Solar and Space Physics Missions in China

WU Ji
National Space Science Center, CAS
March 28, 2018

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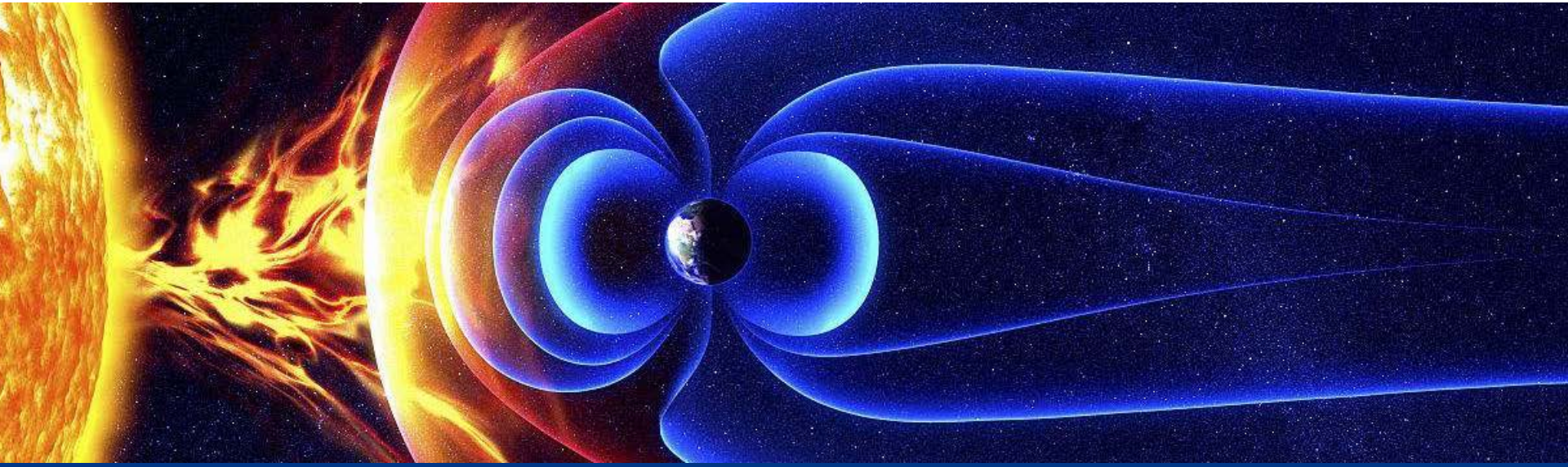
- Space Missions
- Ground-based Projects



Solar and space physics missions

- Space missions
  - Solar wind Magnetosphere Ionosphere Link Explorer (SMILE)
  - Advanced Space-borne Solar Observatory (ASO-S)
  - Magnetosphere-Ionosphere/Thermosphere Coupling Exploration (MIT)
  - ……
- Ground-based projects
  - Chinese Meridian Project 1&2
  - International Space Weather Meridian Circle Plan (IMCP)

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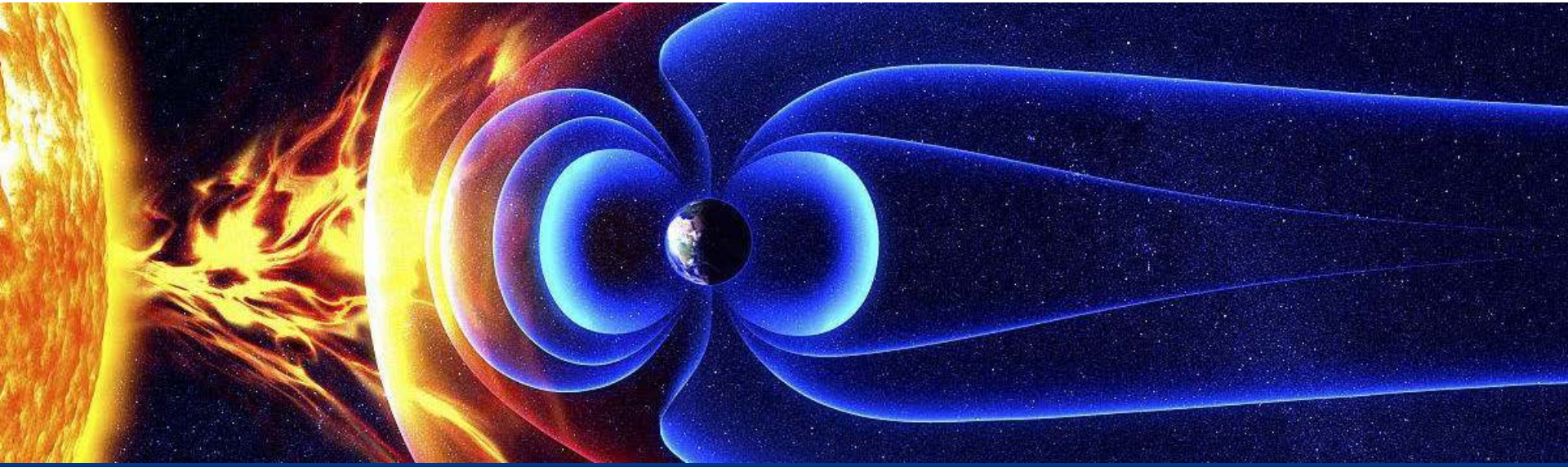
- Space Missions
- Ground-based Projects



