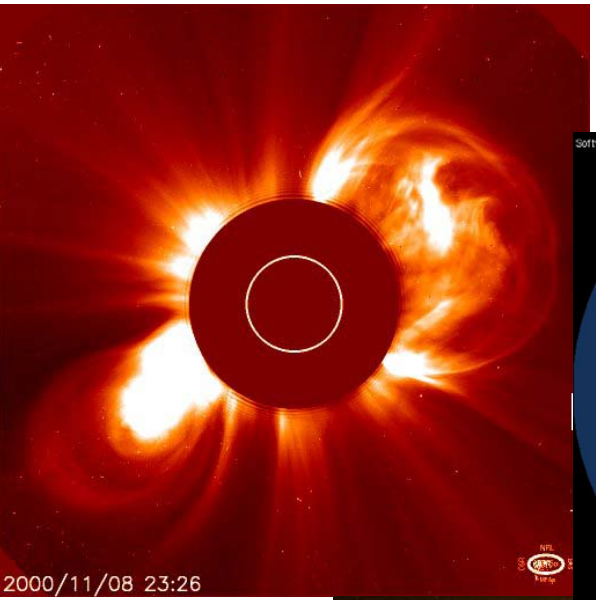
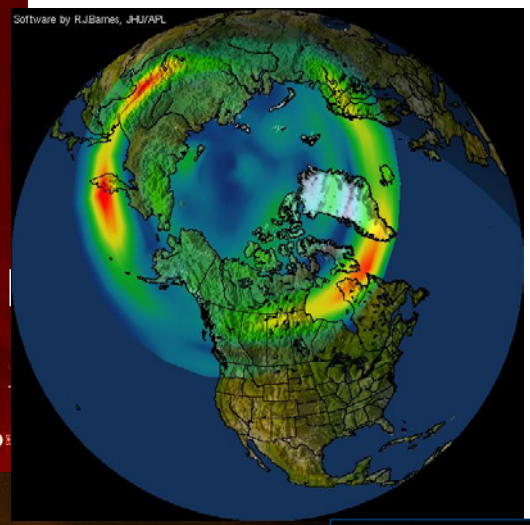
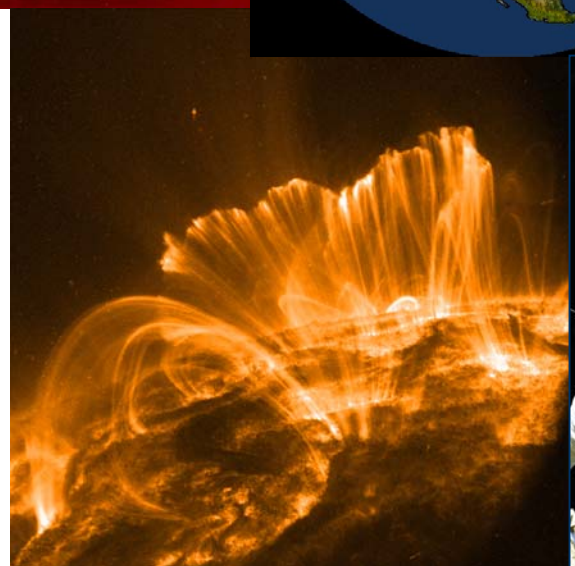
NASA's Sun-Earth Connection Program &ILWS

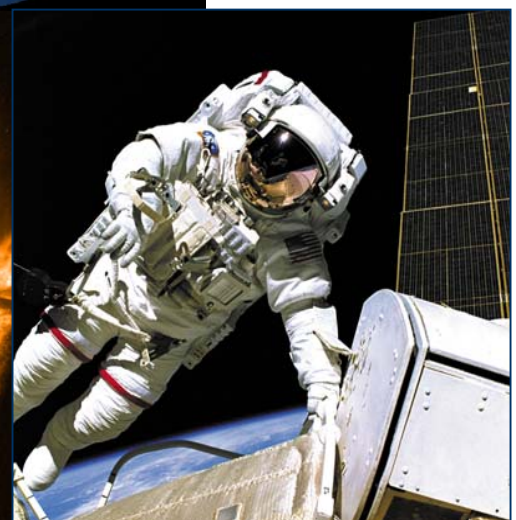




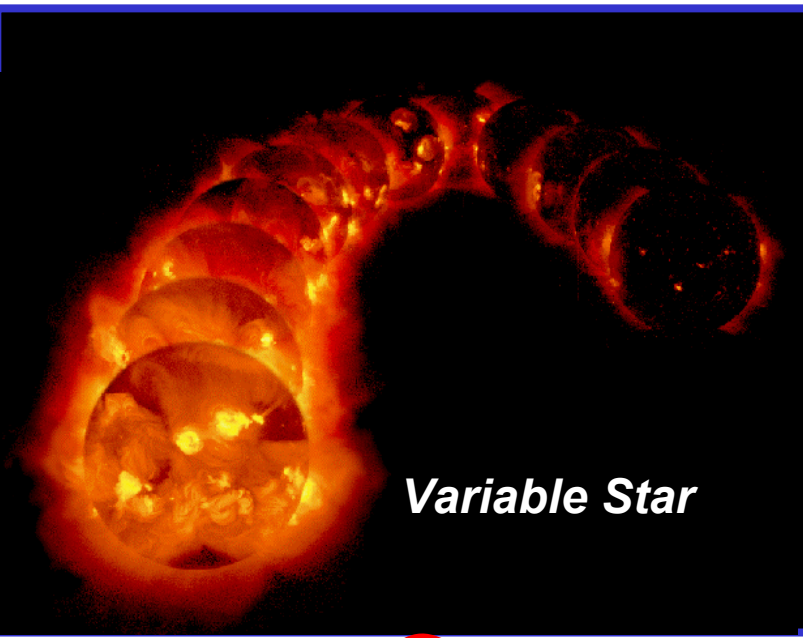
Madhulika Guhathakurta
Office of Space Science,
CodeSS
NASA Headquarters

