# Living With A Star (LWS)

## SEC MISSIONS AND PLANS
## Solar Terrestrial Probes (STP)

**Madhulika Guhathakurta(mguhatha@hq.nasa.gov)**
SUN-EARTH CONNECTIONS DIVISION
NASA, OFFICE OF SPACE SCIENCE

Alpbach Summer School, July 23- August 1, 2002

# The Sun-Earth Connected System

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***Variable Star***

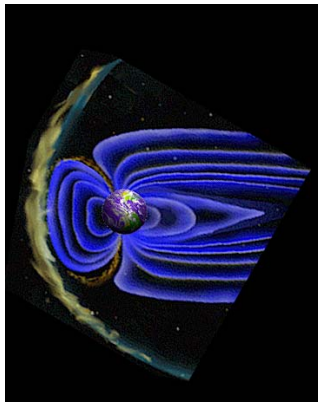
**Varying**

- **Radiation**
- **Solar Wind**
- **Energetic Particles**

**Interacting**

- **Solar Wind**
- **Energetic Particles**

***Planet***



**Interacting**

- **Magnetic fields**
- **Atmosphere**
- **Plasma**
- **Energetic Particles**

**Interacting**

- **Magnetic Fields**
- **Plasmas**
- **Energetic Particles**

***QUESTIONS:***

- ***How and why does the Sun vary?***
- ***How do the Earth and planets respond?***
- ***What are the impacts on humanity?***

## Sun-Earth System -- Driven by 11 Year Solar Cycle

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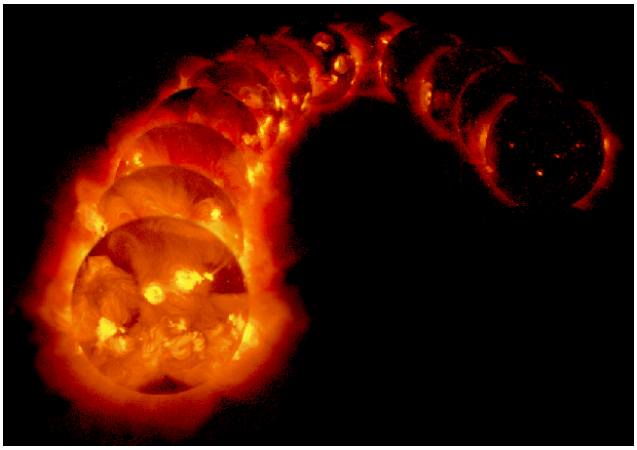
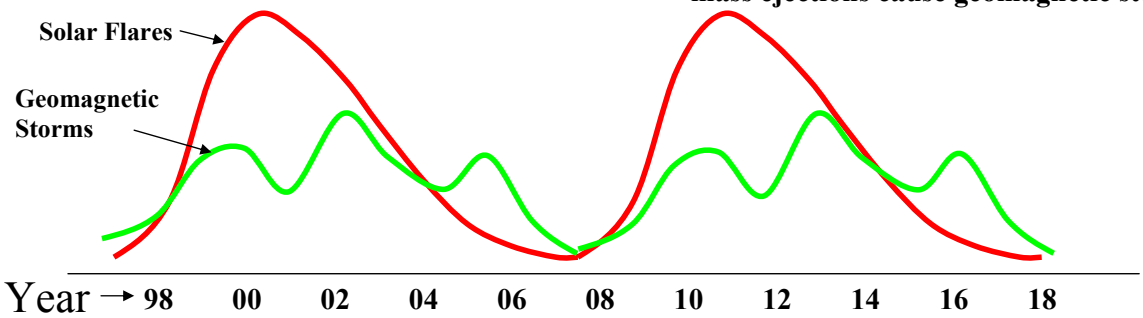


**Solar Maximum:**

- **Increased flares, solar mass ejections, radiation belt enhancements.**
- **100 Times Brighter X-ray Emissions 0.1% Brighter in Visible**
- **Increased heating of Earth's upper atmosphere; solar event induced ionospheric effects.**

**Declining Phase, Solar Mnimum:**

- **High speed solar wind streams, solar mass ejections cause geomagnetic storms.**



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# Why Do We Care?

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- 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

# Living With a Star: *Objectives*

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***LWS is a systems study of three linked questions:***

- **How and why does the Sun vary?**
- **How does the Earth respond?**
- **What are the impacts on life and society?**

**- Understand solar variability and its effects on space and Earth environments.**

**- Obtain information for mitigating undesirable effects of solar variability on human technology.**

**- Understand how stellar variability can affect life on Earth.**

*** To enable better understanding of global climate change caused by both natural (solar variability, volcano eruptions) and human drivers.**

*** To better predict how stellar variability affects life in other stellar systems.**



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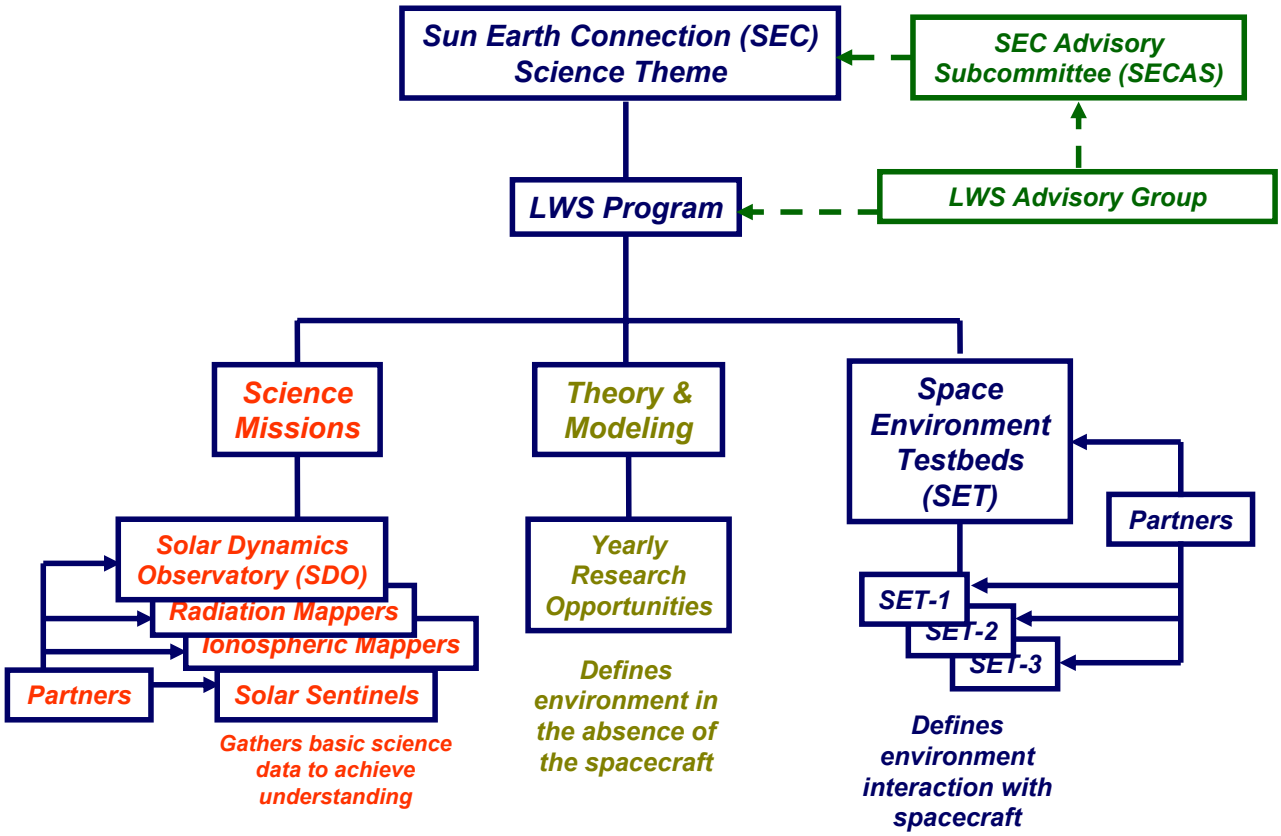
Living With a Star (LWS) Program Architecture