1. Solar wind Magnetosphere Ionosphere Link Explorer (SMILE)

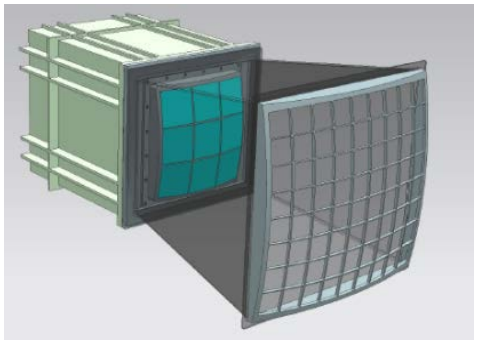
Science Objectives

- Determine when and where transient and steady magnetopause reconnection dominates
- Define the substorm cycle, including timing and flux transfer amplitudes
- Define the development of CME-driven storms, including whether they are sequences of substorms

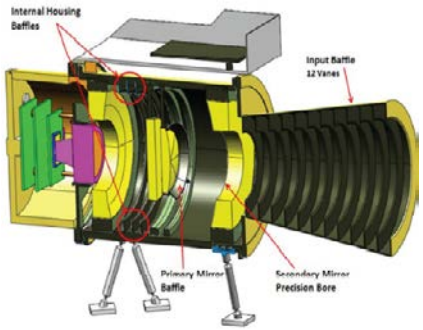
Payloads

- Soft X-ray Imager (SXI)
- Ultra-Violet Imager (UVI)
- Light Ion Analyzer (LIA)
- MAGnetometer (MAG)

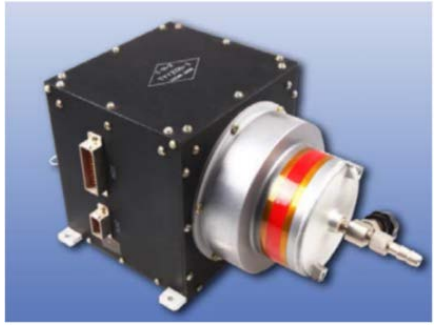
Payload	Mass (kg)	Power(W)
SXI	26.1	18.7
UVI	10.5	32
LIA	2.0	5.0
MAG	2.5 + 5.5 (boom)	3.5
Total	41.1	59.2