May 19, 2003





Sun-Earth Connection (Sec) Program



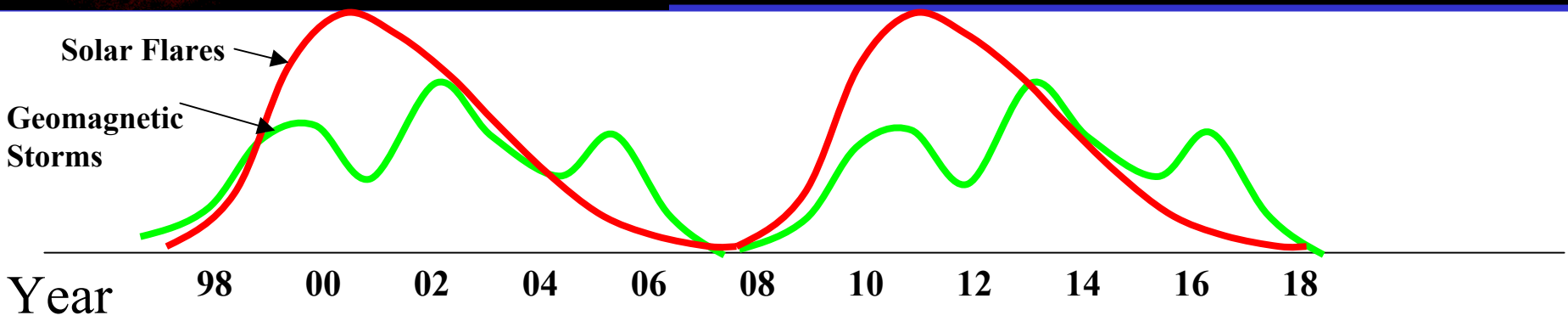
Variable Star

Varying

- Radiation
- Solar Wind
- Energetic Particles

Driven by 11 Year Solar Cycle

Planet



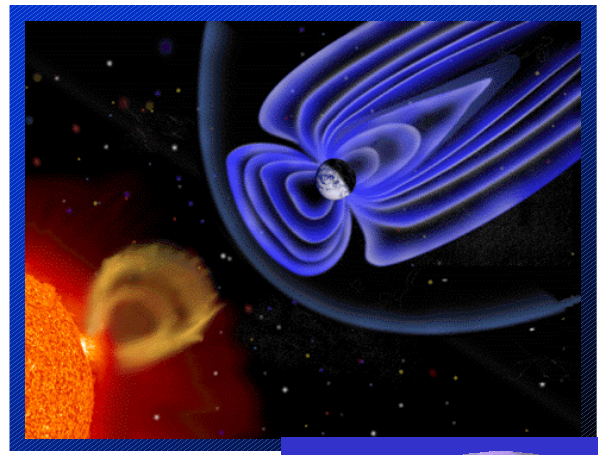
Understanding the changing Sun and its effects on the Solar System, life, and society is one of the goals of the Sun-Earth Connection Theme.

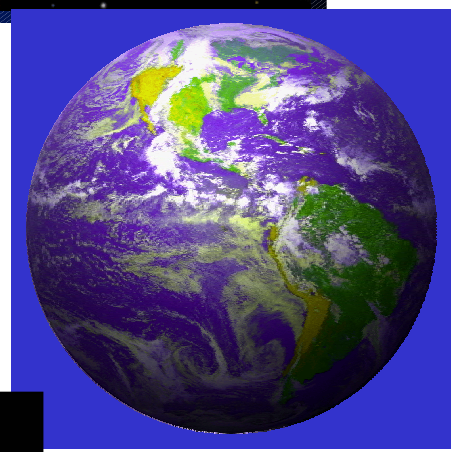
Why Do We Care?

- Solar Variability Affects Human Technology, Humans in Space, and Terrestrial Climate.
- The Sphere of the Human Environment Continues to Expand Above and Beyond Our Planet.

- Increasing dependence on space-based systems

- Permanent presence of humans in Earth orbit and beyond





SEC Program Elements

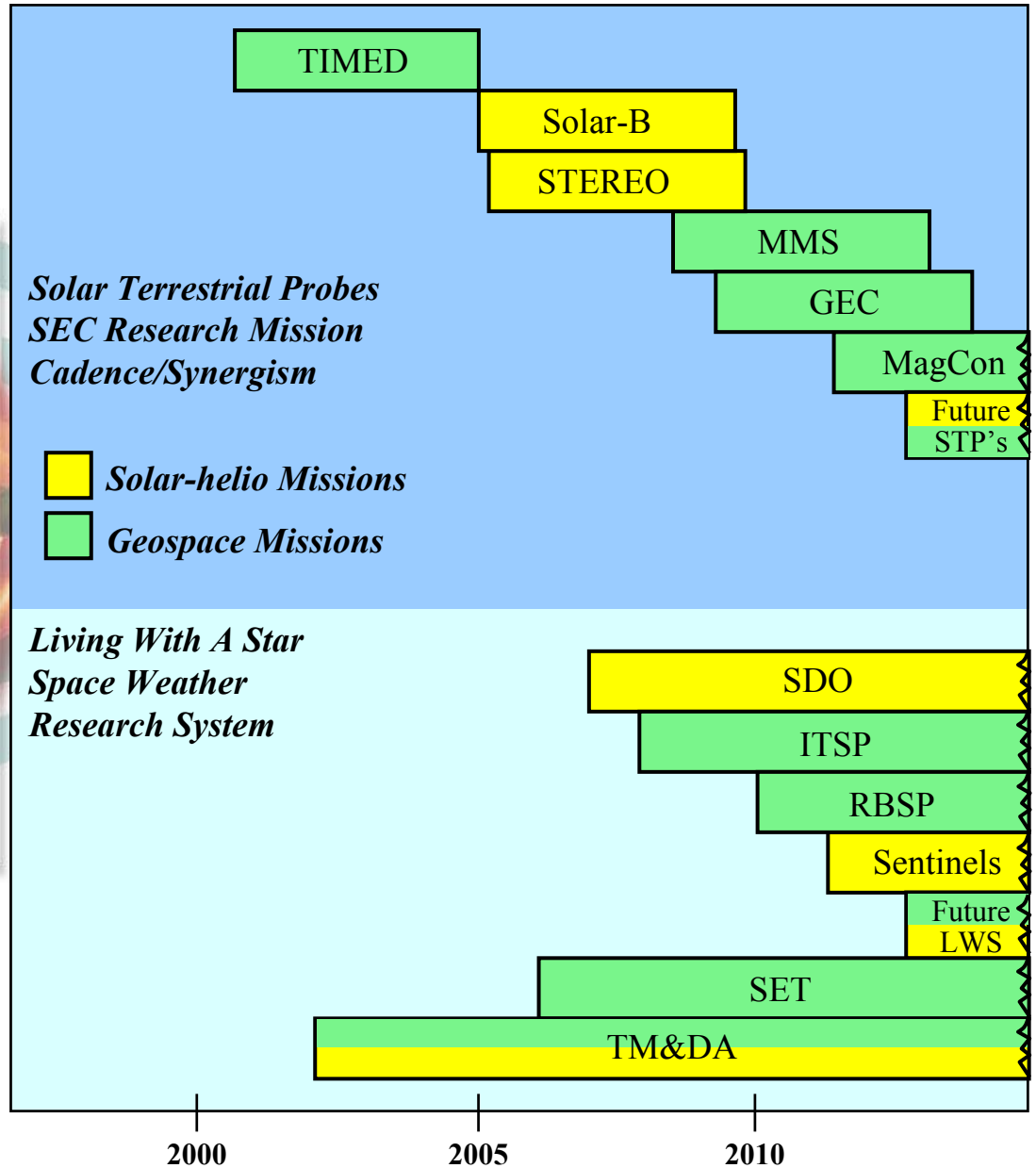
- **Strategic Plans**
  - 2002-03 has been important for SEC Strategic Planning
- **Operating Missions**
  - Currently 14 operating missions support the research program
- **Program Mission Lines**
  - There are two SEC mission lines:
    - Solar Terrestrial Probes (STP)
    - Living With a Star (LWS)
- **Cross-Divisional Mission Lines**
  - There are two mission lines operated for the benefit of the Office of Space Sciences:
    - Explorer Mission Line
    - New Millennium Technology Mission Line
- **Supporting Research and Technology Program**