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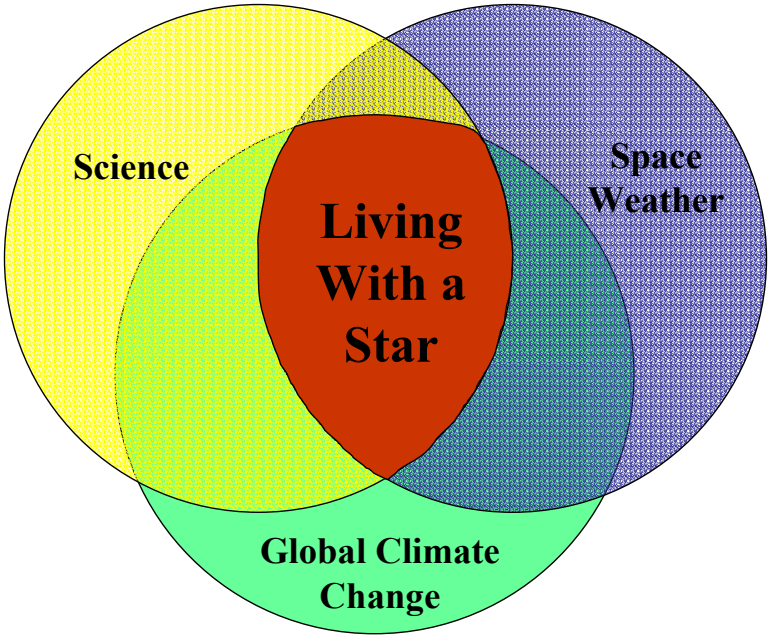
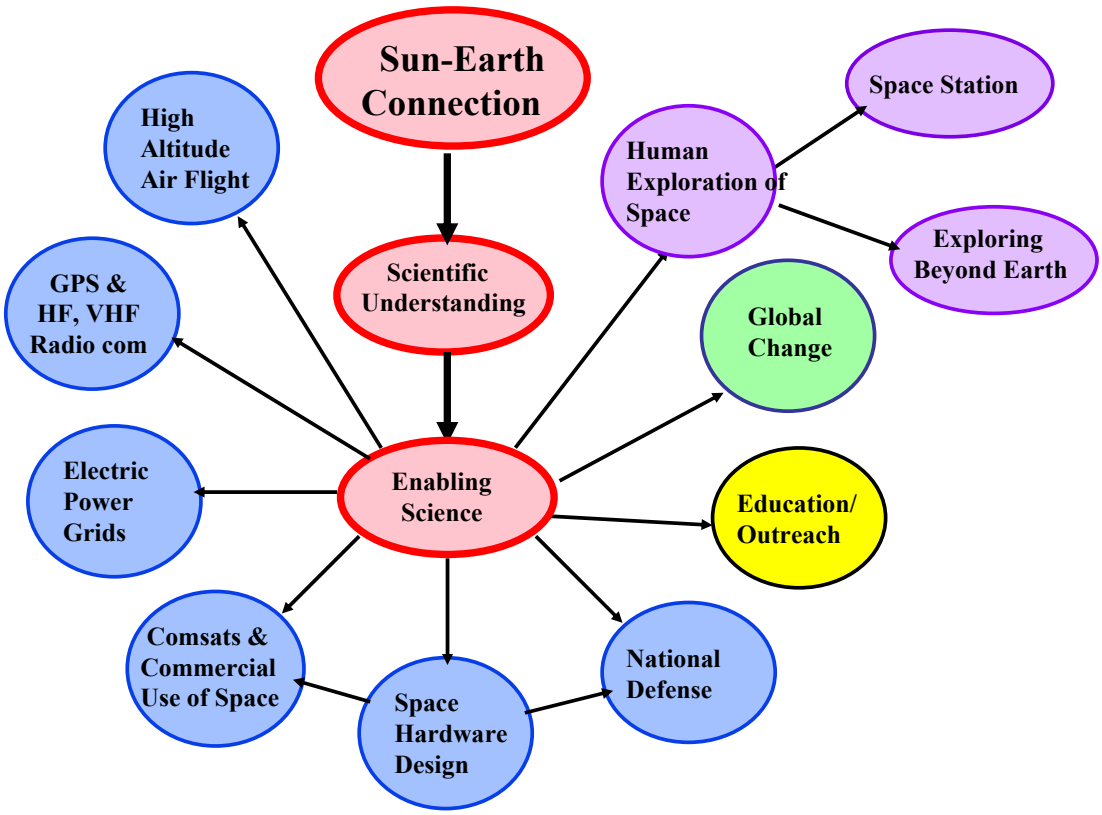
# Living With A Star





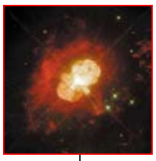



# Sun Earth Connections

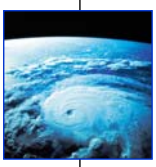


# GOALS & OBJECTIVES AGENCY LEVEL

**The LWS program is a cross-cutting initiative whose goals and objectives have the following links to each of the four NASA Strategic Enterprises:**

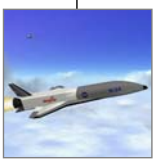


- Space Science**: LWS quantifies the physics, dynamics, and behavior of the Sun-Earth system over the 11-year solar cycle.**



- Earth Science**: LWS improves understanding of the effects of solar variability and disturbances on terrestrial climate change.**

- Human Exploration and Development**: LWS provides data and scientific understanding required for advanced warning of energetic particle events that affect the safety of humans.**



- Aeronautics and Space Transportation**: LWS provides detailed characterization of radiation environments useful in the design of more reliable electronic components for air and space transportation systems.**

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# SOCIETAL CONSEQUENCES OF SOLAR VARIABILITY

**Human Radiation Exposure**

- Space Station
- Space Exploration and Utilization
- High Altitude Flight

**• Impacts on Technology**

- Space Systems
- Communications, Navigation
- Terrestrial Systems

**• Terrestrial Climate**

- Short Term
- Long Term

# LWS SOCIETAL OBJECTIVES

- **Solar Influences on Global Climate Change (GCC)**
  - **GCC is single most important environmental problem facing humanity.**
  - **Affects major national/international policies due to economic impact of GCC and/or mitigation.**
- **Space Environmental "climate" data (e.g., specification models)**
  - **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.**



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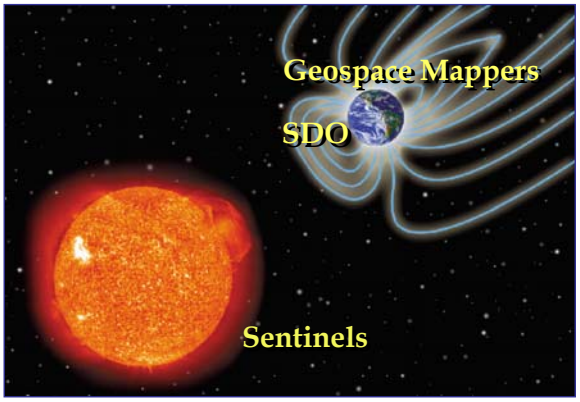
# SEC Programs