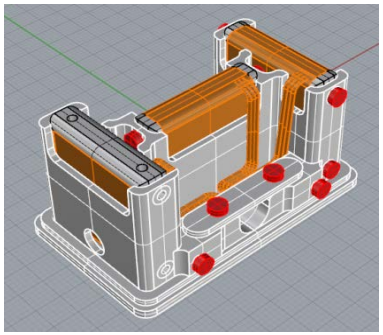
SXI



UVI



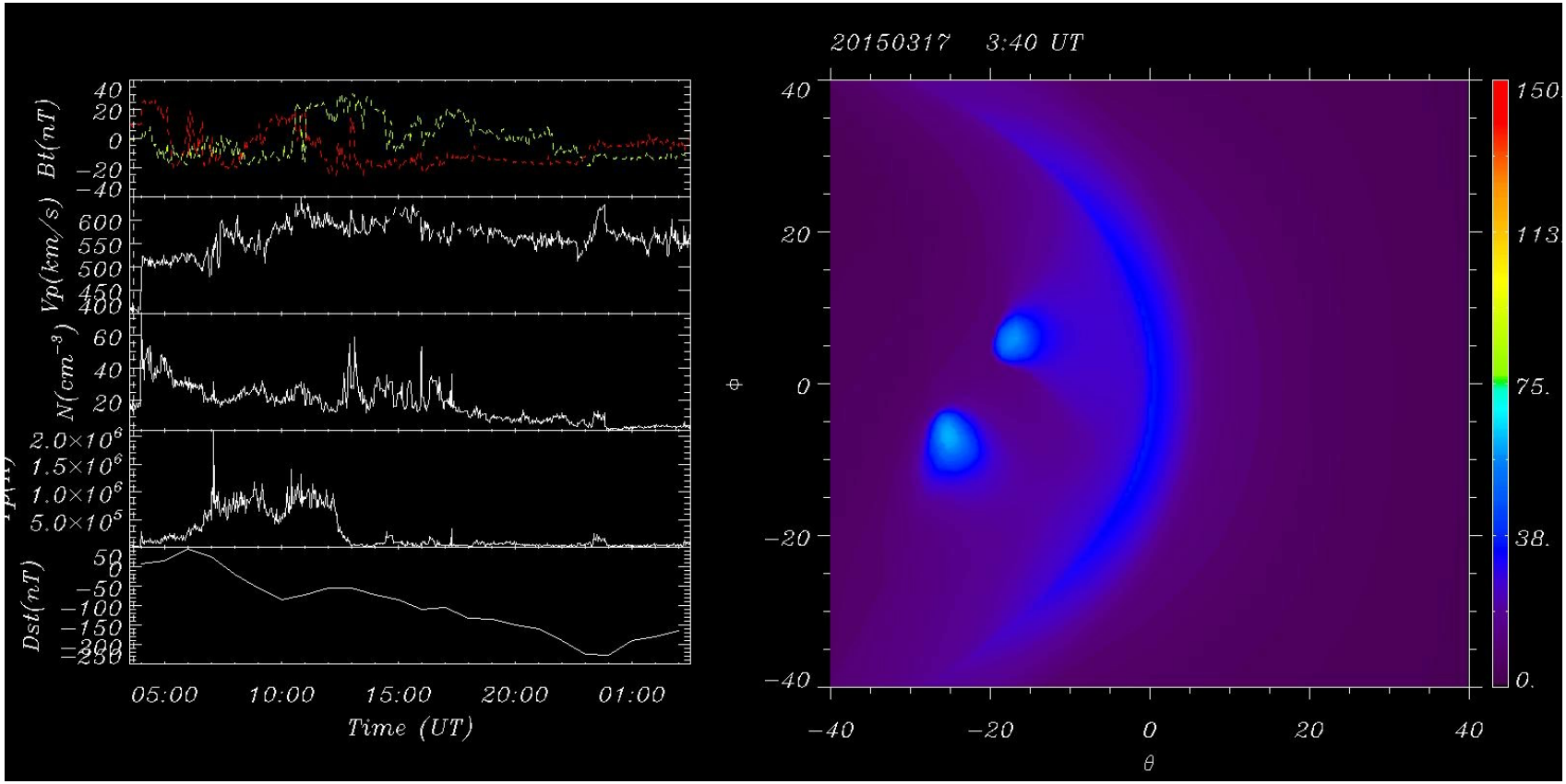
LIA



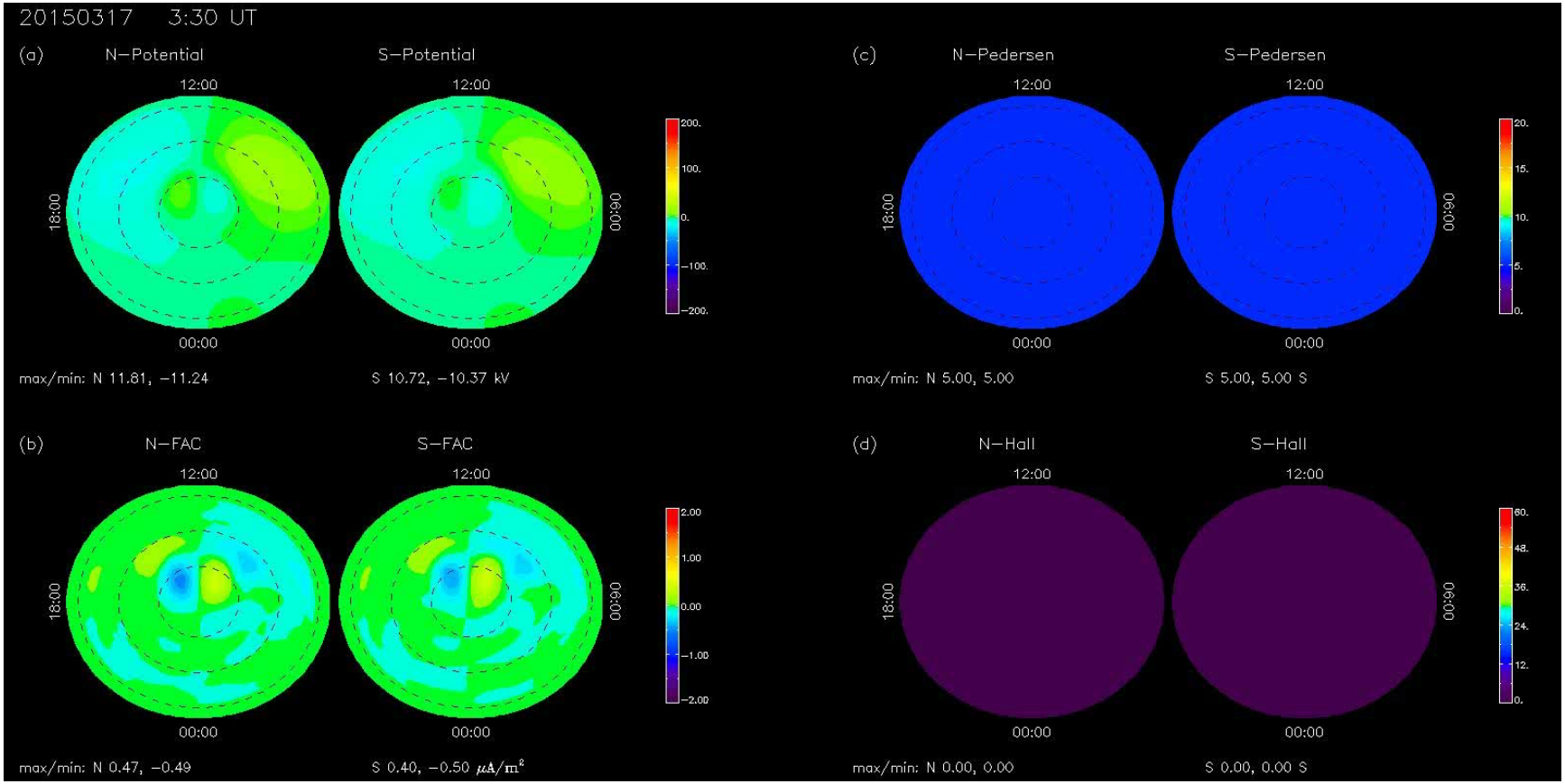
MAG

The payload and satellite will be provided by scientists and industry from both Europe and China

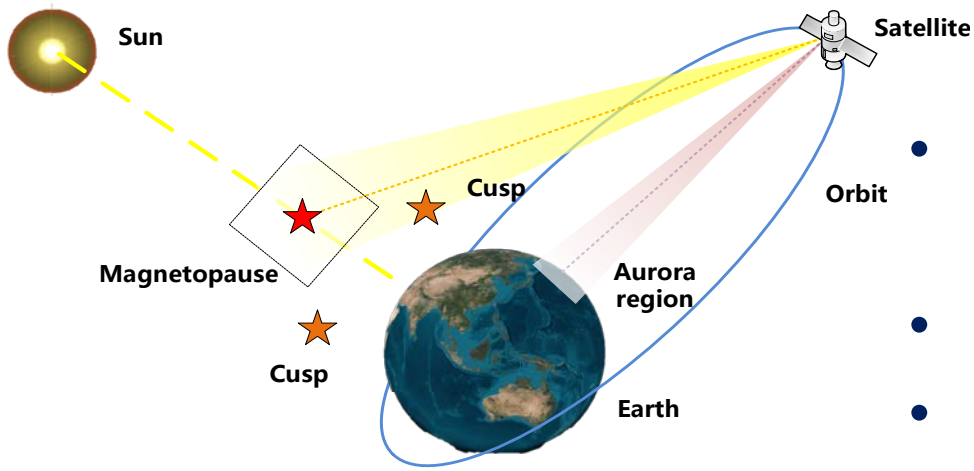
SMILE SXI's simulation—Mar. 17, 2015 solar storm



