Space Physics:

Recent Advances and Near-term Challenge

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- Significant advances from the past decade
- Key scientific challenges
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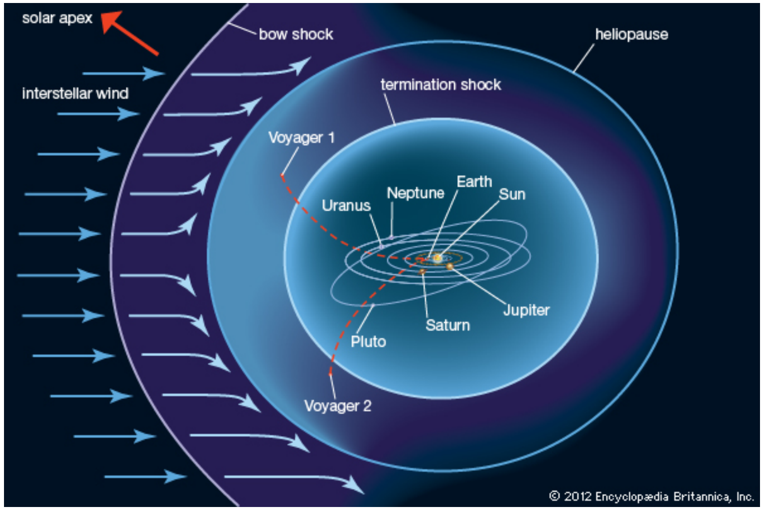
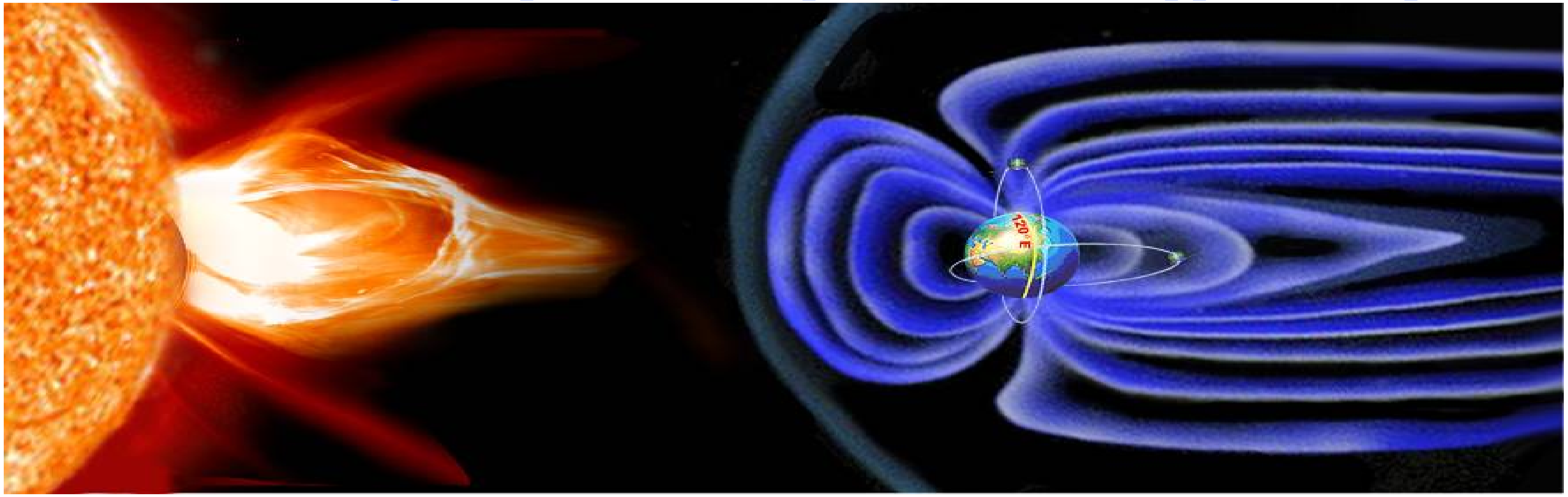
Scope of Space Physics



Heliosphere: **covers the physics of the solar wind and its expansion through interplanetary space**

Solar wind – magnetosphere – ionosphere – middle-upper atmosphere



Advances: Heliosphere

- Observations of propagating disturbances from Sun to Earth, and beyond, and combination of in-situ and remote-sensing observations from different perspectives, including continuous in-situ L1 monitoring of solar wind and SEP properties, multi-point, multi-scale measurements in near-Earth solar wind, and use of interplanetary scintillation for heliosphere mapping
- Stereoscopic views of heliospheric events
- Observations of wide-angle SEP events
- Exploratory modeling of CME propagation

Advances: SW-M Interaction

- Continuous remote-sensing of solar activity and in-situ L1 monitoring of solar wind and SEP properties
- Multi-point, multi-scale measurements within the magnetosphere and improved coverage by ground-based observatories
- Advanced magnetospheric modeling, including CME-geomagnetic-field interactions, in different approaches (MHD, hybrid, kinetic) and including energetic particles
- Improved characterization of substorm dynamics (field evolution, system couplings)

Advances: ITM

- **Extending observational coverage and increasing regional resolution of ITM dynamics , enabling near real-time TEC and critical-frequency maps, and advances in 3D reconstruction**
- **Empirical model development based on long-term data bases**
- **Development of physics-based models and understanding of the processes involved**

Highlight - 1

Significant progress in understanding the origin and evolution of the solar wind

New observations of the photosphere and lower corona from Hinode, SDO etc. have revealed significant information on the mechanisms of coronal heating, which is ultimately the driver of the solar wind.