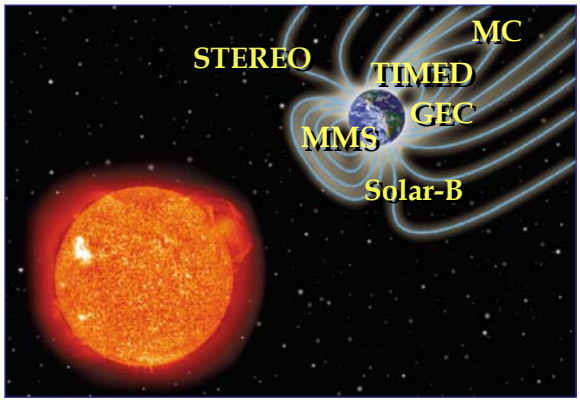



### Living With a Star (LWS)

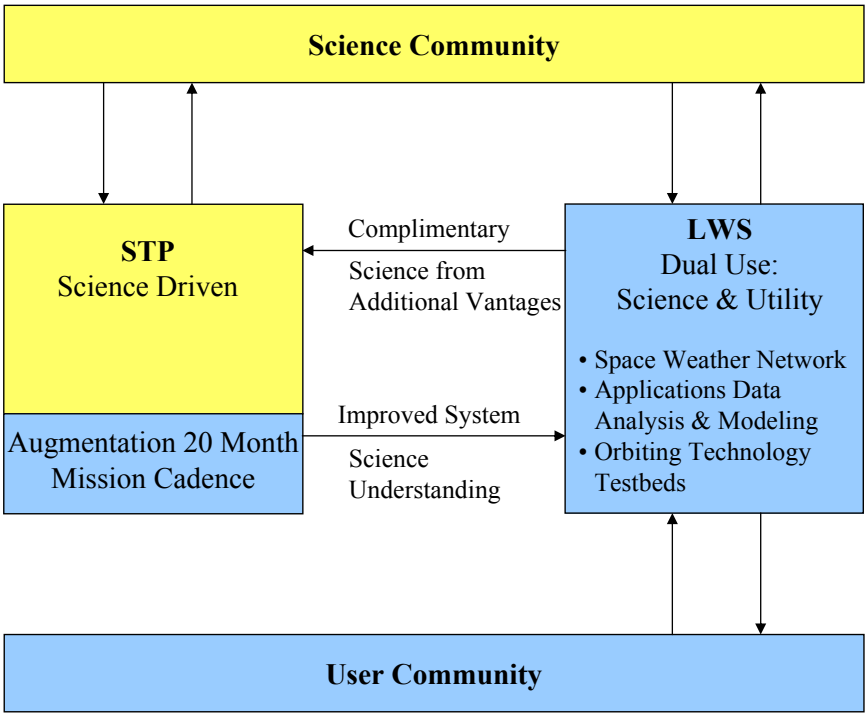
Missions to establish the space weather research network for characterization of the Sun-Earth System behavior and identification of the critical physics that link parts of the system

### Solar Terrestrial Probes (STP) Program

Missions launched every 20 months with focused investigations to explore specific scientific research questions



## Program Relationships
## Solar Terrestrial Probes (STP) and Living with a Star (LWS)

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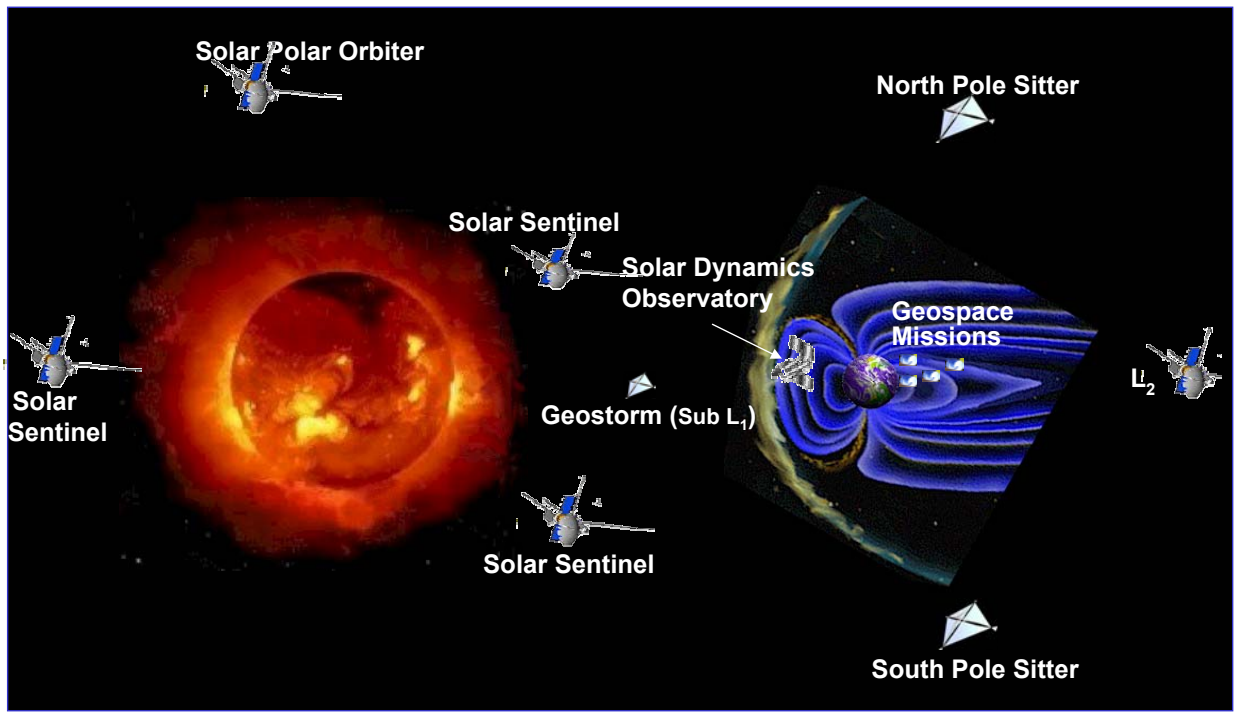
# LWS Space Weather Research Network




**Distributed network of spacecraft providing continuous observations of Sun-Earth system**

- ***Solar Dynamics Network*** **observing Sun & tracking disturbances from Sun to Earth.**
- ***Geospace Missions Network*** **with constellations of smallsats in key regions of Geospace.**