Relationship of SEC Primary Science Objectives to the STP and LWS Strategic Programs

Explore the fundamental physical processes of space plasma systems

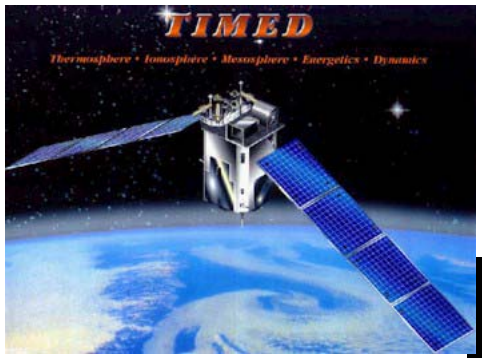
Understand the changing flow of energy & Matter throughout the Sun, heliosphere, and planetary environments

Define the origins and societal Impacts of variability in the Sun-Earth Connection

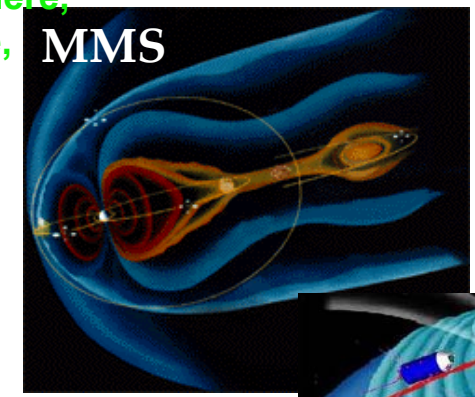


Solar Terrestrial Probes (STP)

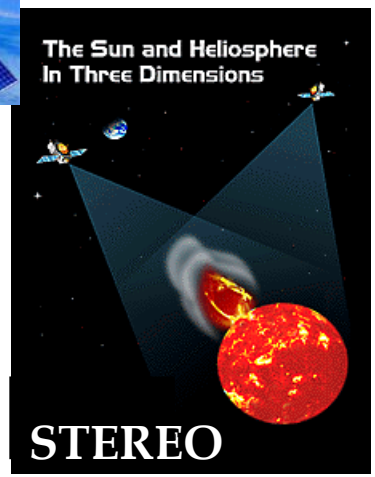
SOLAR TERRESTRIAL PROBES
NASA GODDARD SPACE FLIGHT CENTER



Determine basic structure and understand energy balance of mesosphere, lower thermosphere, ionosphere

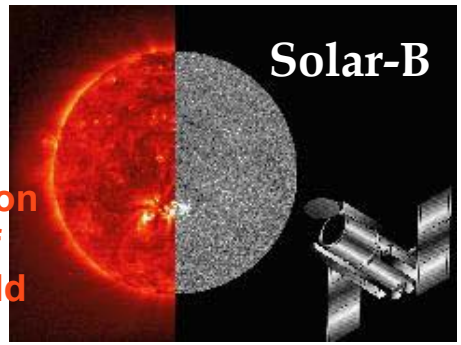


Understand fundamental plasma processes of reconnection, acceleration and turbulence



Understand origin, evolution, and propagation of CME's

Understand plasma interactions with the atmosphere



Understand creation and destruction of solar magnetic field

Understand processes that control the dynamic state and energy flow of the magnetosphere

LWS, Develop the scientific understanding necessary to effectively address those aspects of the connected Sun-Earth system that directly affect life and society.

- **Solar Dynamics Observatory**
  - Three investigations selected in August 2002 for phase A development and now transitioning to phase B
- **Geospace Missions**
  - Geospace Mission Definition Team identifies the Ionospheric-Termospheric Storm Probe and Radiation Belt Storm Probe Missions as highest priority.
- **Sentinels**

  Mission architecture under study with International Living With a Star (ILWS) partners
- **Space Environment Testbeds**

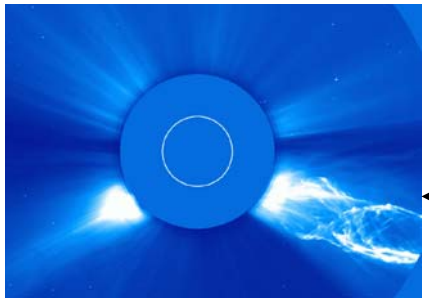
  Improve the engineering approach to accommodation and/or mitigation ofthe effects of solar variability on spacecraft design and operations

  -NRA every year
  - NRA every year. TRT goals and priorities team selected. (report due in summer of 2003)
- **Solar Probe Mission**
  - Engineering study completed. There will be a Science Technology and Definition Team formed in Summer/Fall of 2003.

