Extended Missions

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My Experience

- **Experiment scientist on Skylab 1973-**
- **Experiment scientist on SMM 1980-**
- **US project Scientist for the joint ESA/NASA mission SOHO 1985-1998**
- **Senior Project Scientist for the Living With a Star program 1999-2003**
- **Assistant to the NASA Chief Scientist 1999-2003**

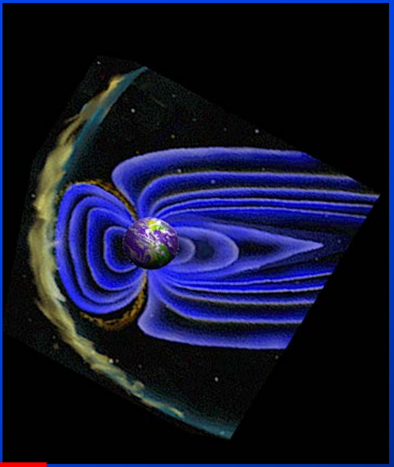
Heliophysics Big Picture

- What do we want to achieve scientifically?
- Some background about the system.
- How we want to achieve it.
- Overview of Missions
- Address questions of panel task
- Address questions from panel.

The Sun-Earth Connected System

Variable Star

Planet



Varying

- Radiation
- Magnetic field
- Solar Wind
- Energetic Particles

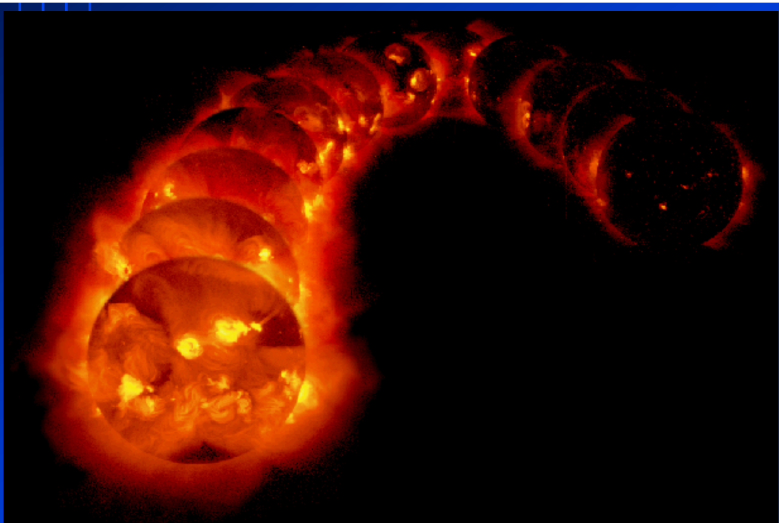
Interacting

- Solar Wind
- 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

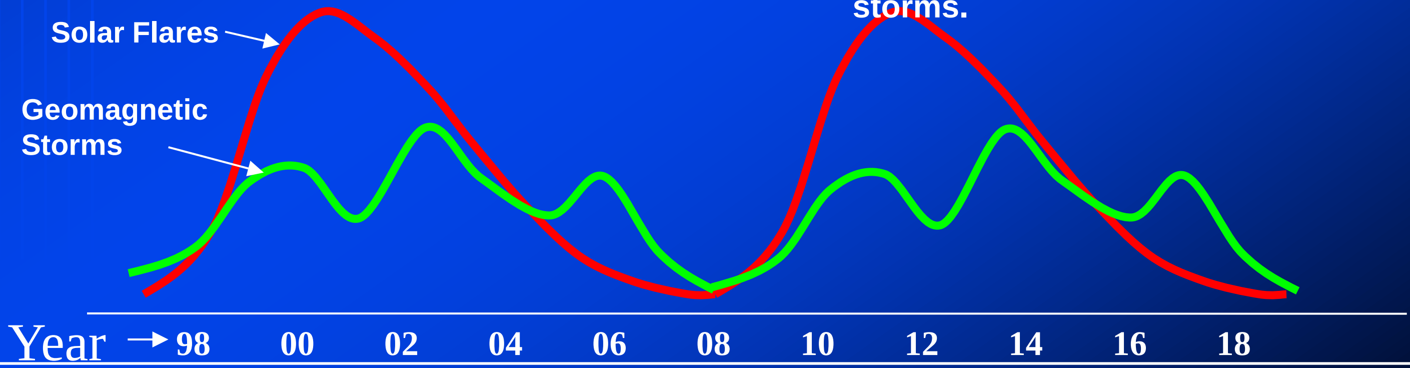


Solar Maximum:

- 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.