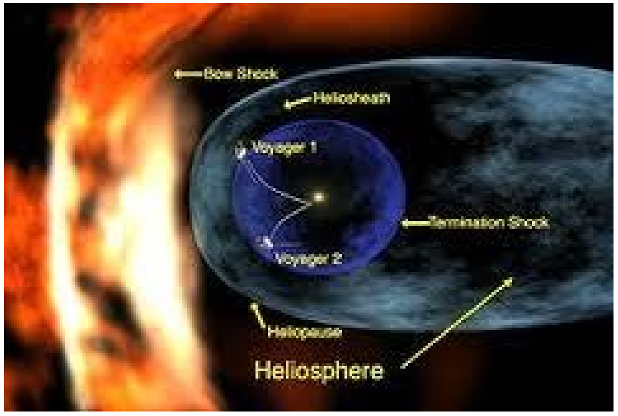
Highlight - 2

Striking advances in understanding both explosive solar flares and the coronal mass ejections that drive space weather

Significant progress was made in understanding how magnetic energy is explosively released in flares, and CMEs are likely due to distortions of the coronal magnetic field.

Highlight - 3

Groundbreaking discoveries about the surprising nature of the boundary between the heliosphere and the surrounding interstellar medium

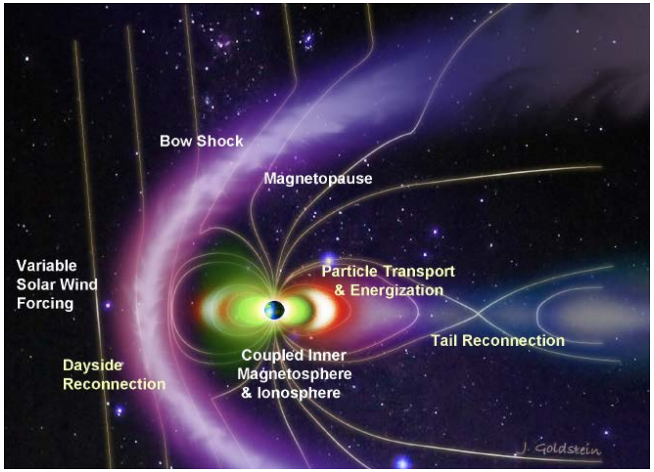


A series of groundbreaking discoveries were made as the Voyager spacecraft approached and crossed the termination shock (TS) and entered the heliosheath on their way to the heliopause.

These measurements and results from the Interstellar Boundary Explorer (IBEX) and Cassini have significantly altered our understanding of how the solar system interacts with the interstellar medium

Highlight - 4

New imaging methods that permit researchers to directly observe space weather-driven changes in the particles and magnetic fields surrounding Earth



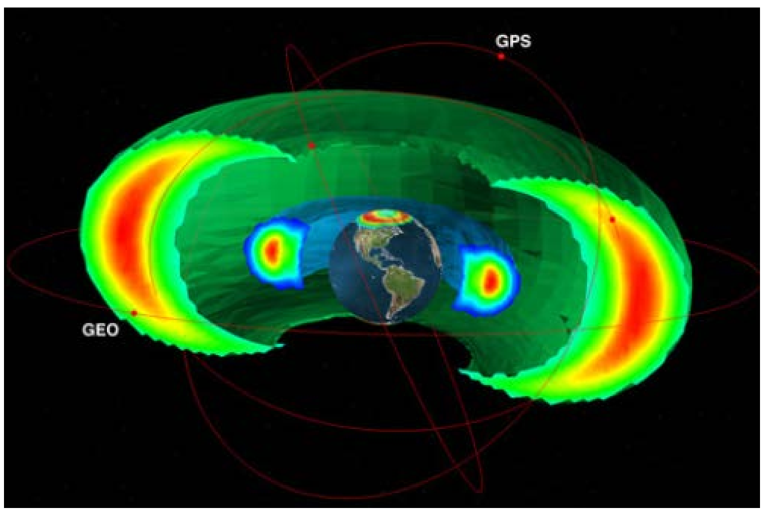
Global imaging of the invisible plasma populations of the magnetosphere was used to identify its large-scale response to this variable solar wind forcing.

The plasmasphere was imaged in the extreme ultraviolet.

Numerical models and global energetic neutral atom (ENA) imaging were used to image the ring current

Highlight - 5

Significantly deeper knowledge of the numerous processes involved in the acceleration and loss of particles in Earth's radiation

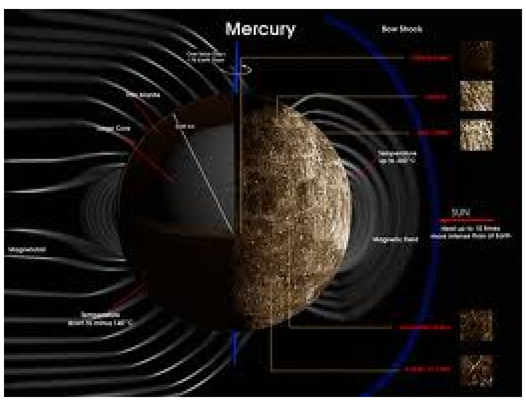


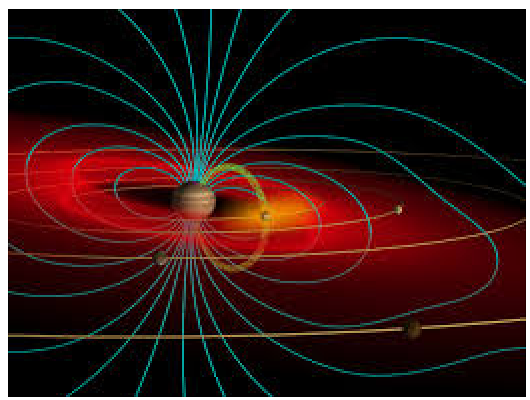
Substantial progress was made understanding how magnetic reconnection works.