The Solar Dynamics Observatory (SDO)

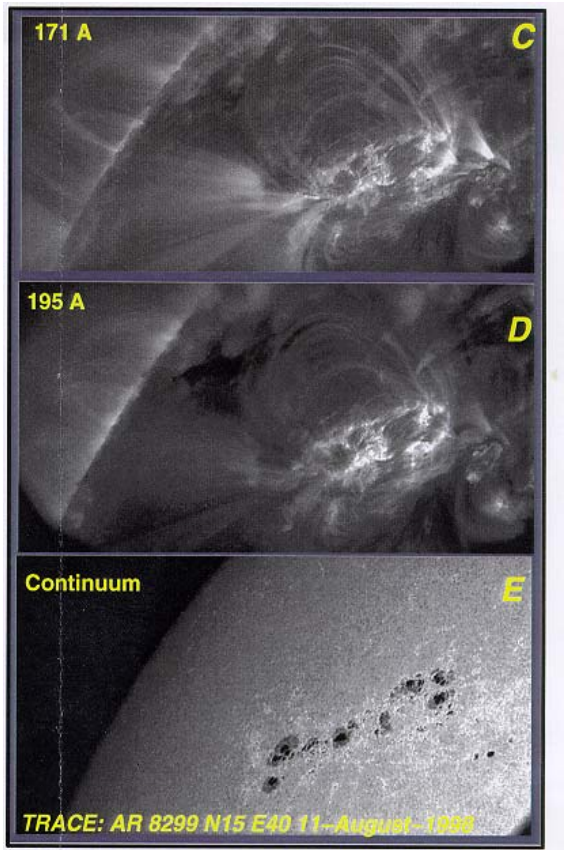
- **First Living With a Star (LWS) Mission, part of Sun-Earth Connection theme**
- **Will characterize the dynamic state of the Sun enhancing the understanding of solar processes and space weather. Viewed as SOHO follow-on**
- **NASA GSFC will manage the mission, build the S/C in-house, manage and integrate the instruments, develop/manage the Ground System & Mission Operations, and perform Observatory environmental testing at GSFC**
- **SDO Investigations:**
  - **Helioseismic Magnetic Imager (HMI); PI: Phil Scherrer – Stanford; Images the Sun's helioseismic and magnetic fields to understand the Sun's interior and magnetic activity**
  - **Solar Heliospheric Activity Research & Prediction Program (SHARPP); Atmospheric Imaging Assembly (AIA) & Guide Telescope (GT) and White light coronagraph (KCOR); PI: Russ Howard – NRL; Images the corona to link changes to surface and interior changes**
  - **Extreme Ultraviolet Variability Experiment (EVE); PI: Tom Woods – LASP, Univ. of CO; measures the solar extreme ultraviolet (EUV) irradiance to understand variations**
- **August 2007 EELV launch from KSC into GEO-Transfer Orbit (GTO), circularize to GEO-Sync Orbit, inclined 28.5 degrees**
  - Provide continuous high rate data (150 Mbps) stream to dedicated ground station
  - Spacecraft: robust, three-axis stabilized, solar-tracking with low jitter
- **Design Drivers: Continuous high data rate/volume, Geosynchronous orbit (mass to orbit, radiation), 5 year mission life, Instrument pointing and stability**

Solar Dynamics Observatory - Next Generation SOHO



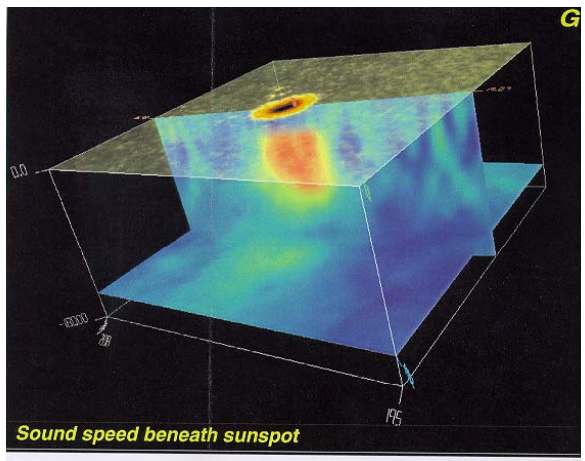
Imaging CME's

- **Investigating solar dynamical processes and phenomena**
- **Observing development of magnetic and subsurface phenomena related to 1) flare &CME energy storage & triggering 2) The solar dynamo driving the solar cycle.**
- **High data rate from GEO orbit for studying dynamics (SOHO limited by low data rate from L1)**



Imaging Magnetic Structures
(rapid time sequences -- "movies")

Solar EUV and UV Irradiance



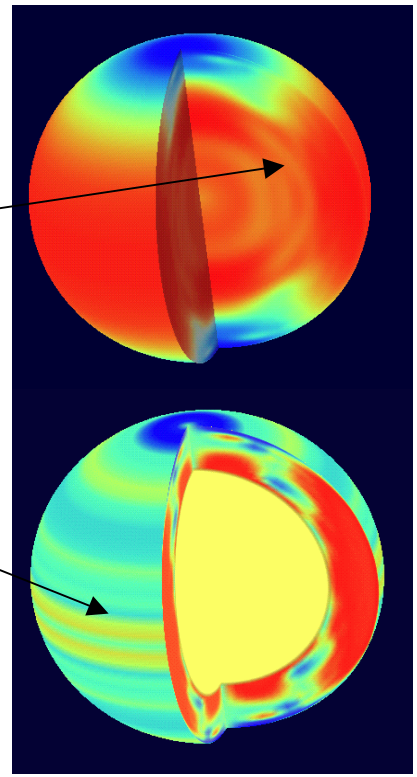
Sunspot data from MDI High Resolution, 18 June 1998

Imaging Subsurface Structures

Red: Faster Rotation
Blue: Slower Rotation

Solar Dynamo?

Link to solar cycle?

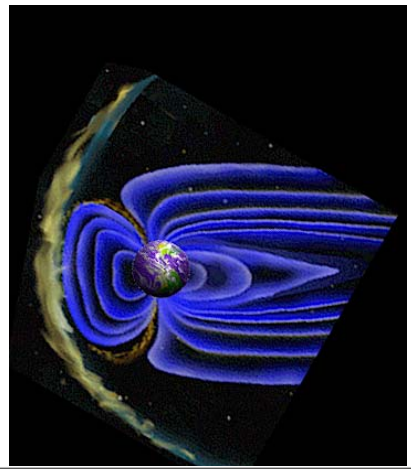


Imaging Solar Interior

Geospace Missions Network

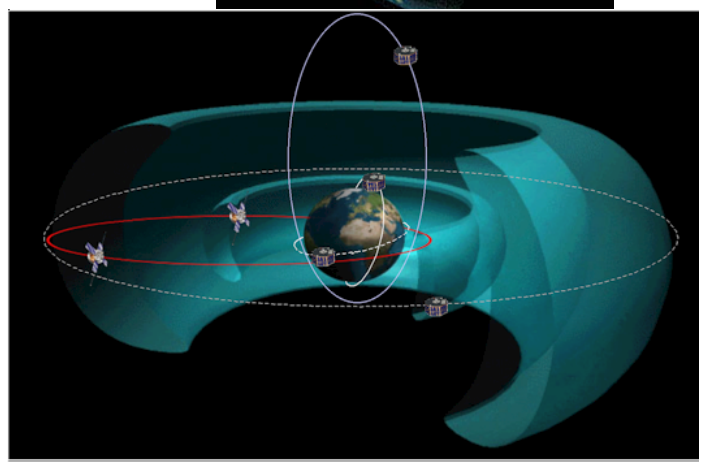
Goal

Increase scientific understanding of how the Earth's ionosphere and magnetosphere respond to changes due to solar variability