# STP/LWS TIMELINE

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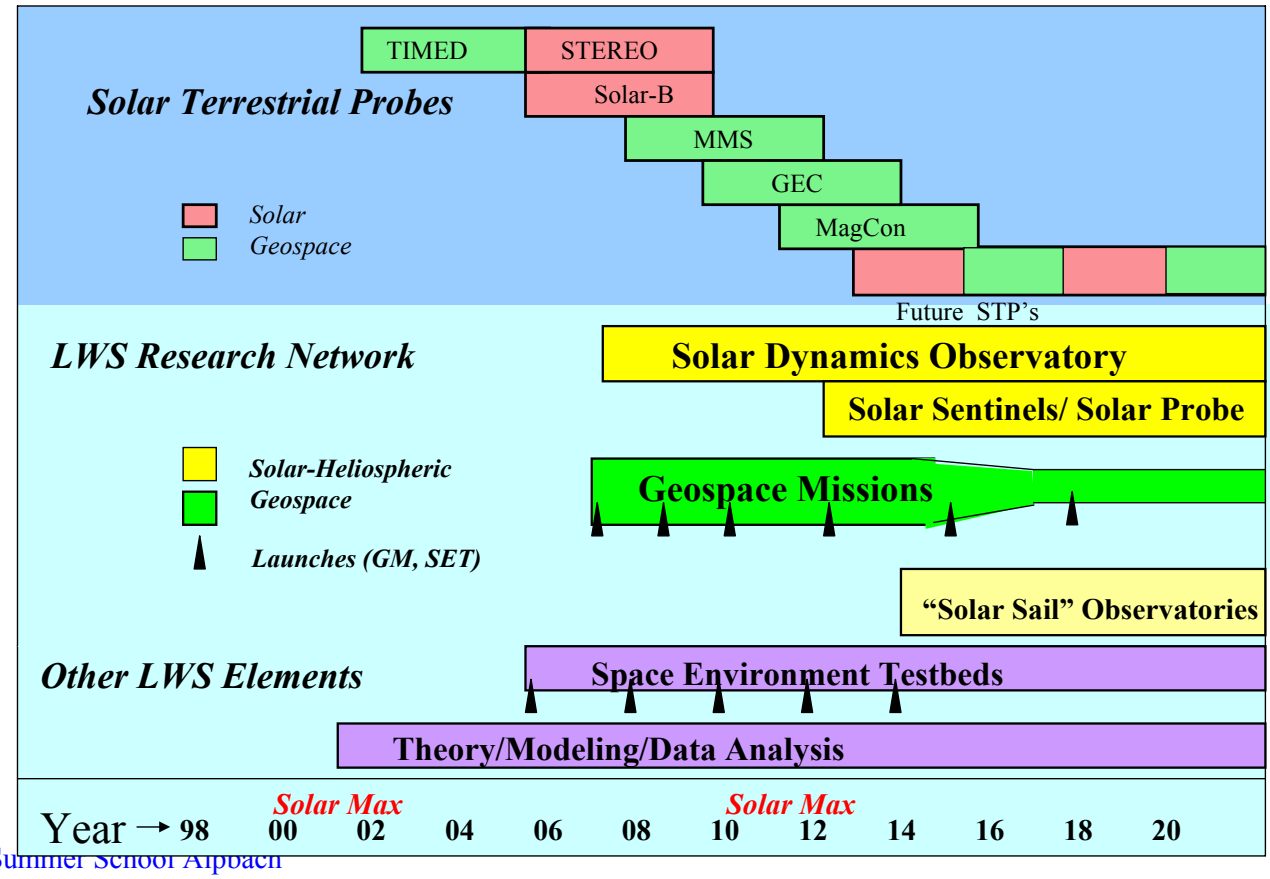
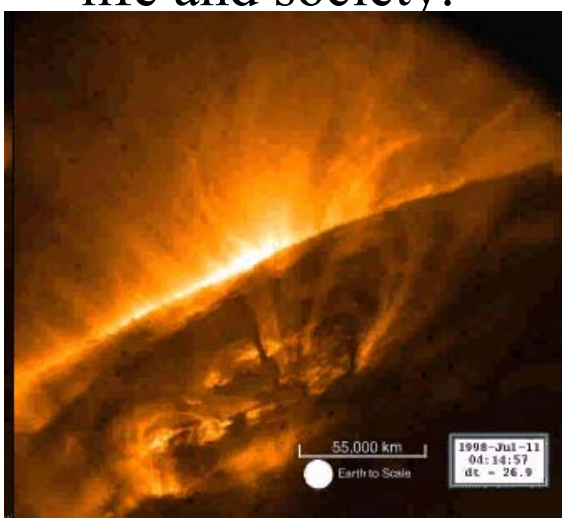
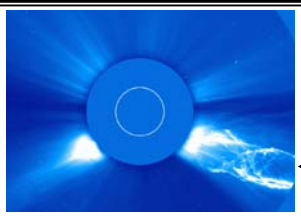





# LWS Missions Goal

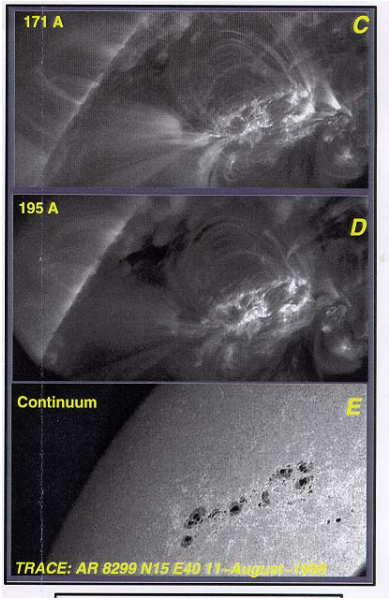
Develop the scientific understanding necessary to effectively address those aspects of the connected Sun-Earth system that directly affect life and society.



Imaging CME'S

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

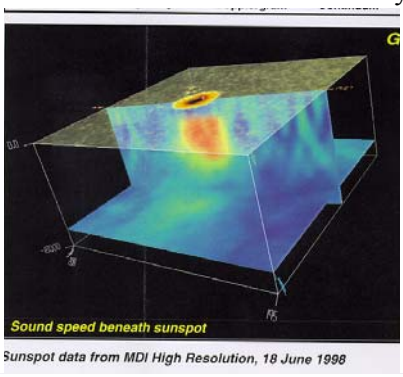



**Imaging Magnetic Structures**
**(rapid time sequences -- "movies")**

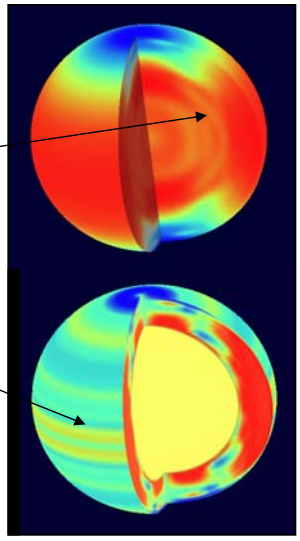
*Red: Faster Rotation*
*Blue: Slower Rotation*

**Imaging Subsurface Structures**

Solar Dynamo?




Link to solar cycle?



**Imaging Solar Interior**

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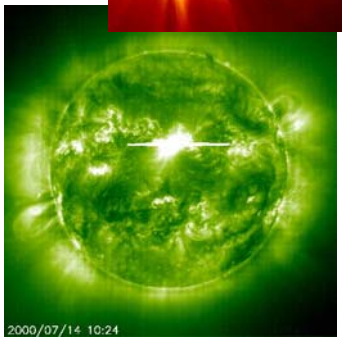
# The Solar Dynamics Observatory (SDO)

## Goal

**Observe the Sun's dynamics to increase understanding of the nature and sources of solar variations**

## Focus areas

- **Origin, structure and variability of the Sun's magnetic field**
- **Relationships between the Sun's magnetic field and solar mass and energy releases**



# The Solar Dynamics Observatory (SDO)

- **Status**
  - **Pre-mission concept is complete**
    - **Geosynchronous orbit**
    - **3-axis stabilized spacecraft**
    - **5-year primary lifetime**
    - **Complement of solar-pointed instruments selected via AO**
  - **GSFC in-house implementation approach approved by Code S**
  - **Instrument AO released in January 2002**
    - **Proposals were due on April 24; Instrument selections expected in September 2002**
- ***Launch – August 2007***





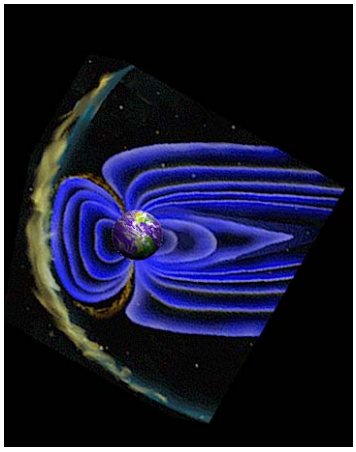
# The Geospace Missions Network

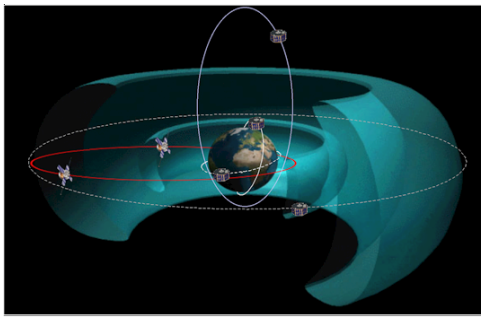
**Goal**

**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**
- **Mid-latitude Ionosphere**
  - **Effects of changes in ionizing radiation on the ionosphere**
  - **Variations of neutral density and drag, plasma density and drifts, scintillations, auroras, and winds**





# Objectives of the Geospace Plan

Understand those geospace phenomena that have the largest impact on society.