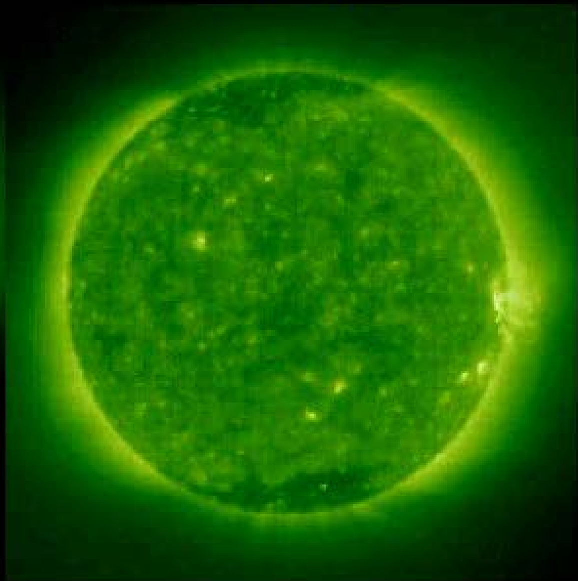
Declining Phase, Solar Minimum:

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

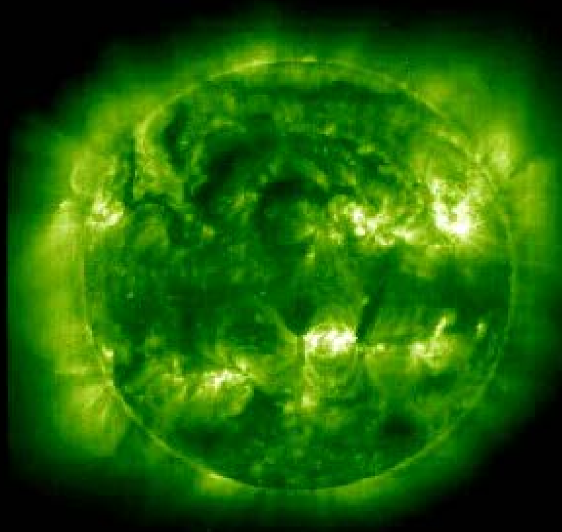


EIT Solar Min-Max

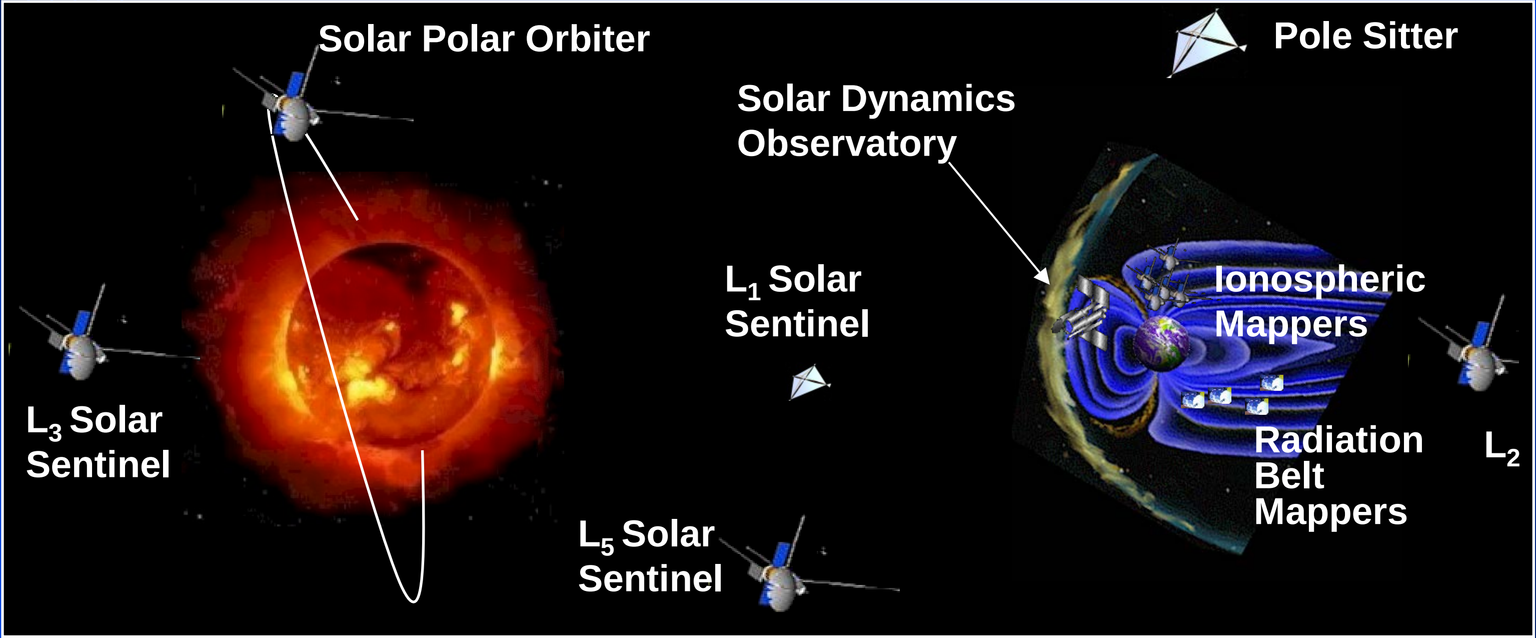
EIT 195 Å
Dec. 1996



EIT 195 Å
June 1999



Desired Living With A Star 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 Dynamics Network*** **with constellations of smallsats in key regions of geospace.**

Benefits of Extensions

1. Overall opinion
   a. Individual instruments
   b. Total system
2. Solar Missions