SMILE UVI's simulation— Mar. 17, 2015 solar storm



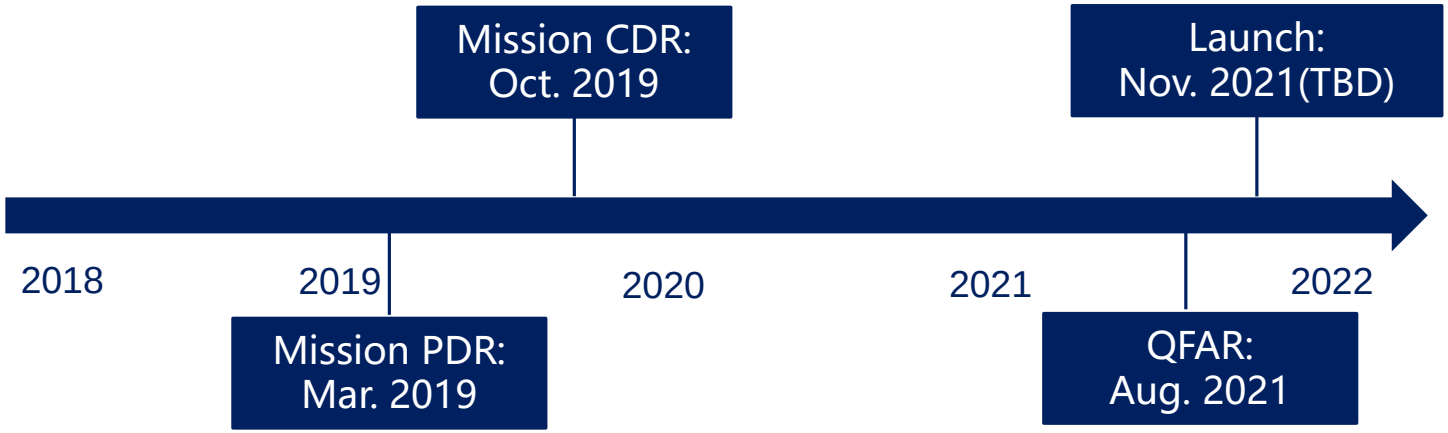
Mission Profile



- **Orbit** : 5000km@perigee
  19 RE@apogee
- **Mass (PLM+SVM+PM)**: <2000kg
- **Planned Launch**: ~2022
- **Lifetime** : 3 years

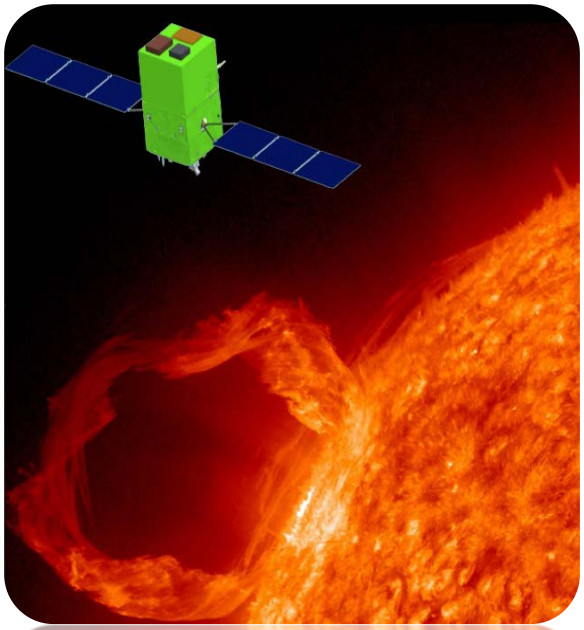
Schedule

- *The technical and economic feasibility demonstration of SMILE completed in Feb. 2016*
- *SMILE officially approved by CAS in Nov. 2016*