Preliminary analysis indicates that these occur in the radiation belts, the thermosphere/ionosphere and the polar cap.

Understanding *and* characterization is important for developing the needed physics-based and empirical space environment models and for diagnosing and predicting the wide variety of space weather effects:

- global climate change
- satellite anomalies
- satellite drag
- communication/navigation/radar disruptions
- human exposure to radiation



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# Implementation Approach

The Geospace Plan has four components:

- The Geospace Missions Network (primary component)
- Missions of Opportunity
- Leveraged Programs
- Instrument Development Program

# The Geospace Missions Network

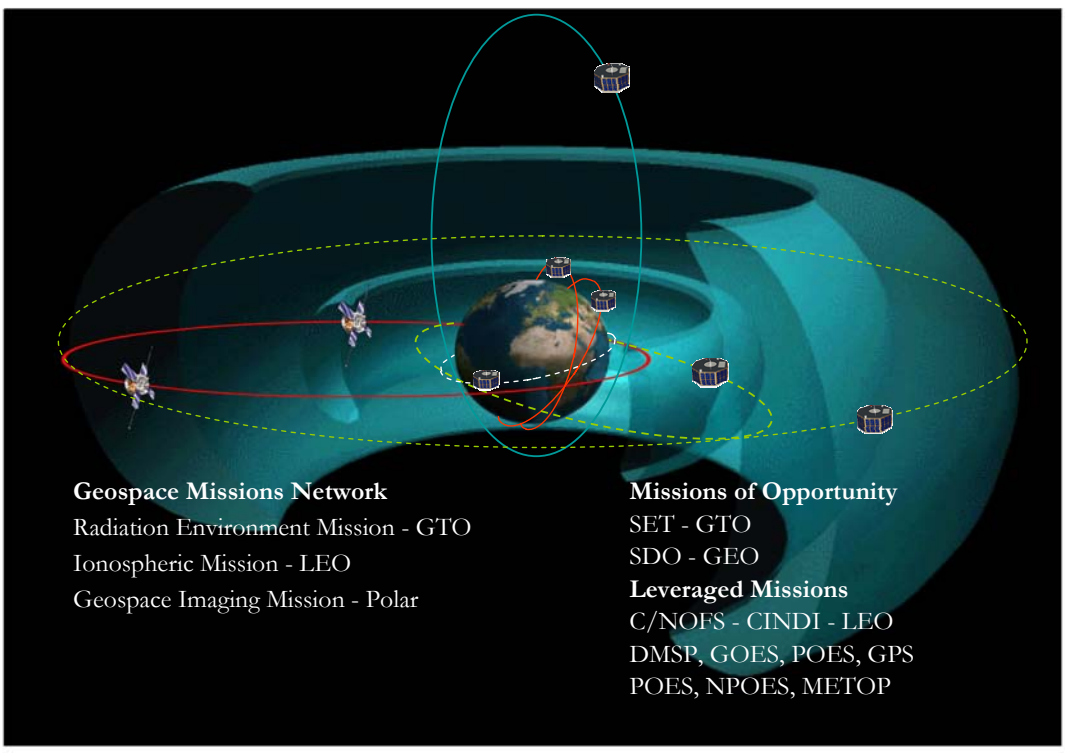
- **Status**
  - **Network science and mission architecture currently under study by Geospace Mission Definition Team (GMDT)**
    - **Science and technical support being provided by GSFC and APL**
  - **GMDT report expected in late Summer, 2002**

**Concept: Two types of spacecraft:**

- **Ionospheric Mappers: 2 spacecraft, 3 year life**
- **Radiation Belt Mappers: 2 spacecraft, 2 year life**



# Possible Geospace Network
## and Missions of Opportunity



# The 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**



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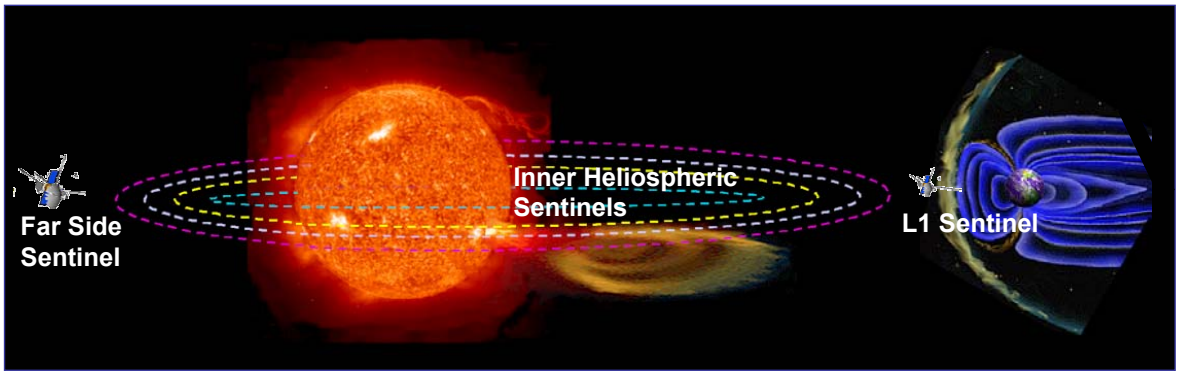
## Inner Heliosphere Sentinels Science Objectives




- Determine the structure and long-term (solar cycle and much longer) climatic variations of the ambient solar wind in the inner heliosphere *(in situ)*
- Determine how large-scale solar wind structures propagate and evolve in the inner heliosphere *(in situ combined with remote sensing)*
- Determine what dynamic processes are responsible for the release of geoeffective events *(in situ combined with remote sensing)*
- Determine how and where energetic particles are released and accelerated *(in situ combined with remote sensing)*

# Inner Heliosphere Sentinels Objectives

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*Solar Orbiter (SO) carries relevant instruments*

| Science Objectives | Space Weather Application | Measurement Requirement | Location |
|---|---|---|---|
| What is the ambient 3D structure of the heliosphere near the ecliptic? | Increase accuracy of forecasts<br>Input to climatology models<br>Radial profile | Solar wind plasma and composition<br>Vector magnetic field<br>Energetic particles<br>Remote sensing of heliosphere | From various radial and longitudinal ventage points in the inner heliosphere |
| How do large structures evolve during transit to Earth? (CMEs, Shocks, Fast Streams) | Increase accuracy of forecasts<br>Input to models<br>Radial profile | Solar wind plasma and composition<br>Vector magnetic field<br>Radio burst tracker<br>Remote sensing of heliosphere<br>Remote sensing of photosphere/corona | From various radial and longitudinal ventage points in the inner heliosphere<br>Both sides of the Sun |
| What are the dynamic processes in the corona as can be determined from heliospheric observations? | Identify source regions and mechanisms hence provide forecasting capability. | Solar wind plasma and composition<br>Vector magnetic field<br>Energetic particles<br>Remote sensing of photosphere/corona | From various radial and longitudinal ventage points in the inner heliosphere<br>Both sides of the Sun |
| How and where are energetic particles released and accelerated? | Develop SEP forecasting capability. | Energetic particles<br>Radio burst tracker<br>Vector magnetic field<br>Remote sensing of photosphere/corona | From various radial and longitudinal ventage points in the inner heliosphere<br>Both sides of the Sun |