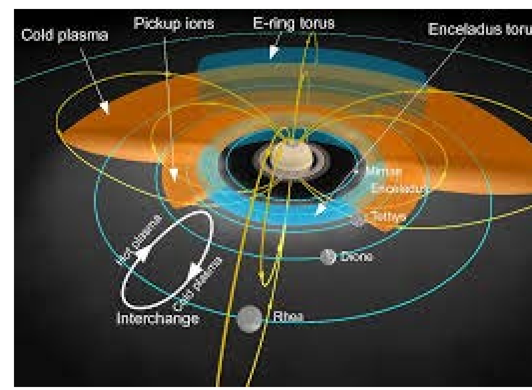
Wave-particle interactions (WPI) have been established as key drivers of particle energy gain and loss in the radiation belts

Highlight - 6

Major advances in understanding the structure, dynamics, and linkages in other planetary magnetospheres (Mercury, Jupiter, and Saturn)



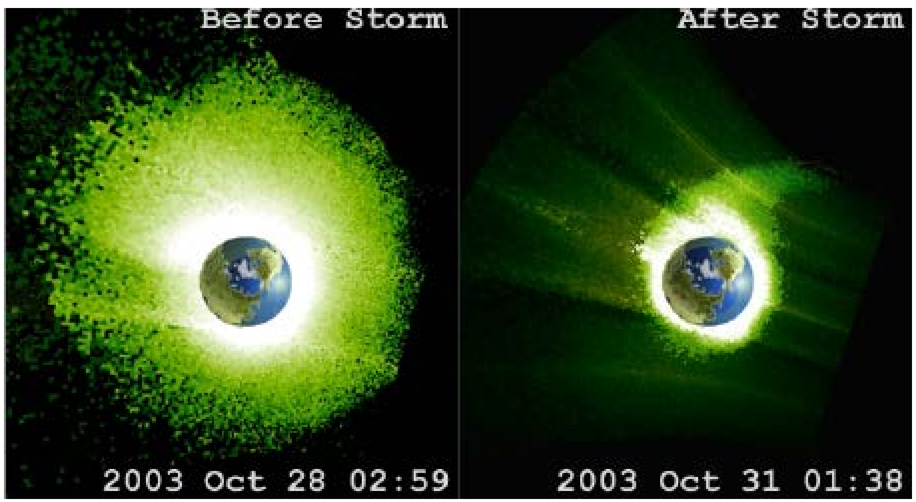




Mercury

Highlight - 7

New understanding of how oxygen from Earth's own atmosphere contributes to space storms

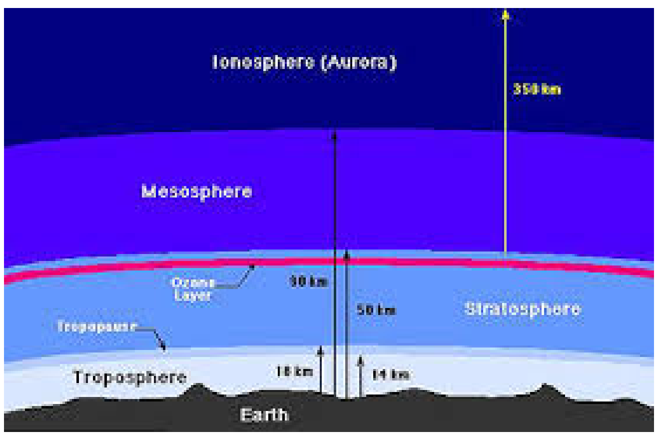


Recent results from NASA's FAST and IMAGE satellites revealed intense outflows of ionospheric ions during storms.

The influence of the O+ outflow plays an important role in global magnetospheric dynamics

Highlight - 8

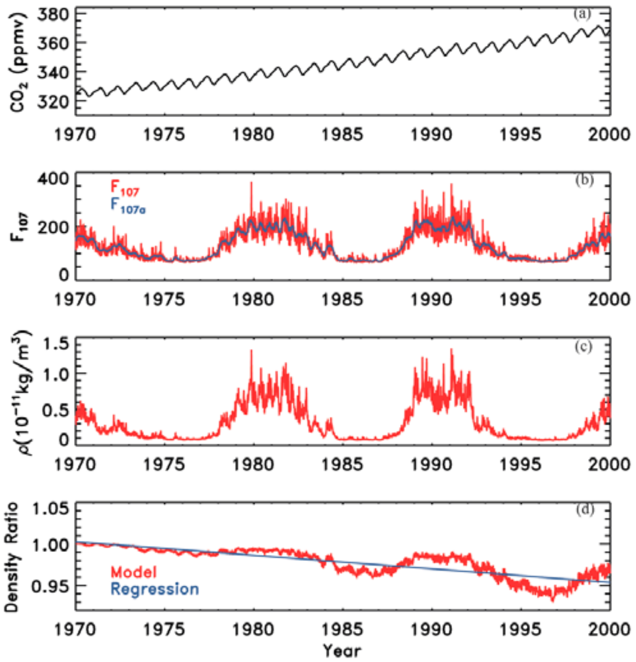
The surprising discovery that conditions in near-Earth space are linked strongly to the terrestrial weather and climate below



Present estimates indicate that waves propagating upward from the lower atmosphere contribute about as much to the energy transfer in the ionosphere-thermosphere system as does forcing from above in the forms of solar EUV and UV radiation, precipitating particles, resistive heating and winds driven by magnetospheric convection.