Focus areas

- **Radiation belts**
  - **Origin and dynamics of the radiation belts**
  - **Evolution of the radiation belts during magnetic storms**
- **Ionosphere**
  - **Effects of changes in ionizing radiation on the ionosphere**
  - **Variations of neutral density and drag, plasma density and drifts, *scintillations, auroras, and winds***



Solar Sentinel Missions

Goal

Understand the transition and evolution of eruptions and flares from the Sun to the Earth's magnetosphere

Focus areas

- ***Determine the structure and long-term climatic variations of the ambient solar wind in the inner heliosphere***
- ***Determine how geo-effective solar wind structures propagate and evolve in the inner heliosphere***
- ***Determine what solar dynamic processes are responsible for the release of geo-effective events***
- ***Determine how and where energetic particles are released and accelerated***

Status

- ***Mission architecture under study with International Living With a Star (ILWS) partners***
- ***Launch – TBD***

SET OVERVIEW

Improve the engineering approach to accommodation and/or mitigation of the effects of solar variability on spacecraft design and operations

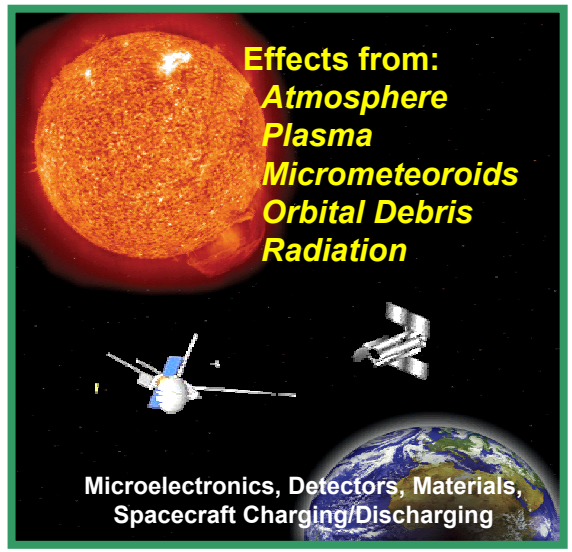
- **Goals**

  Apply results to advanced spacecraft subsystems and detector and instrument systems to achieve Space Science objectives

  Leverage opportunities with Aerospace Technology Enterprise, industry, and other agencies

  Transfer capabilities to industry and other government agencies

  Engage public interest in Sun-Earth Connection science by showing direct relevance to daily use of technology



- **Implemented as missions of opportunity via cost-sharing partnerships with various international and defense partners**
- **SET-1, tentatively planned to launch on DMSP in late 2005/early 2006. Formal agreement for DMSP launch being worked**
- **NRA for SET experiments released by HQ September 17; proposals received December 18, proposals selected in May,03**
- **Additional SET flights planned approximately every 2 years as funding permits**

System-wide Approach

- LWS is a sophisticated program focusing not on any one region of space, but instead on our Sun Earth Region as one System
- A very important part of LWS is the study of the connection between the regions and how one drives a response in another

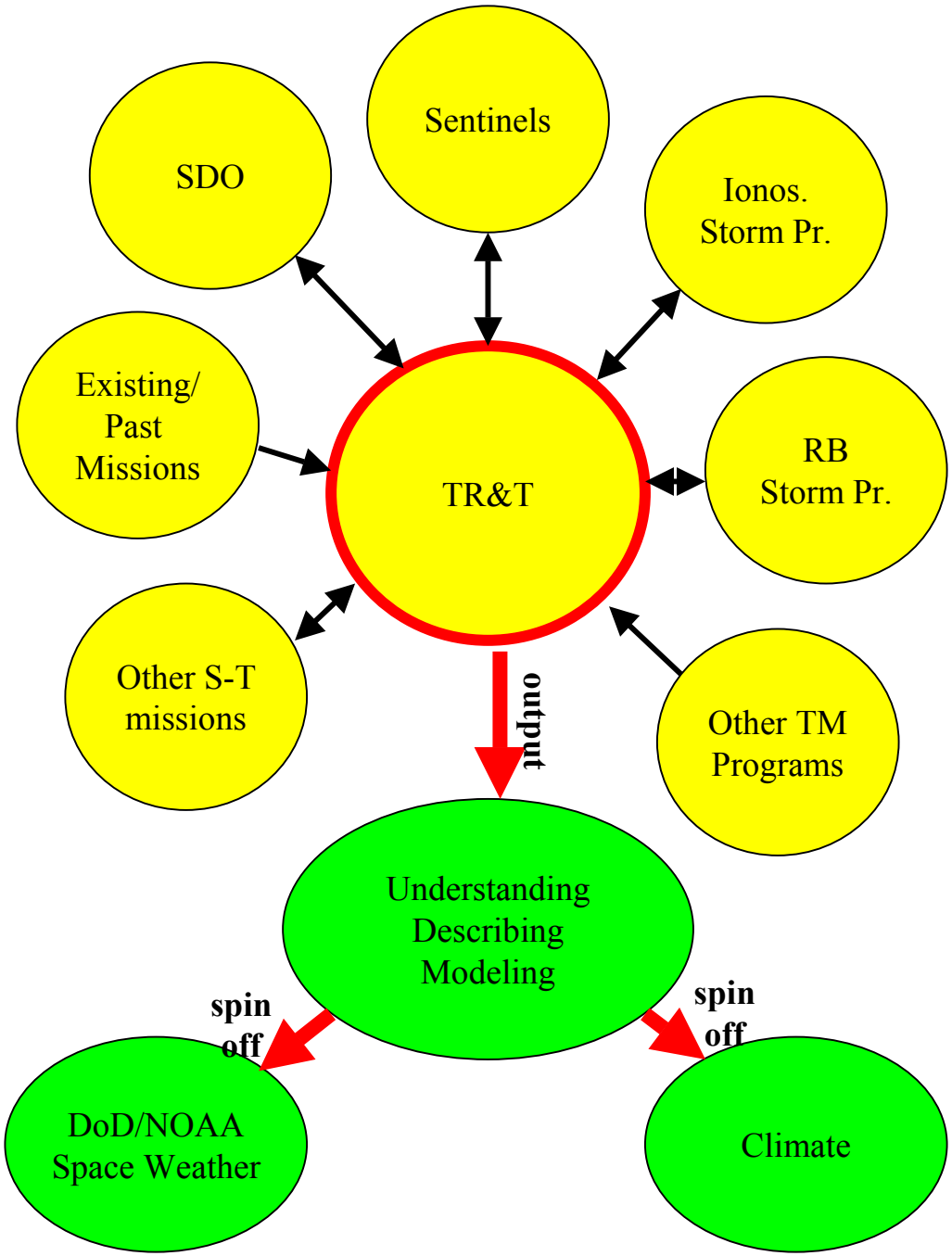
Science Application

- The main goal of the LWS Program is to understand "*how solar variability affects humans and technology*"