= ***In situ*** **obs. also planned for SO**

= **Some obs. capability on SO**



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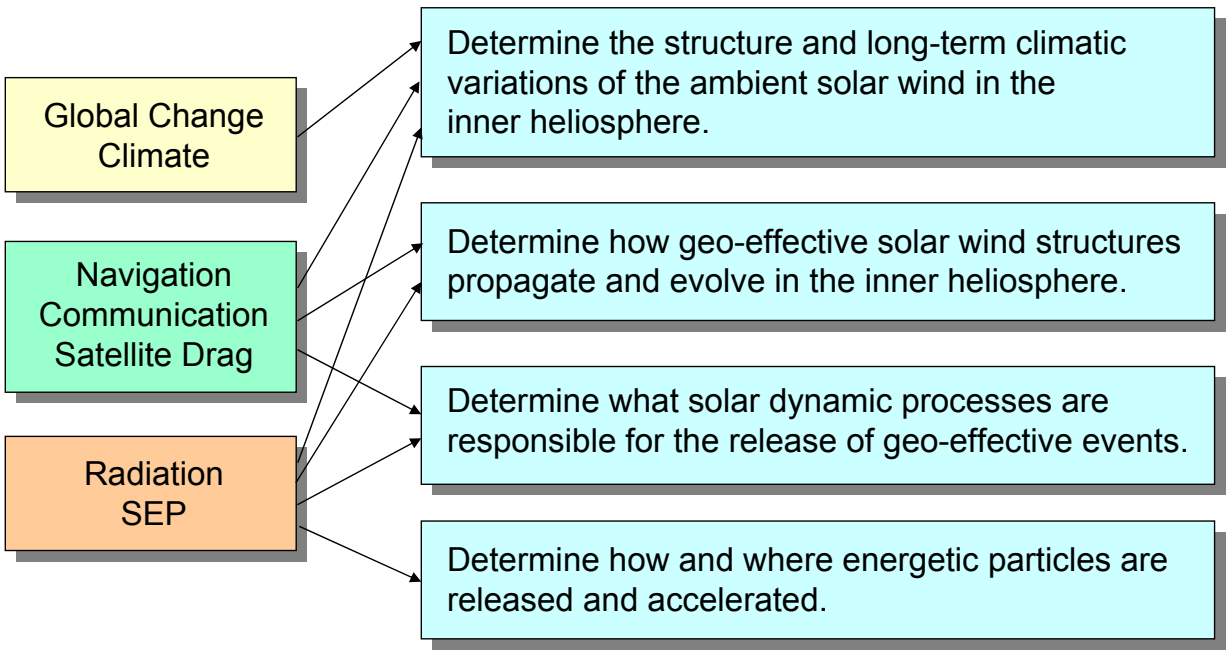
## Societal Impacts

## Science Objectives

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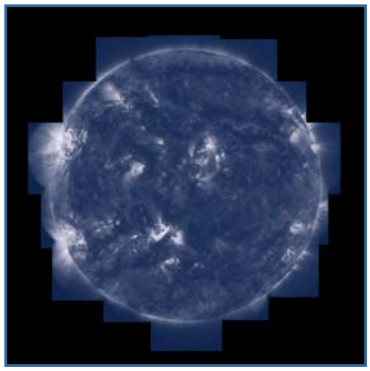
# *Living With A Star, Targeted Research & Technology aka Theory, Modeling And Data Analysis (TMDA)*

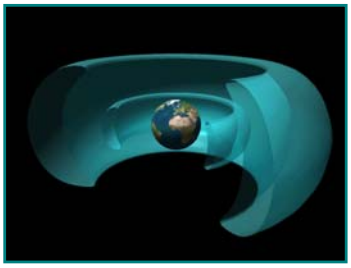
## Objective

**Perform ground-based research to refine the understanding of space weather & the role of solar variability in terrestrial climate change**



## Approach

- **Develop new instrument techniques, models, and concepts for investigating solar and geospace disturbances**
- **Improve scientific knowledge of space environment conditions and variations over the solar cycle**
- **Improve understanding of the effects of solar variability on long-term climate change**
- **Improve the environment specification models & predictive capability**
- **Issue of yearly Research Opportunities in Space Sciences (ROSS) Announcement of Opportunity**



**Status:** ***The 2002 Research Opportunities in Space Science NASA Research Announcement (NRA) solicited 2 types of investigations:***

*Science investigations using existing space data & Geospace instrument development*

*Proposals were due on 4/12/02 & are being evaluated*



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## Targeted Data Analysis & Modeling

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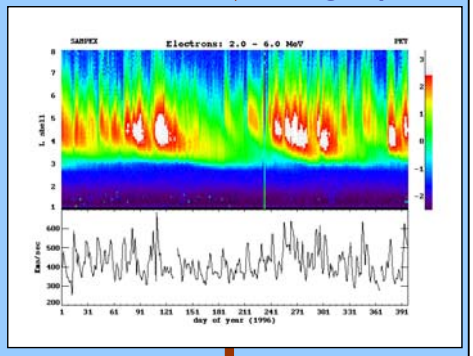
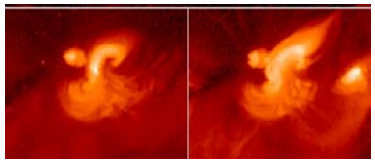
**Exploit data from present and past missions:**

- **To improve knowledge of space environmental conditions and variations over solar cycle.**
  - **To obtain reliable environmental specs for cost-effective design of spacecraft and subsystems to minimize space environmental effects & damage.**
  - **Important for commercial comsats and military space systems which must have "all weather" capability.**
- **Develop new techniques and models for predicting solar/geospace disturbances which affect human technology.**
  - **Recent example: "S Marks the Spot" discovery of an x-ray signature in regions with high probabilities for producing CME's.**
- **Develop cost-effective techniques for assimilating data from networks of spacecraft.**

***Science - Data → Design Specs***



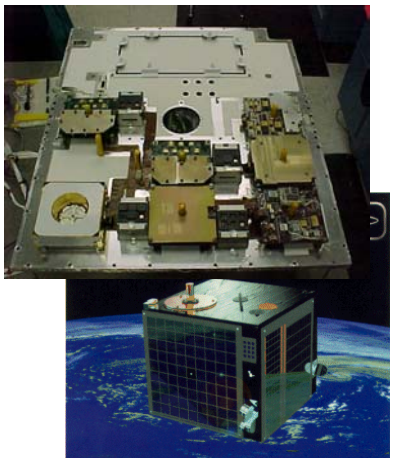

***Bridges Gap Between Science Data Collection & Design/Ops Engineer***



# Living With a Star Space Environment Testbeds

## Objective

- Improve the engineering approach to accommodate and/or mitigate the effects of solar variability on spacecraft design & operations

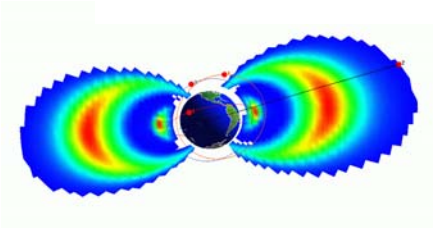


## Approach

- Collect data in space to validate the performance of instruments for LWS science missions & new space technology
- Collect data in space to validate new & existing ground test protocols for the effects of solar variability on emerging technologies & components
- Develop & validate engineering environment prediction & specification models, tools, & databases

## Scope

- Spacecraft hardware & design /operations tools whose performance changes with solar variability





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*Living With a Star Space Environment Testbeds*

## *Status*

***•An SET Pathfinder has been approved: 3 experiments from STRV 1-d***

*–Experiments include partners from CNES, ONERA, & TIMA*

*–NASA is proposing with ESA on an ESA-led proposal submitted to the ESA-issued "Call for Ideas" for the next PROBA (2) mission; proposals are due 5/15/02*