Highlight - 9

The emergence of a long-term decline in the density of Earth’s upper atmosphere, indicative of planetary change



A systematic decrease by several percent per decade in thermosphere mass density is now evident in the record of satellite orbit decay measured since the beginning of the space age. This change is thought to be largely in response to the increase in atmospheric CO2.

Key Scientific Goals

- **Goal 1.** *Determine the origins of the Sun's activity and predict the variations of the space environment.*
- **Goal 2.** *Determine the dynamics and coupling of Earth's magnetosphere, ionosphere, and atmosphere and their response to solar and terrestrial inputs.*
- **Goal 3.** *Determine the interaction of the Sun with the solar system and the interstellar medium.*
- **Goal 4.** *Discover and characterize fundamental processes that occur both within the heliosphere and throughout the universe.*

Challenges: Heliosphere

- **Determine how magnetic energy is stored and explosively released and how the resultant disturbances propagate through the heliosphere**
- **Shock propagation through pre-existing solar wind and resulting SEP production and propagation**
- **Improved understanding of how heliospheric magnetic field and solar wind modulate galactic cosmic rays**
- **Discover how the Sun interacts with the local interstellar medium**

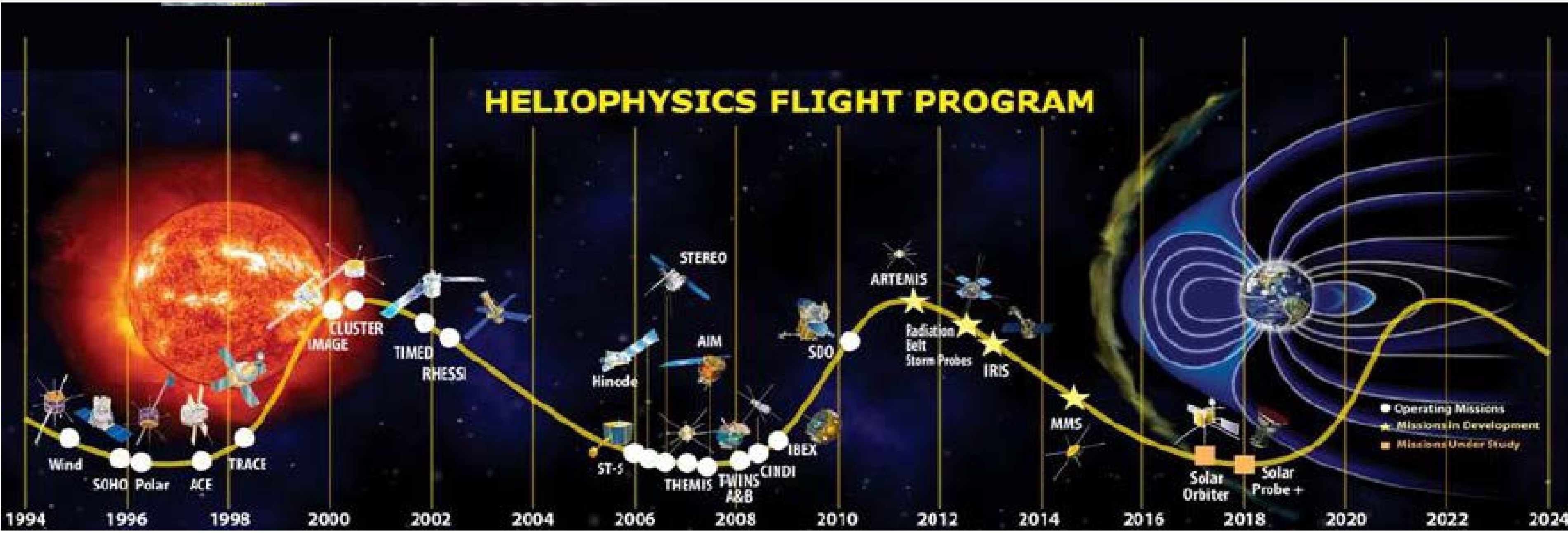
Challenges: SW-M Interaction

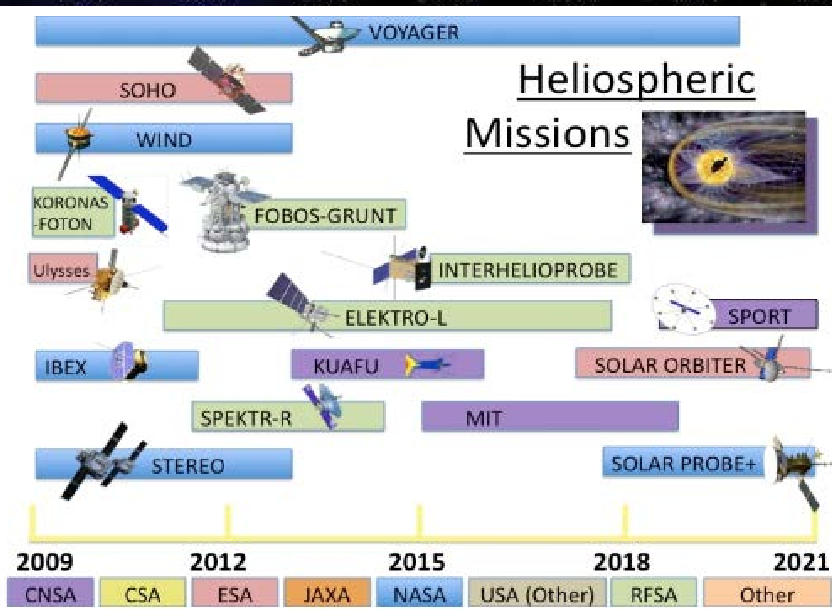
- Establish how magnetic reconnection is triggered and how it evolves to drive mass, momentum, and energy transport.
- Identify the mechanisms that control the production, loss, and energization of energetic particles in the magnetosphere.
- Determine how coupling and feedback between the magnetosphere, ionosphere, and thermosphere govern the dynamics of the coupled system in its response to the variable solar wind.
- Critically advance the physical understanding of magnetospheres and their coupling to ionospheres and thermospheres by comparing models against observations from different magnetospheric systems.