- This takes basic science research, which leads to further understanding, and in turn can be adapted to operations to improve nowcasting and forecasting

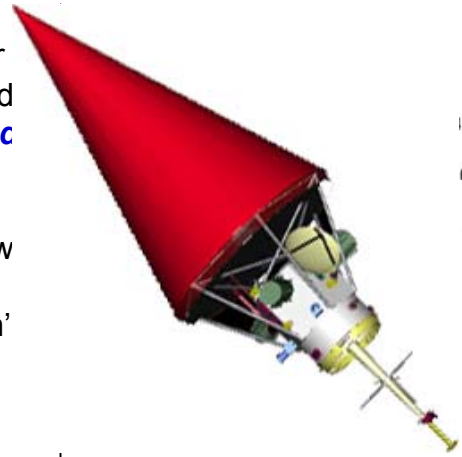
LWS Output

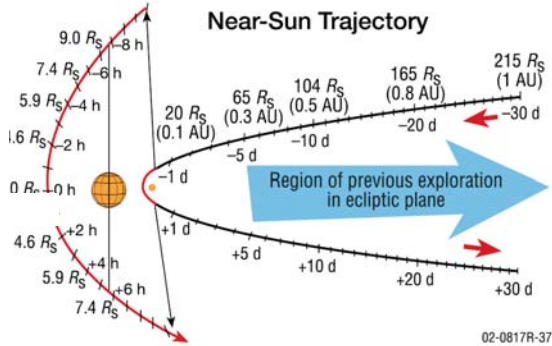
"Models must be seamlessly linked and new ideas and new concepts injected so that the final product is a working end-to-end model or models accurately depicting the comprehensive knowledge generated by the LWS program."


SDO
Sentinels
Ionos.
Storm Pr.
Existing/
Past
Missions
TR&T
RB
Storm Pr.
Other S-T
missions
output
Other TM
Programs
Understanding
Describing
Modeling
spin
off
spin
off
DoD/NOAA
Space Weather
Climate

SOLAR PROBE

Content: Solar Probe (SP) is humanity's ***first*** visit to our star to explore the complex and time varying interplay of the Sun and Earth which affects human activity. SP will determine ***where and what physical processes heat the corona & accelerate the solar wind to its super-sonic velocity.*** A combined remote sensing and in-situ sampling from within the solar corona itself w provide a **"ground truth"** never before available from astronomical measurements made from spacecraft in the Earth' orbit or LaGrange points.





Relevance: **1st priority** of the National Academy Space Studies Board (2002): a "large class" mission of **high importance**, providing vital contributions to NASA's Space Science strategic goals. The Solar Probe Mission will contribute to:

(I) **Understanding and protecting our home plane,** by providing new physical insight into mechanisms linking the Sun-Earth System.

(II) **Exploration of the universe**, by ***characterizing*** and investigating the solar system (from 4 solar radii to Jupiter's orbit at 5 AU) near the central star, the Sun.

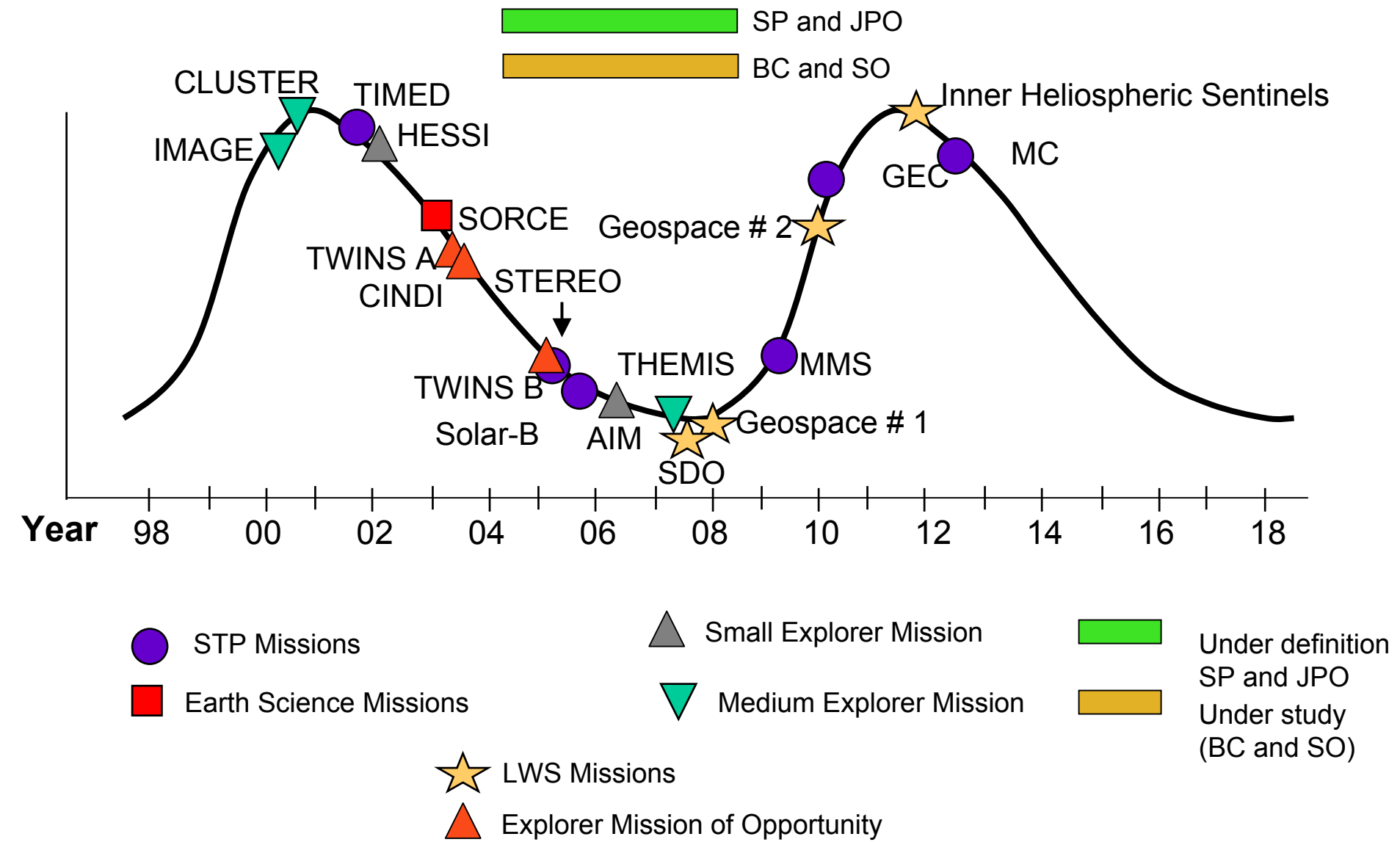
(III) I**nspiring the next generation of explorers** by ***completing the reconnaissance of the solar system***, via a scientifically compelling and technically sophisticated mission. SP will discover and communicate new knowledge, not only of cultural and intellectual value, but also of political and economic value.