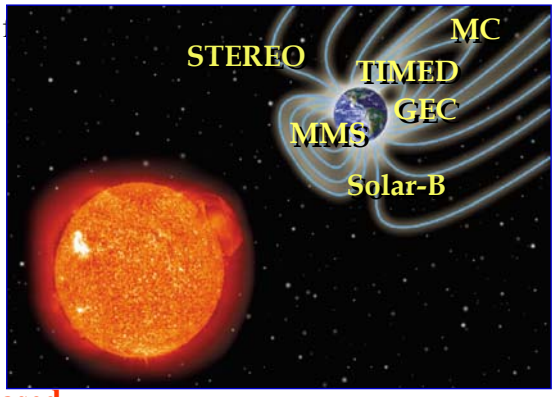
***•SET plans follow-on projects every ~2 years***

*–Experiments in 5 categories will be solicited from partnering & an NRA due out in ~6/02*

***•Categories are: Induced environments; materials performance; detectors/sensors; microelectronics; and spacecraft charging/discharging***

# Solar Terrestrial Probes (STP) Program

- A strategic element of the Sun-Earth Connection Science Roadmap
- A continuous sequence of flexible missions designed for the sustained study of critical aspects of the connected Sun-Earth system
- A creative blend of in-situ and remote sensing observations, multiple platforms, addressing focused science objectives
- The community-selected initial Solar Terrestrial Probes are:
  - Thermosphere Ionosphere Mesosphere Energetics Dynamics (TIMED) (**Launched 12/7/01**)
  - Solar-B (**Development Phase**)
  - Solar-Terrestrial Relations Observatory
  - (STEREO, **Confirmed for Development Phase**)
  - Magnetospheric Multiscale (MMS, **AO to be released in Summer, 2002**)
  - Global Electrodynamic Connections (GEC, **Pre Phase A**)
  - Magnetospheric Constellation (MC, **Pre Formulation**)




*Initial STP Missions*



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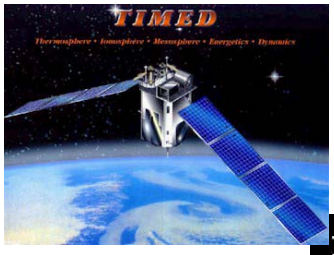
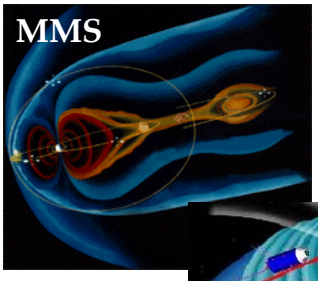
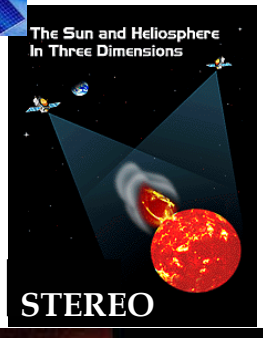
# Solar Terrestrial Probes (STP)




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

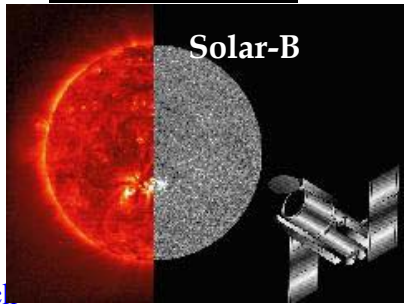



Understand fundamental plasma processes of reconnection, acceleration and turbulence



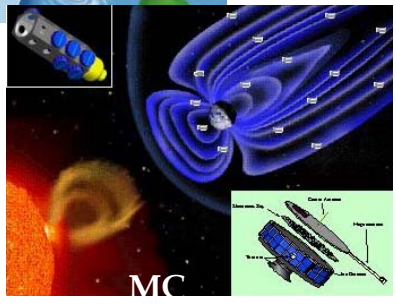

Understand origin, evolution, and propagation of CME's


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

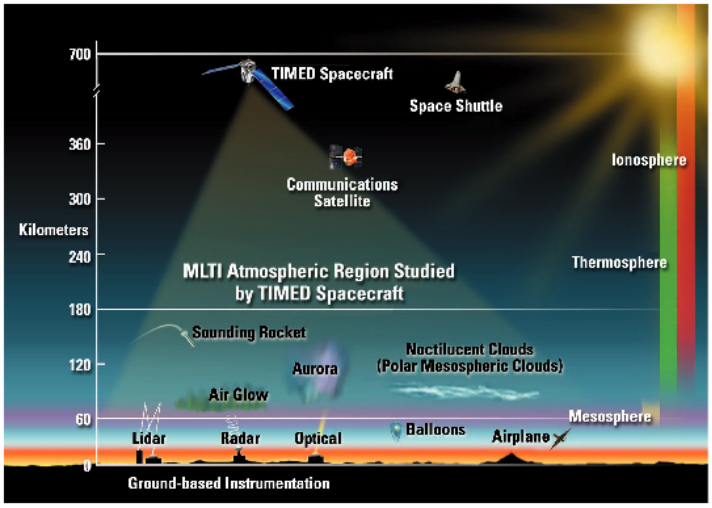


# Thermosphere Ionosphere Mesosphere Energetics and Dynamics (TIMED) Project

M. Guhathakurta NASA Headquarters7/23/02-8/1/02

## Science Objectives

- Global investigation of MLTI region between 60 - 180 km.
- Temperature, pressure, chemical composition, winds, energy inputs and outputs.
- Four Principal Investigators
- Six Interdisciplinary Investigators
- National Science Foundation/CEDAR ground-based Collaborative Investigators
- **Launched December 7, 2001**




Summer School Alpbach

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# Magnetospheric Multiscale (MMS) Science Objectives

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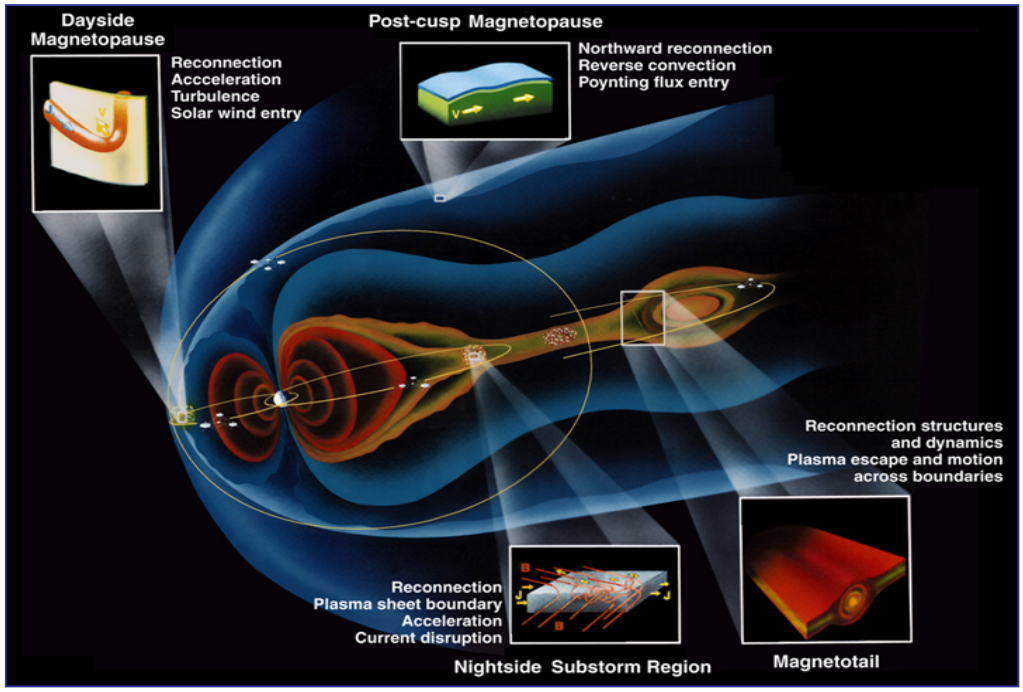
## The Solar Terrestrial Probe for Understanding Fundamental Plasma Processes

- **Understand the fundamental physical processes of:**

**- Reconnection**
**- Acceleration**
**- Turbulence**

**AO to be released in Summer, 2002**

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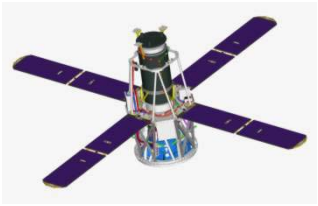
# High Energy Solar Spectroscopic Imager (RHESSI)



SMEX

***Principal Investigator***
Dr. Robert Lin
Univ. of California, Berkeley

***Science Theme***
Sun-Earth Connection (SEC)

***Launch Date/Site***
February 2002, KSC/ETR

***Launch Vehicle***
Pegasus XL

***GSFC Project Manager***
Frank Snow

***Major Partners***
Paul Scherrer Institute
Goddard Space Flight Center
University of California, Berkeley
Spectrum Astro

***Science Objective***

The primary objective of the HESSI mission is to explore the basic physics of particle acceleration and energy release in solar flares.