3. Heliospheric Missions
4. Geospace Missions

a) Individual Instruments: Extended Missions

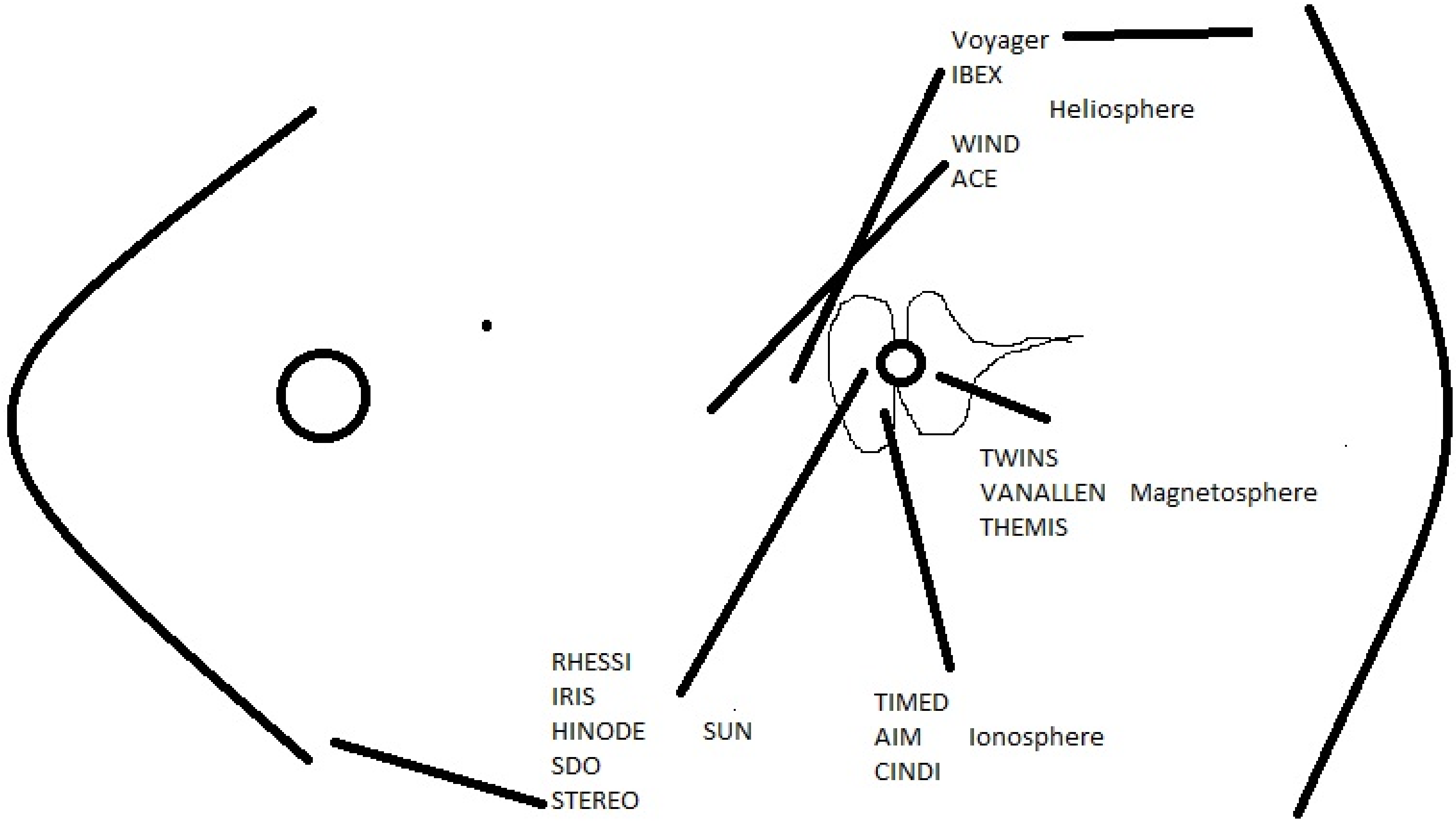
- It takes a significant amount of time after launch to understand the characteristics of an instrument and how best to operate it. Frequently the best observations are made during the extended phase.
- We don't have the resources to launch many instruments at the same time. To cross calibrate and make complementary observations, at least some missions need to operate beyond the primary planned mission phase.