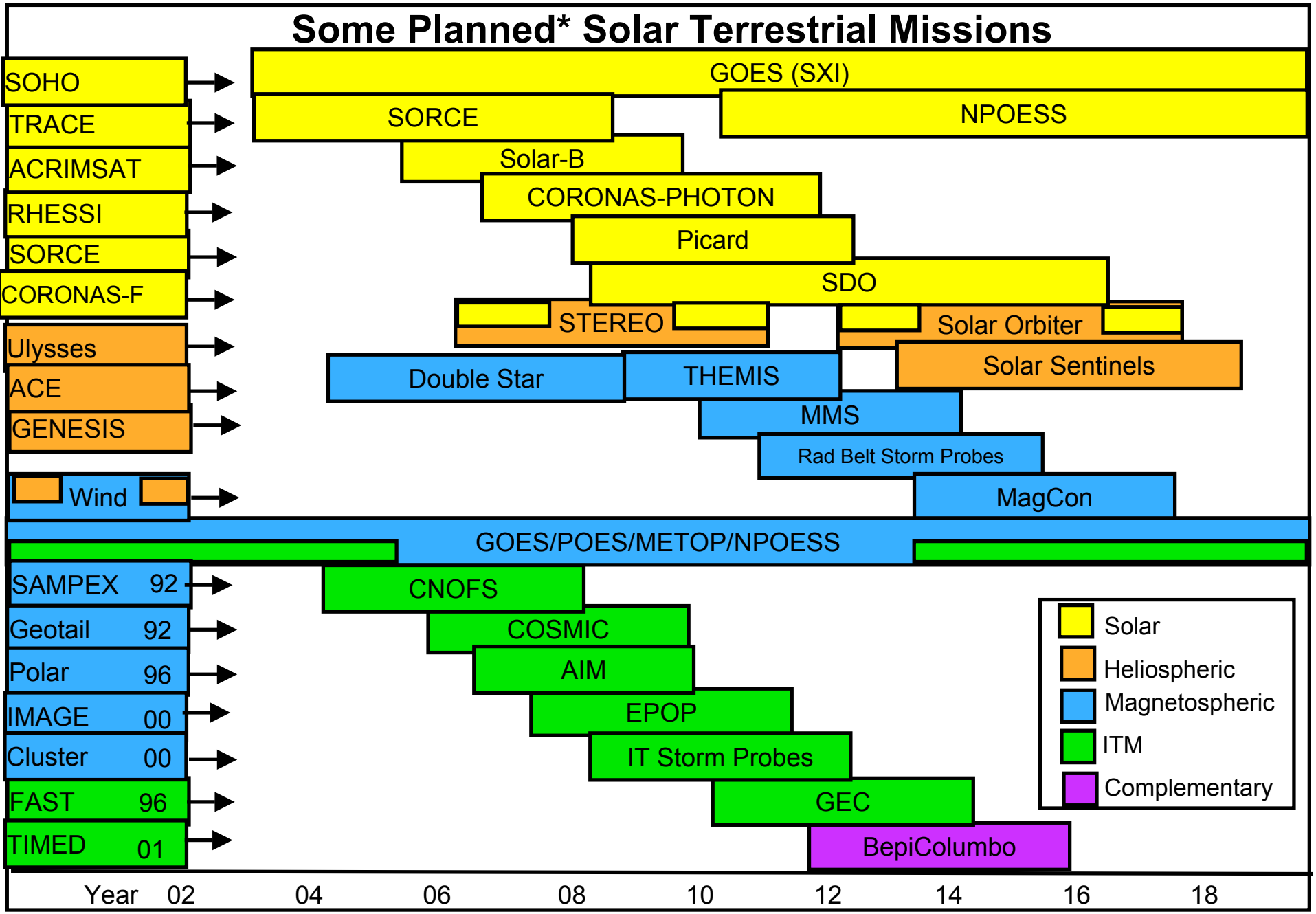
Mission Model: A large class strategic mission within the Living with a Star Program. Investigation goals and priorities determined by STDT study; scientific investigations selected by AO competition.

Task Milestones/Products:

Dec. '03	**Complete Science Definition Team Report**
Oct. '04	**Instrument Selection/ Begin Phase A**
Oct. '07	**Begin Phase B**
Apr. '09	**Begin Phase C/D**
Aug. '12	**Launch**
Aug. '15	**Pass 1 by Sun**
Aug. '19	**Pass 2 by Sun**

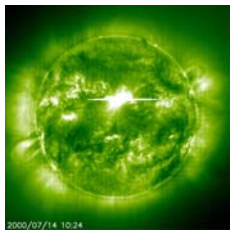
SEC Strategic Plan

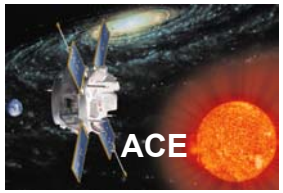


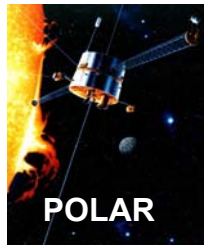


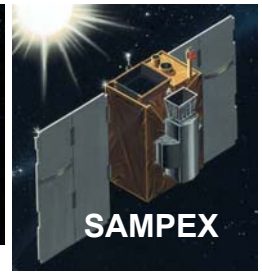
* In development and/or funded

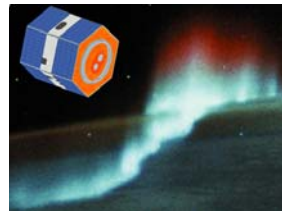
Studying the Solar-Terrestrial Particle Chain 1994 vs. 2004











Solar Source

Situation—

1994:

No continuous solar images

2004:

Continuous views of sun in UV, x-rays, visible wavelengths (SOHO, NOAA/SXI, RHESSI, etc.)