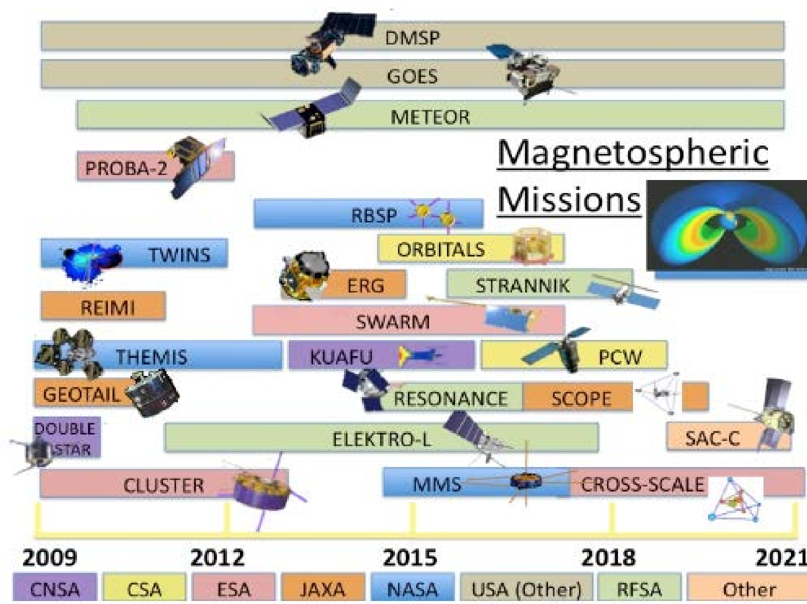
Challenges: AIM

- **Understand how the ionosphere-thermosphere system responds to, and regulates, magnetospheric forcing over global, regional and local scales.**
- **Understand the plasma-neutral coupling processes that give rise to local, regional and global structures and dynamics in the AIM system.**
- **Understand how forcing from the lower atmosphere via tidal, planetary, and gravity waves, influences the ionosphere and thermosphere.**
- **Determine and identify the causes for long-term (multi-decadal) changes in the AIM system.**

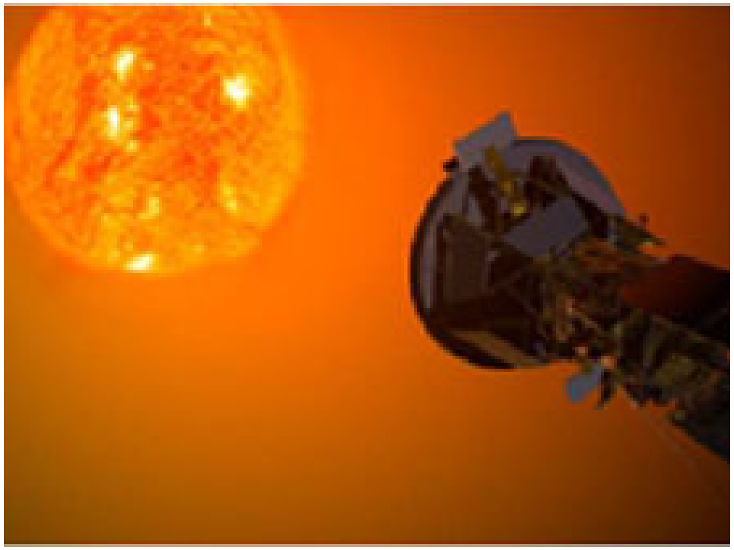
Future Missions







SP+ (Solar Probe Plus)



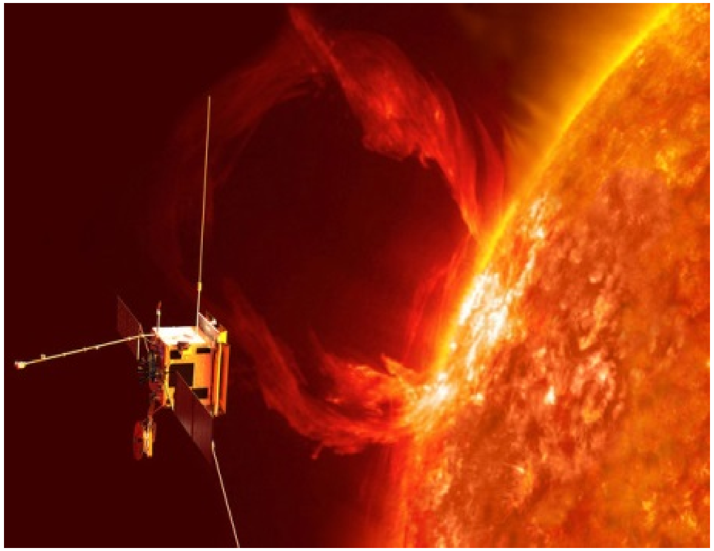
To probe the outer corona of the Sun

Orbit： 8.5 Rs – 0.73 AU

Scientific Goals:

- **Determine the structure and dynamics of the magnetic fields at the sources of solar wind**
- **Trace the flow of energy that heats the corona and accelerates the solar wind**
- **Determine what mechanisms accelerate and transport energetic particles**
- **Explore dusty plasma near the Sun and its influence on solar wind and energetic particle formation**

SO (Solar Oribter)



To perform detailed measurements of the inner heliosphere and solar wind

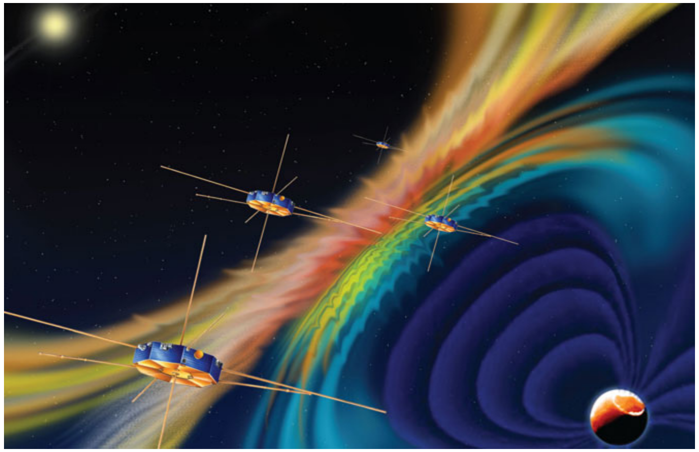
Orbit： 60 Rs – 0.3 AU

Launch: 2017

Scientific Goals:

- **How and where do the solar wind plasma and magnetic field originate in the corona?**
- **How do solar transients drive heliospheric variability?**
- **How do solar eruptions produce energetic particle radiation that fills the heliosphere?**
- **How does the solar dynamo work and drive connections between the Sun and the heliosphere?**

MMS (Magnetospheric Multi-scale Mission)



Earth's magnetosphere as a laboratory to study the microphysics of magnetic reconnection

Orbit： 1. 2 Re - 25 Re

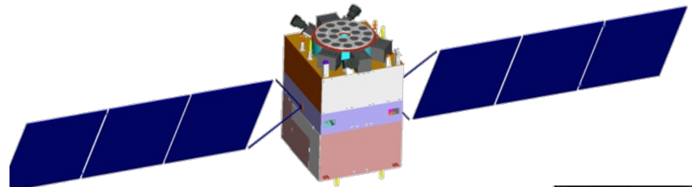
Launch: 2014

Scientific Goals:

- What determines when reconnection starts and how fast it proceeds?
- What is the structure of the diffusion region?
- How do the plasmas and magnetic fields disconnect and reconnect in the diffusion regions?
- What role do the electrons play in facilitating reconnection?
- What is the role of turbulence in the reconnection process?
- How does reconnection lead to the acceleration of particles to high energies?

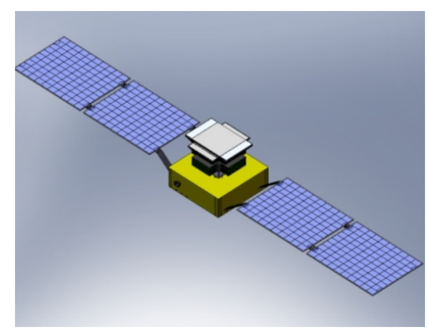
China Strategic Pioneer Program on Space Science

Content	Means
Black Hole	HXMT
Microgravity / Life Science	SJ-10
Quantum Theory	QUESS
Dark Matter	DAMPE
Space Weather	KUAFU



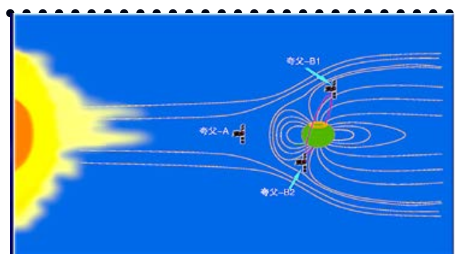
Project 1

Project 2



Project 3

Project 4



Project 5

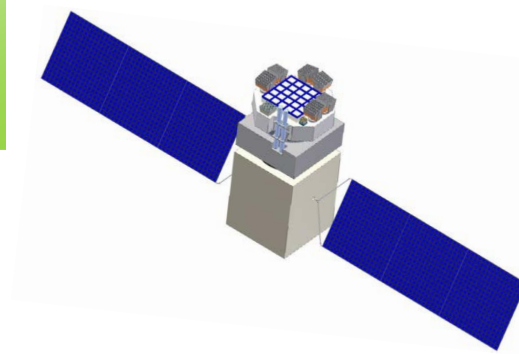
China Strategic Pioneer Program on Space Science