a) Individual Instruments: Extended Missions (cont.)

- The scientific cycle is:
  - Observation,
  - Analysis,
  - Modeling,
  - Suggest new observations,
  - Repeat cycle.
- This cycle time is almost always longer than a mission’s primary phase.

b) Total System: Extended Missions

- In heliophysics we are studying a system from the interior of the Sun (helioseismology) to interstellar space (Voyagers).
  - Helioseismology, primarily the generation of magnetic fields that drive the system.
  - Everything else, measures the response of the system.
- This requires simultaneous measurements throughout this environment.



Voyager
IBEX
Heliosphere
WIND
ACE
TWINS
VANALLEN
Magnetosphere
THEMIS
RHESSI
IRIS
HINODE
SUN
SDO
STEREO
TIMED
AIM
Ionosphere
CINDI

b) Total System: Extended Missions: cont.

- There are obviously not the resources to build, launch, and operate all of the instruments and spacecraft needed simultaneously. Thus, the need for extended missions.
- The total scientific process that leads to new and improved science, using existing spacecraft, requires a longer time frame than the prime phase of missions.

Summary of Benefits

- The highest quality science from most instruments and spacecraft are obtained after the prime phase, when scientists have obtained a better understanding of their instruments.
- The system science of heliophysics requires that at least some, if not all, spacecraft operate during an extended phase.

Solar Missions

Spacecraft	Launch Date
SOHO	1995
RHESSI	2002
Hinode	2006
Stereo	2006
SDO	2010
IRIS	2013

- SOHO ESA/NASA, very limited
- Hinode Japan/NASA

Geospace Missions

Spacecraft	Launch Date
TIMED	2001
AIM	2007
Themis	2007
TWINS	2008
CINDI	2008
VanAllen	2012

Heliosphere

Mission	Launch Date
Voyager	1977
Wind	1994
ACE	1998
IBEX	2008

Total Cost of all Extended Missions

~$80,000,000.

This includes mission operations, data reduction to level 1 and sometimes higher, and some PI team science.

Senior Review Process

- Proposals for extension submitted by each PI team.
- Panel of cognizant scientists created by NASA HQ
- Panel reviews proposals and rates missions based on past performance and proposed work. This includes how well the spacecraft and instruments are functioning.
    - This process is quite rigorous in that most panel members are intimately aware of the data quality and science being addressed by more than one mission.

Biennial Senior Reviews

- As a previous project scientist, it is my opinion that the two year review cycle is unnecessary and onerous on the PI teams and project scientist. The time could be better spent doing science.
- It may be helpful to allow more discussion between HQ and the project scientists and allow more discretion on the part of the HQ responsible person.
- In the review process I noticed that one or two disgruntled scientists made it difficult to produce a truely objective review.

Balance Between New and Old

- As stated above, the cost of extending approximately 15 older missions is on the order of $80 million.
- One new reasonable sized mission costs between $300 million and a billion or more.
- One does not gain many new missions by ending older missions.
- There is also the issue that it takes time to understand the data from a new mission, so extensions are necessary.

Innovation

One of the most cost effective innovations that NASA could invoke would be the acceptance of risk. This would be in the areas of spacecraft and instrument building and mission operations.

END