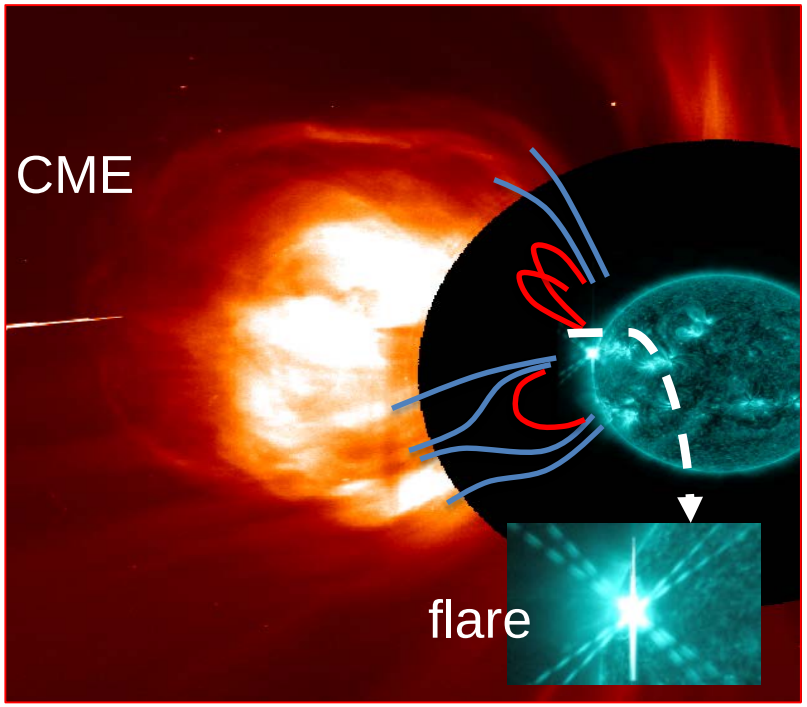


- Launch including 6-month margin

2. Advanced Space-borne Solar Observatory (ASO-S)



Science Objectives

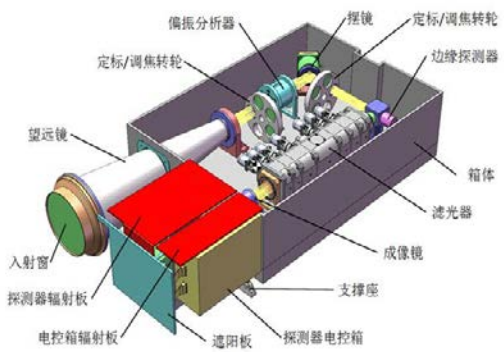


- To study solar magnetic field, solar flares, CMEs, their physical formations, mutual interactions, and close connections

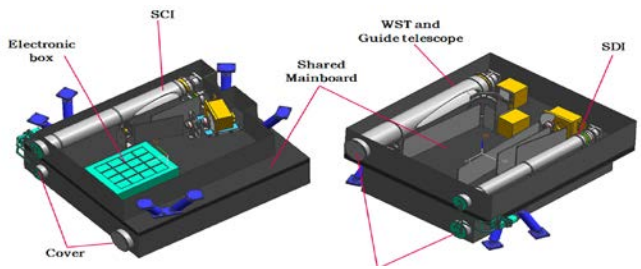
So far China has no solar dedicated satellite in orbit.

Payloads

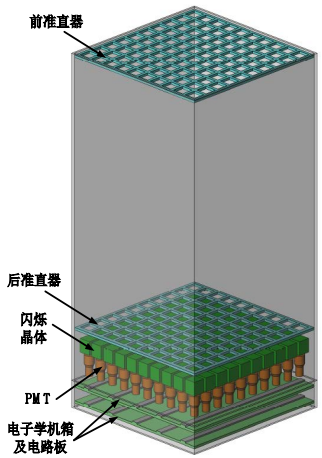
- Full-Disc Vector Magnetograph (FMG)：solar magnetic field
- Hard X-ray Imager (HXI)：solar flare
- Lyman-alpha Solar Telescope(LST)： CME