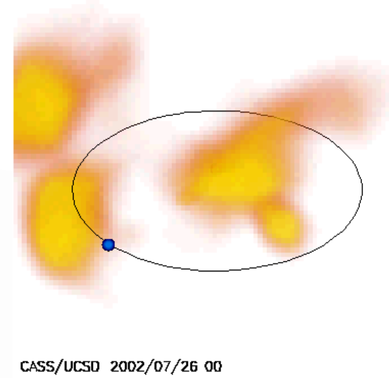
Content

Means

Selection and pre-study of missions for 2015-2020

Background Development

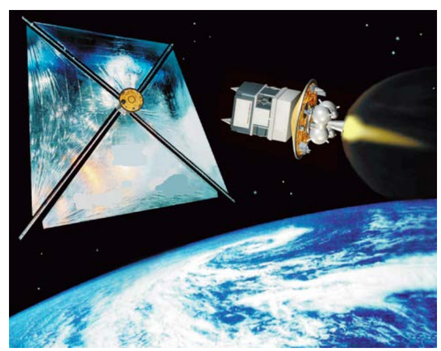


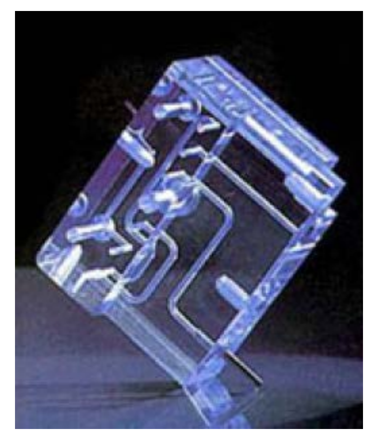


Project 6

Strategic research on future mission concepts and technologies

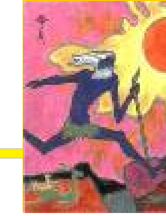
Pre-Study



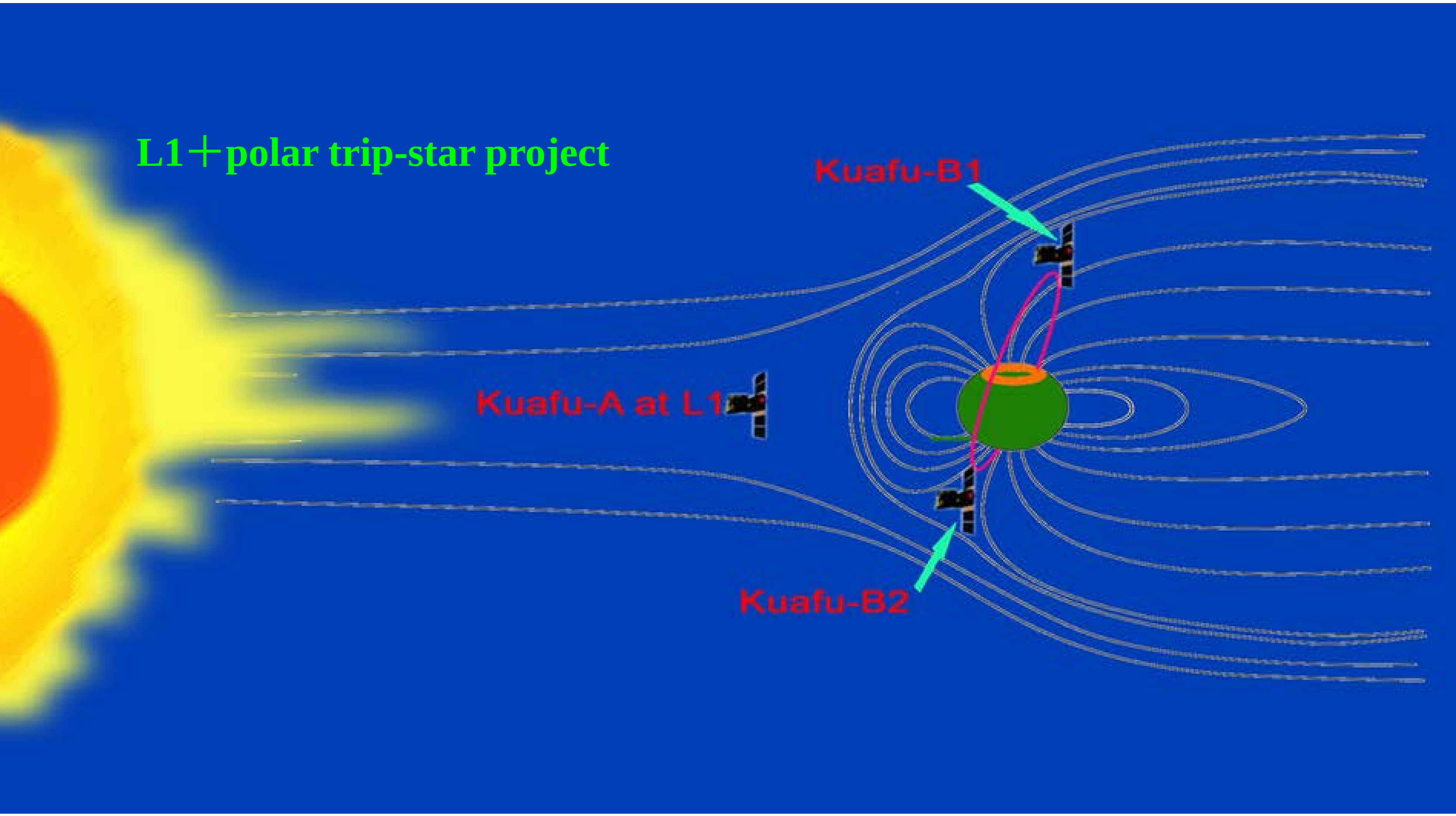


Project 7

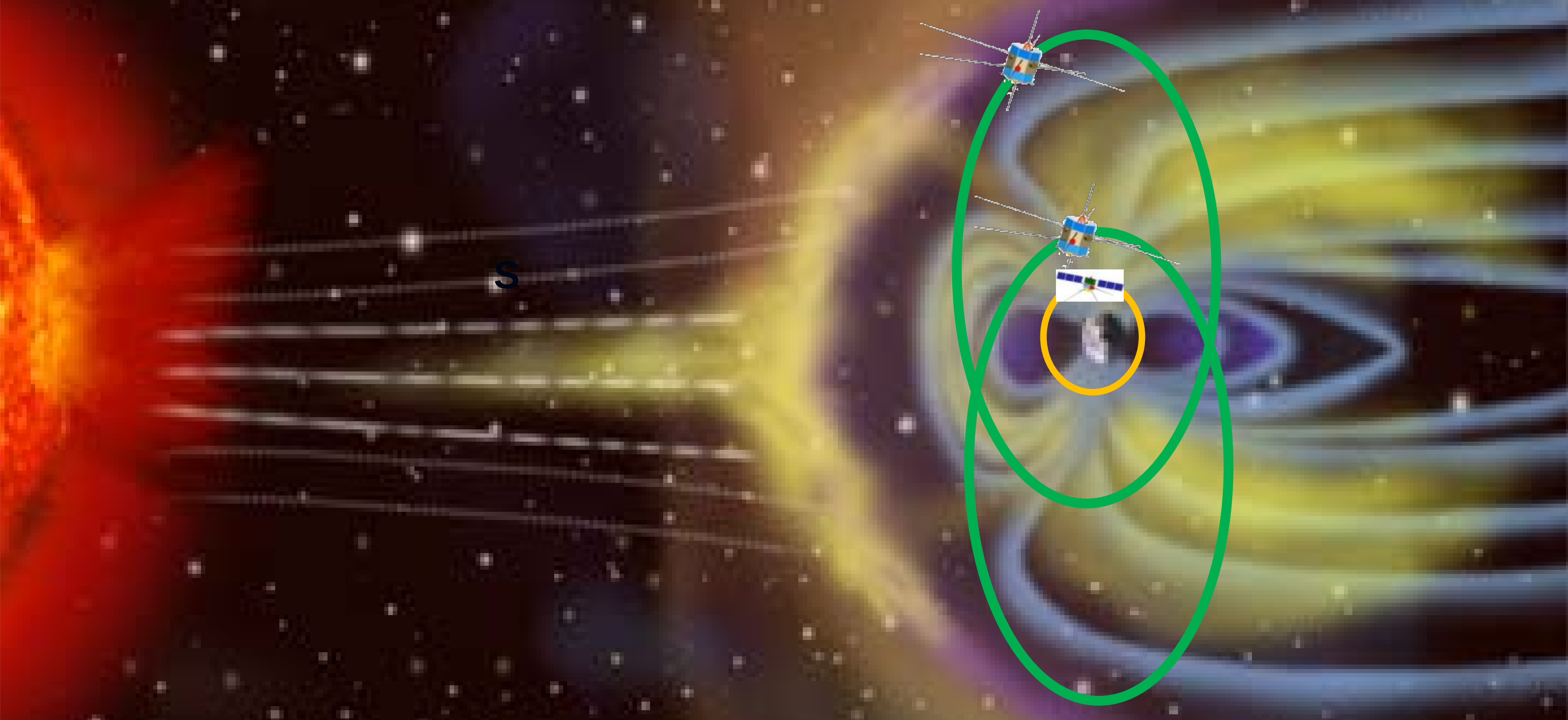
KuaFu



Solar Storm、Aurora and Space Weather Exploration



Concept Study (phase 0) Supported by CNSA (2009)
Background-study (Phase A) Supported by CAS (2011)



Magnetosphere－Ionosphere－Thermosphere (MIT) Coupling Exploration

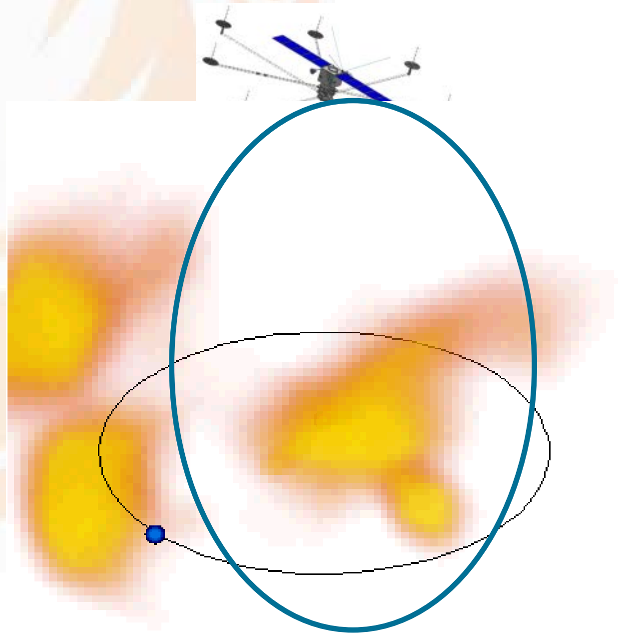
Solar Polar ORbit Telescope (SPORT)

➢Science Objectives:

SPORT will be the first mission to image the propagation of CME continuously off the ecliptic plane.

- ✓Imaging & tracking interplanetary CMEs propagation
- ✓Observation on solar high latitude area

Orbit realization	solar polar orbit (with the gravity assist of Jupiter)
Inclination	>72 °
perihelion	0.7AU
aphelion	5AU



Summary

- **Although the discipline of space physics have made remarkable advances over the last decade, more space missions are necessary to address key scientific challenging questions, in order to improve scientific understanding of the solar terrestrial coupling system.**

- **It is noteworthy that some of the most surprising discoveries have come from comparatively small missions.**

Thank You !

We acknowledge the use of materials from "Solar and Space Physics : A Science for a Technological Society" (2012) "COSPAR SWx Science Roadmap" (2013), and ILWS website.