Solar Wind Drivers

Lack of continuous solar wind measurements

Continuous data from ACE

Seed Population

Limited measure of outer magnetospheric particle populations

Excellent data on plasma sheet sources of seed population (CLUSTER, GEOTAIL, POLAR, etc.)

Precipitation And Loss

Some available data on precipitation (SAMPEX, UARS)

SAMPEX configuration, NOAA/POES, POLAR/PIXIE

Atmospheric & Ionospheric Coupling

Little knowledge of atmospheric impacts (only UARS/HALOE)

improved situation with SNOE and TIMED

Some Gaps in Currently Planned Mission Fleet

- **Insufficient spacecraft to sample simultaneously all critical regions & phenomena of complex, time-varying geospace environment**

  - **Imaging of upper terrestrial atmosphere, Earth's magnetosphere are severely limited in currently planned mission fleet.**
  - **Insufficient number, inadequate spatial distribution of spacecraft making *in situ* measurements.**

- **Solar wind to be sampled at only a few points; no replacement for ACE (launched in 1997) at L1 in an approved (funded) program.**

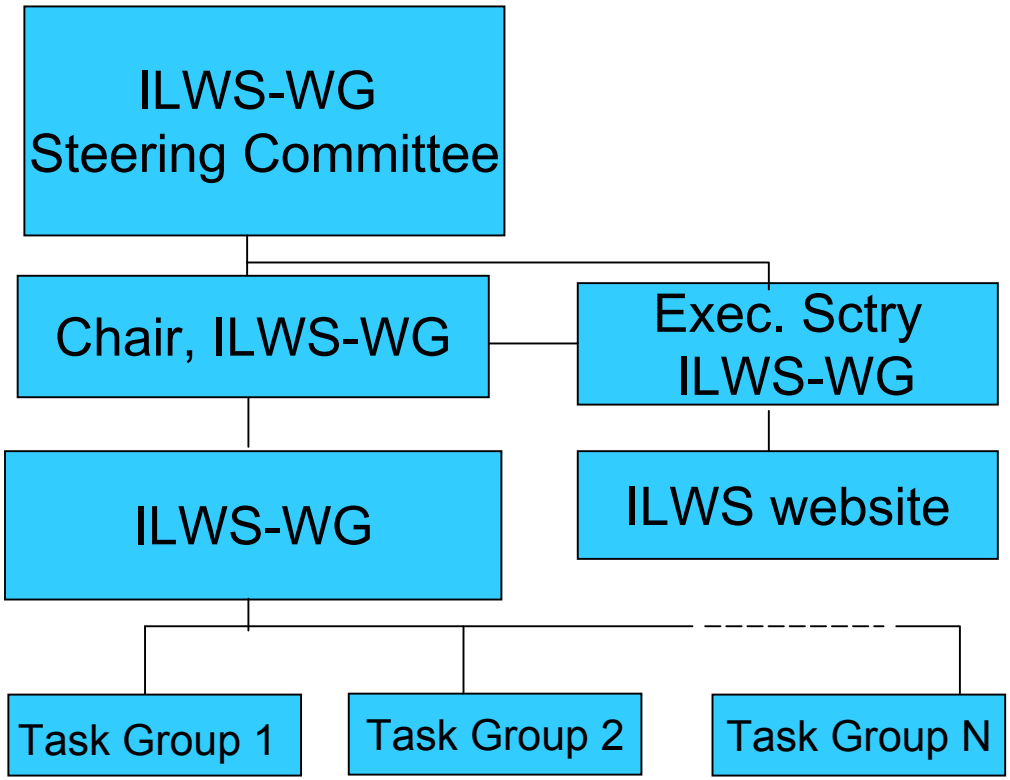
- **Inadequate measurement of solar high energy phenomena (e.g. flares and energetic particles) currently planned for next solar maximum.**

ILWS

ILWS MISSION

- **Stimulate, strengthen and coordinate space research to understand the governing processes of the connected Sun-Earth System as an integrated entity**

ILWS-WG ORGANIZATION



Facilitation

System Concept
Coordination
Prioritization
Findings

Resources and
Opportunities
Data Systems

First ILWS Working Group Meeting Nice, April 14-15, 2003

- **22 Space Organizations and 2 representatives of the G-B Community, committed to contribute to ILWS over the next decade**

  NASA, ESA, RASA, ISAS, CSA, NOAA, 11 ESA M-S, CRL, Ukraine, Brazil, Hungary, China

  in addition CAWSES (SCOSTEP- Chair S. Basu) and GB-Task Group (Chair E. Donovan)

  (members not attending: Belgium and India; after the meeting Australia joined WG)
- **Presentation of National Plans for Missions in the ILWS Realm**
- **Discussion of Mission Synergies and Potential Coordination**
- **Three Task Groups established:**
  - **Ionosphere Thermosphere Coupling (Chair R. Heelis)**
  - **Magnetosphere (Chair H. Koskinen)**
  - **Ground-Based Coordination (Chair E. Donovan)**

  - **"Solar Sentinels" (start after completion of Solar Orbiter science definition)**
  - **"Solar Task Group**
  - **"Data Systems and End Users" (to be defined later)**

First ILWS Working Group Meeting Nice, April 14-15, 2003 (cont.)

Four Main Areas of Mission Synergies / Collaborations identified

- **Sun and Heliosphere**
  - SOHO, SDO, STEREO, Solar-B, CORONAS-Photon, Picard, …
  - Ulysses, Solar Sentinels (incl. B-C), Solar Orbiter, Sub-L1 mission…
  - L1-Monitor…
- **Outer Magnetosphere**
  - Cluster, MMS, Themis, MagCon, RAVENS (Canada), SWISE (China)…
- **Inner Magnetosphere**
  - Radiation Belt Storm Probes, Storms (SF/F), SWISE (China), E^{pop} (Canada)...
- **Ionosphere-Thermosphere**
  - Ionosphere Thermosphere Storm Probes, GEC, …
  - SWARM, ACE+, …

Backup