FMG



LST

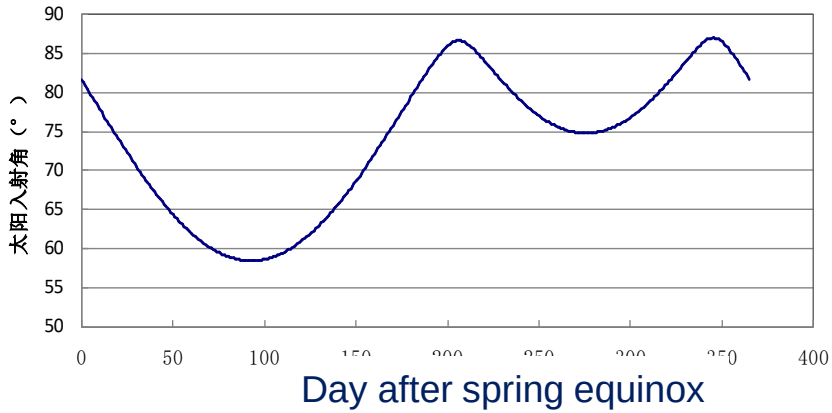


HXI

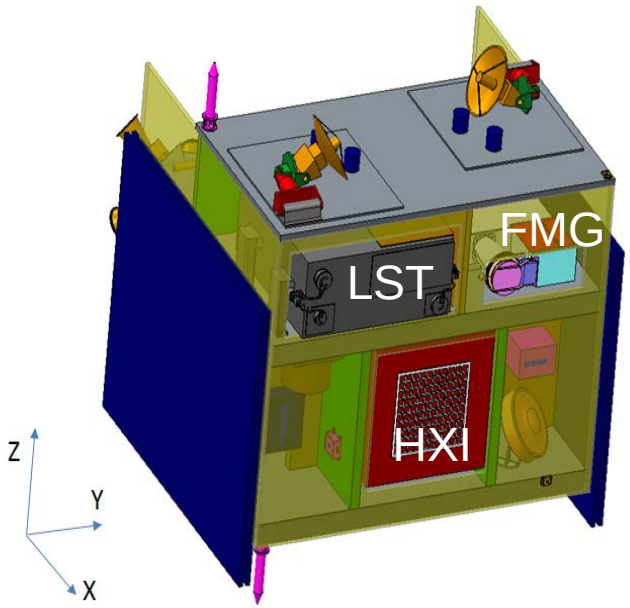
Mission Profile

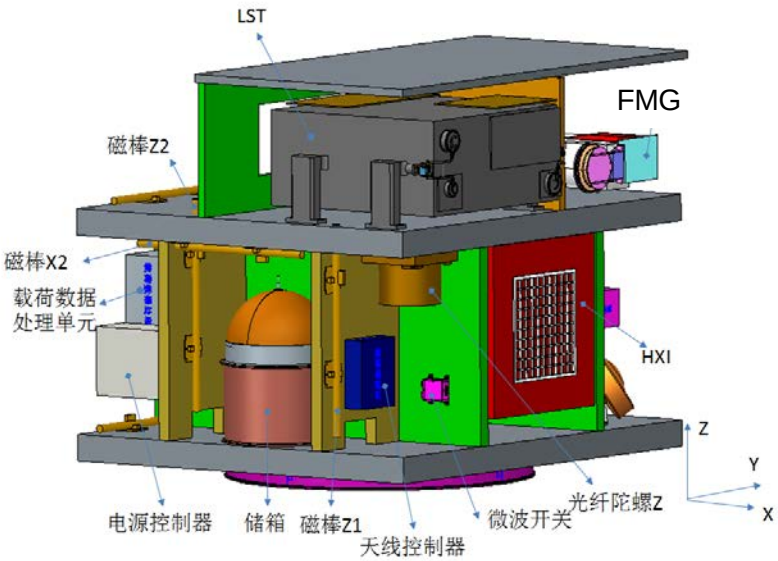
- Orbit: solar synchronous
- Attitude: 720 km
- Attitude Control: 3-axis stabilization
- Pointing accuracy: 0.01°
- Stability: 0.0005°/s (1-2”/20s)
- Payload Mass: <335 kg
- Payload power: 300 W
- Data downlink: 492 GB/day
- Eclipse time: <18min/day during eclipse season

Incident angle of the sunlight to the orbital plane



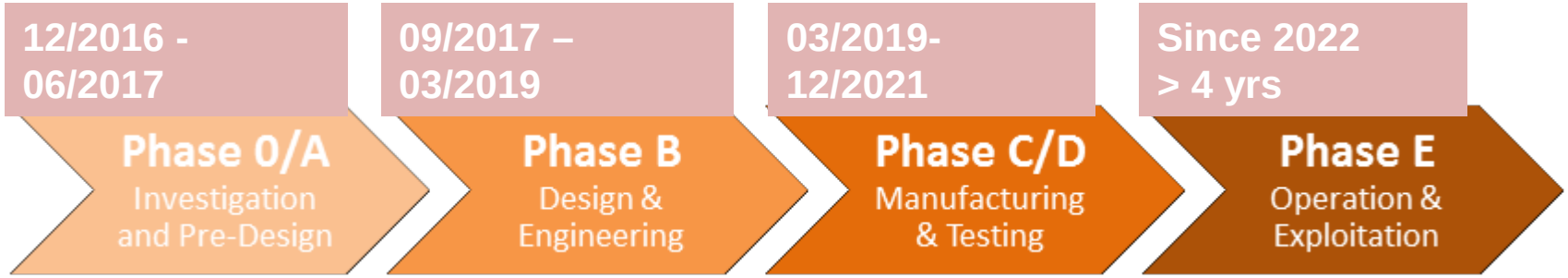
Platform


FMG
LST
HXI
Z
Y
X

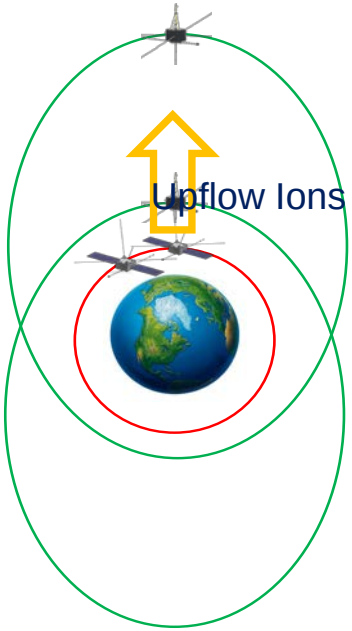

LST
FMG
磁棒Z2
磁棒X2
载荷数据
处理单元
HXI
Z
Y
X
电源控制器
储箱
磁棒Z1
天线控制器
微波开关
光纤陀螺Z

Schedule

- The idea was proposed in 2010 or earlier, a partial heritage from SMESE
- A conceptual study was granted by CAS and NNSFC (Oct. , 2011-Mar., 2013, ~ 90K US$)
- Intensive Study (so-called background phase) was undertaken from Jan., 2014 to Apr., 2016, jointly supported by CAS and NNSFC (~ 1.6M US$)
- Intensive Study (extended): May 2016-Nov. 2016