**Launched February 5, 2002**



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M. Guhathakurta NASA Headquarters7/23/02-8/1/02

## *Potential ESA-NASA SEC Missions Discussed*

**A joint meeting was held between ESA and NASA on April 15, 2002 to coordinate and collaborate on solar terrestrial physics missions and programs to maximize the possibilities for complementary and/or synergistic science.**

**Missions discussed on ESA-NASA sides were:**

**ESA: Solar Orbiter, Bepi Colombo (Solar Sentinel aspect).**

**NASA: Solar Dynamics Observatory (SDO), Geospace Missions, Solar Sentinels, Space Environment Testbeds, Future STP Missions.**

**Outcome:**

1. **US scientists to participate in ESA's Solar Orbiter Payload definition team (meeting at Estec on May 13-15, 2002).**
2. **A task group involving ESA-NASA officials to coordinate collaboration on the early LWS and SEC missions such as SDO, Geospace component of LWS and MMS.**
3. **A working group to coordinate collaboration on intermediate term missions in LWS such as the Solar Sentinels and ESA's Flexi mission, the Solar Orbiter**

## *Draft Charter of the Joint ESA-NASA Solar Orbiter/Solar Sentinels Working Group*

**The Working Group shall study how to modify existing concepts of the Solar Orbiter and Solar Sentinels to more effectively achieve their combined science goals by looking for synergies and complementarities between the two programs. In particular, the Working Group shall:**

- ***Synthesize the goals of the Solar Orbiter and Solar Sentinels as presently defined to determine a prioritized set of science objectives that will enable the LWS and ILWS programs to achieve their stated goals.***
- ***Optimize the scientific cost benefit by devising an implementation strategy that combines NASA and ESA resources.***
- ***Identify key science objectives that can only be accomplished jointly, but not separately.***
- ***Suggest combined mission scenario options to accomplish the ILWS goals.***

**The International Living With a Star Working Group will coordinate the proposed ESA/NASA implementation strategy for the Solar Orbiter and Solar Sentinels with the overall implementation strategy for the International Living With a Star program.**

**Specific Science Definitions Teams will use this report to further refine the specific missions.**

**Schedule & Products**

- ***Establish the charter of the joint working group in May/June 2002***
- ***Formation of the WG and kick off meeting in September/October 2002***
- ***Final report due within a year***



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## *Working Group on International Living With A Star (ILWS-WG)*

**In January, 2002, the IACG accepted the recommendation of the task group that met May 15-17 in Tenerife, and asked NASA to serve as the lead agency in setting up a working group to study prospects for developing an ILWS program.**

**NASA is planning to host the first kick off meeting for ILWS in September 4-6, 2002 in Washington, DC.**

## Purpose of the ILWS-WG:

**To facilitate coordination of solar-terrestrial missions and programs of International space agencies to:**

***(1) Maximize possibilities for complementary and/or synergistic science.***

- ***Optimize the scientific cost benefit obtained from the available resources.***

## *Working Group on International Living With A Star (ILWS-WG)*

## SCOPE:

**The ILWS-WG will:**

- ***Review present programs and plans of participating agencies to study Sun-Earth connections.***
- ***Foster establishment a common architecture for coordinated, synergistic study of the Sun-Earth connected system.***
- ***Facilitate collaboration on projects between agencies in an international Sun-Earth connection program.***
- ***Periodically communicate results of its activities to the scientific community.***

## MEMBERSHIP OF THE ILWS-WG:

***Members of the working group will consist of scientific and/or technical program representatives from national and international agencies planning to contribute to the ILWS program and its space missions. Contributions can consist of instruments, major subsystems of instruments or spacecraft, spacecraft, launch, and/or tracking. The agency representatives will be responsible for collecting and presenting information, inputs, and program priorities from his or her agency. It is expected that each agency will be represented by a small number (one to three) of representatives. NASA will chair the first organizational meeting of the ILWS-WG.***



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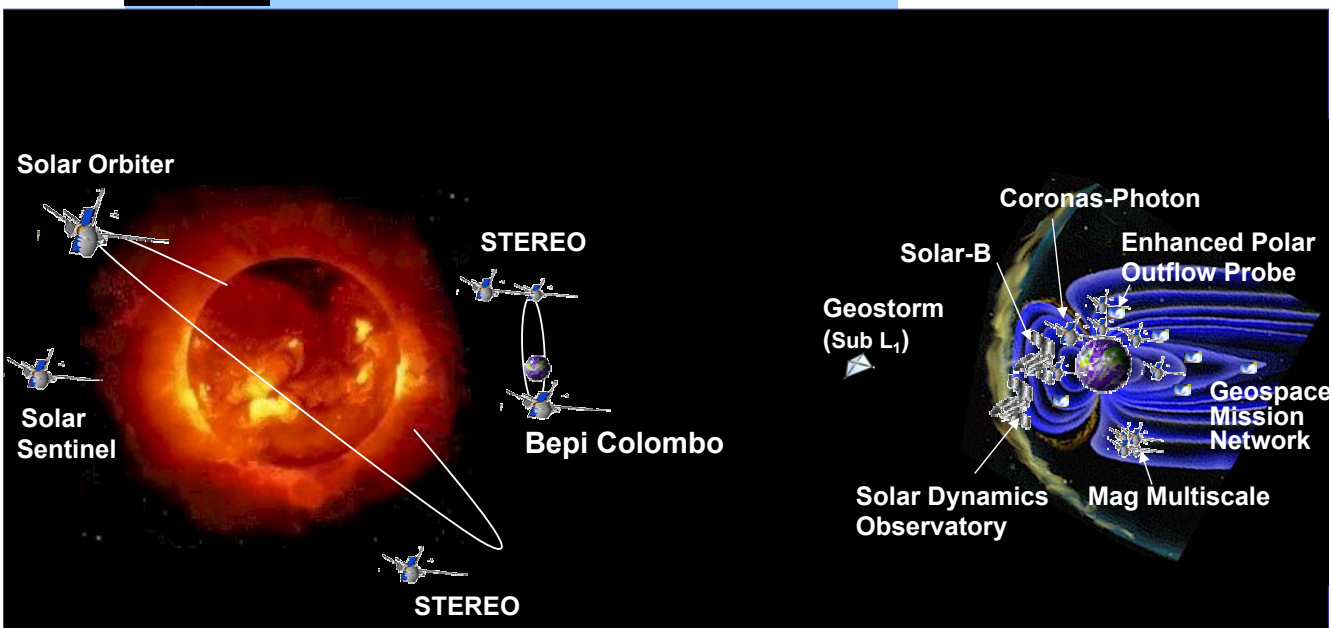
## *International Living With a Star Some Candidate Missions*




**Distributed network of spacecraft providing observations of Sun-Earth system.**

- ***Solar-Heliospheric Network*** **observing Sun & tracking disturbances from Sun to Earth.**
- ***Geospace Mission Network*** **with constellations of smallsats in key regions of geospace.**