment Testbeds (SET). The goal of this program is to improve engineering approaches to accommodate and/or mitigate the effects of solar variability on spacecraft design and operations. An SET Pathfinder of 3 experiments has been approved for flight and follow-on projects are expected to be approved every 2 years.

Another important part of the program is what is called Targeted Research & Technology (TR&T). The goal of this component is to develop new models, concepts, and instrument techniques to improve the scientific knowledge of space environment conditions and climate change over the solar cycle. The goals, objectives, and focuses of this component are currently being

defined by a definition team.

There is an important and significant international component of the LWS program. It is called the International Living With a Star (ILWS) program. The charter of the ILWS committee is to "Stimulate, strengthen and coordinate space research to understand the governing processes of the connected Sun-Earth System as an integrated entity." The objectives of ILWS are To stimulate and facilitate:

1. Study of the Sun Earth connected system and the effects which influence life and society.
2. Collaboration among potential partners in solar-terrestrial space missions
3. Synergistic coordination of international research in solar-terrestrial studies, including all relevant data sources as well as theory and modeling.
4. Effective and user driven access to all data, results and value-added products

The organization of ILWS is open to and consists of space organizations committed to contribute to ILWS over the next decade. Contributions may include any of the following

- Space Flight Missions
- Mission payloads or subsystems
- Mission launch or tracking services
- Additional data sources supporting flight missions (sounding rockets, balloon, or ground-based)
- Data dissemination, storage, distribution and value adding systems Supporting theory and modeling.

IV. SUMMARY

The SEC division in NASA has a very healthy program in Solar, Heliospheric, and Magnetospheric physics. There is a strong pure research line in the STP program and a strong directed line in the LWS program. There is a serious need and willingness for international collaboration. During the next decade we will have many quality data sets with which to study the Sun and space in the Sun/Earth vicinity. There is also strong support for data analysis and theory within these programs. The world community should greatly benefit from this effort.

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