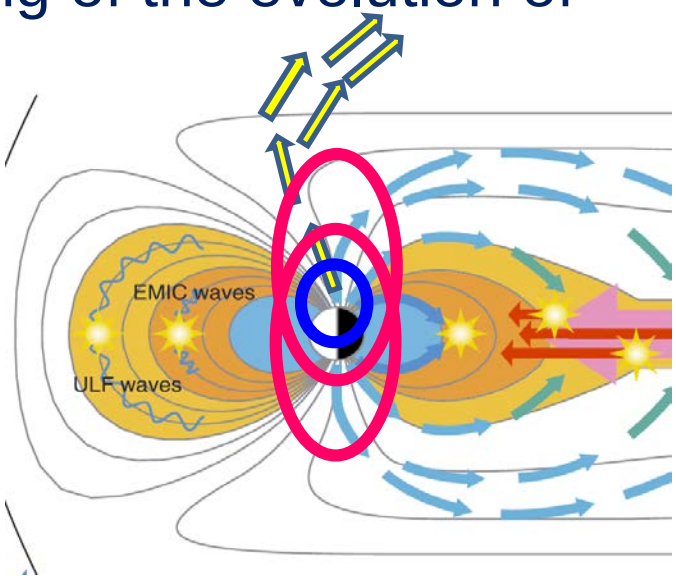


3. Magnetosphere-Ionosphere/Thermosphere Coupling Exploration (MIT)

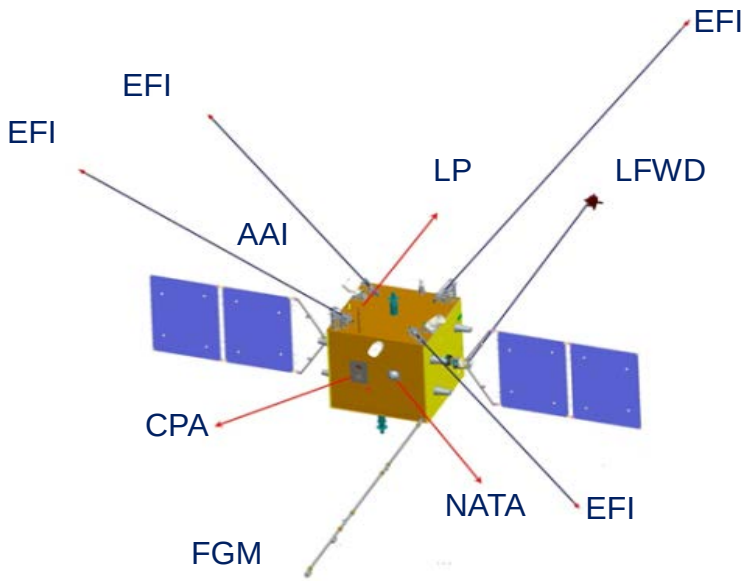


Science Objectives

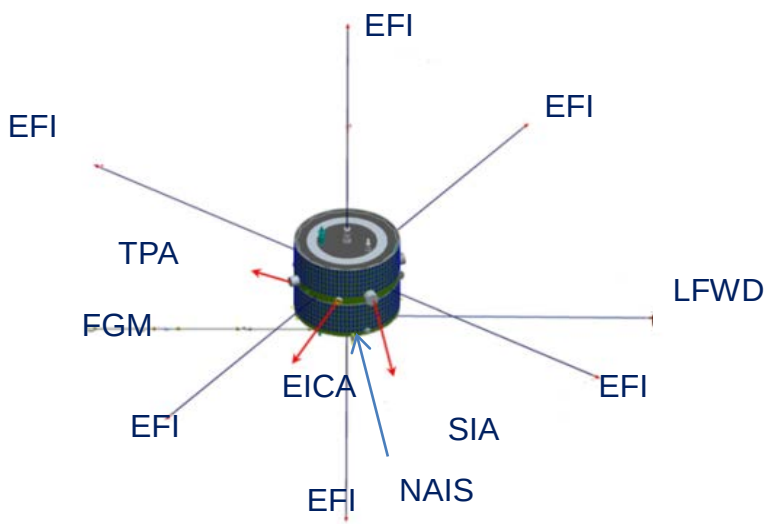
- Understanding the mechanism of ion acceleration and transport in ionosphere / thermosphere
- Unveil the role of the coupling of the earth's spheres in triggering the space storm
- Discover the escape process of the earth particles and deepening the understanding of the evolution of the planetary atmosphere



Payloads



Ionospheric/Thermospheric spacecraft
(ITA & ITB)



Magnetospheric spacecraft
(MA & MB)

Payloads

- Magnetospheric spacecraft (MA & MB)

Thermal Plasma Analyzer	H+, He+, O+, e- Energy range: 1 eV ~ 500 eV (ions) 30 eV ~ 40 keV (e-)
Suprathermal Ion Spectrometer	H+, He+, He++, O+ Energy range: 300 eV ~ 50 keV
Energetic Particle Detector	Energy range: 30 keV ~ 4 MeV (ions) 30 keV ~ 600 keV (e-)
Energetic Ion Composition Analyzer	Energy range: 20 keV ~ 500 keV (H+) 40 keV ~ 500 keV (He+) 50 keV ~ 500 keV (O+)
Neutral Atom Imager	Energy range: 40 keV ~ 300 keV (H, O) Angular resolution: 6° x 2°
Broadband Electromagnetic Field Detector Suite	Magnetic field: ±16000 nT, DC ~ 20 kHz Electric field: ±1 V/m, DC ~ 400 kHz

Payloads

- Ionospheric/Thermospheric spacecraft (ITA & ITB)

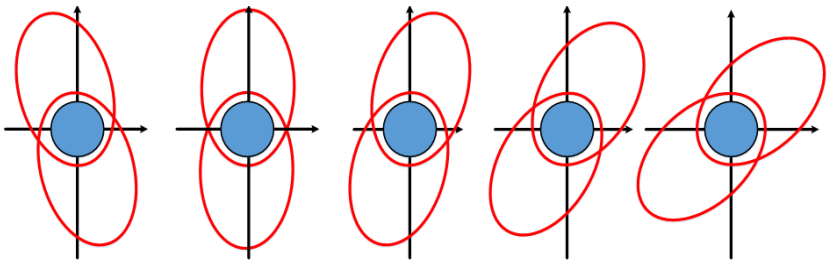
Thermal Plasma Analyzer	H+, He+, O+, O++, e- Energy range: 1 eV ~ 1000 eV (ions) 30 eV ~ 30 keV (e-)
Cold Plasma Analyzer	H+, He+, O+ Plasma density, temperature, drift speed
Energetic Particle Detector	Energy range: 30 keV ~ 4 MeV (ions) 30 keV ~ 600 keV (e-)
Langmuir Probe	Electron density (500 ~ 10^7 cm^{-3}) Electron temperature (500 ~ 10000 K)
Thermosphere Composition Analyzer	1 ~ 34 amu Wind velocity (±1000 m/s) Atmospheric density ($5x10^{-15}$ ~ $5x10^{-11}$ kg/m^3)
Broadband Electromagnetic Field Detector Suite	Magnetic field: ±65000 nT, DC ~ 20 kHz Electric field: ±1 V/m, DC ~ 400 kHz
Aurora & Airglow Camera	120 nm ~ 190 nm (resolution: 2.7 nm) Angular resolution: 0.9°

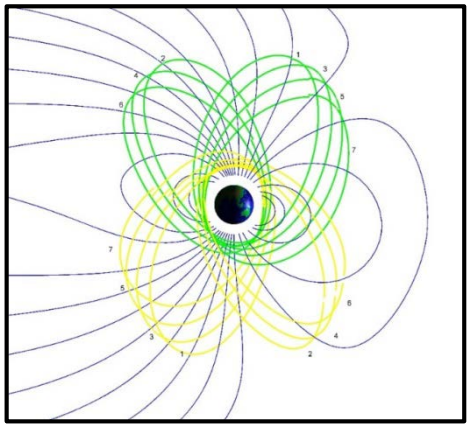
Mission Profile

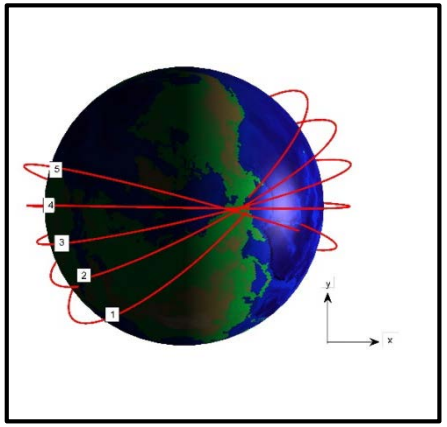
- Features

Spacecraft	ITA	ITB	MA	MB
Inclination	90°	90°	90°	90°
Perigee	500km	500km	1Re	1Re
Apogee	1500km	1500km	7Re	7Re

- Coverage of the orbits

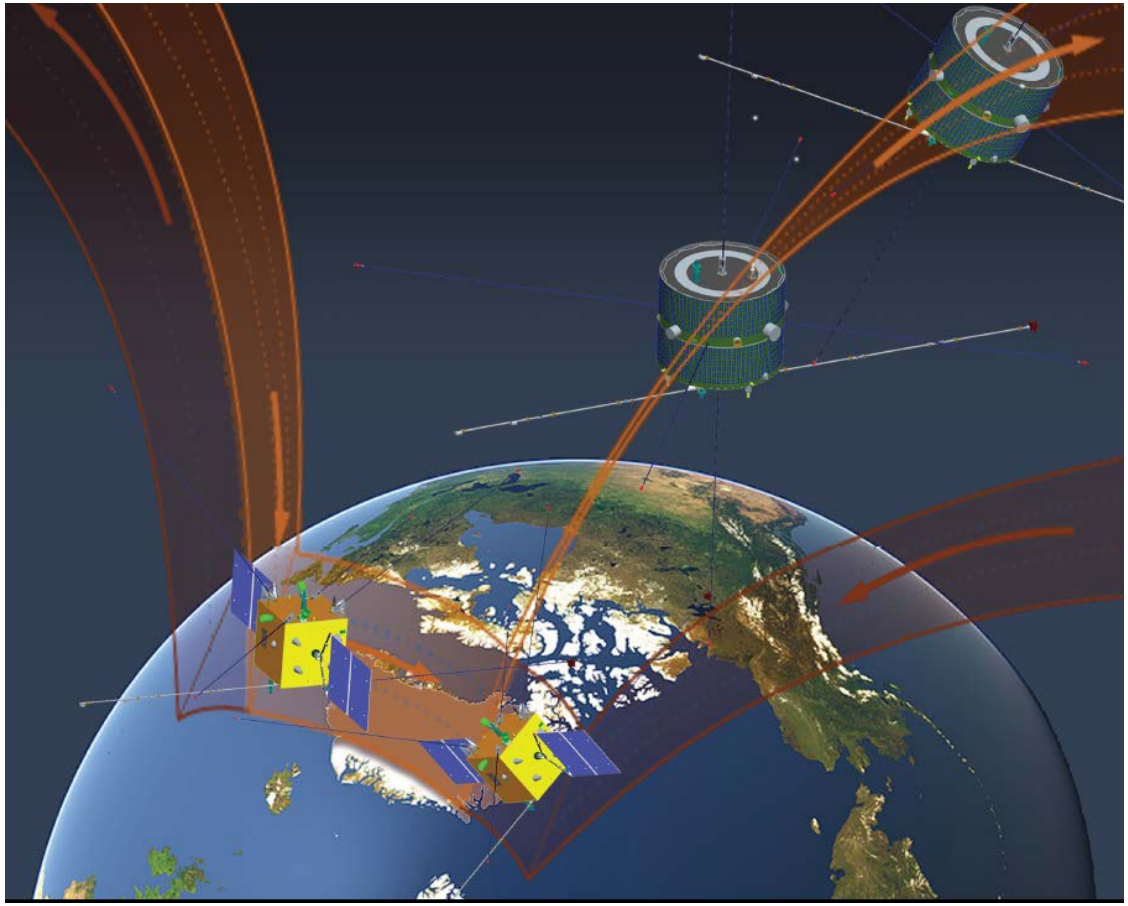






Current Status

MIT mission is in Phase A.



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- Space Missions
- Ground-based Projects

Meridian Project 1 → Meridian Project 2 → International Space Weather Meridian Circle Plan (IMCP)

1. Chinese Meridian Project(1&2)

Meridian Project 1

- Geomagnetic
- Optical-atoms
- Radio
- Rocket

DIM

OFM

FGM

SCM

SED

DEM

ASAI

FPI

LIDA

AURO

CRM

TEL IPS

DPS IONO

DOPP TEC

METR

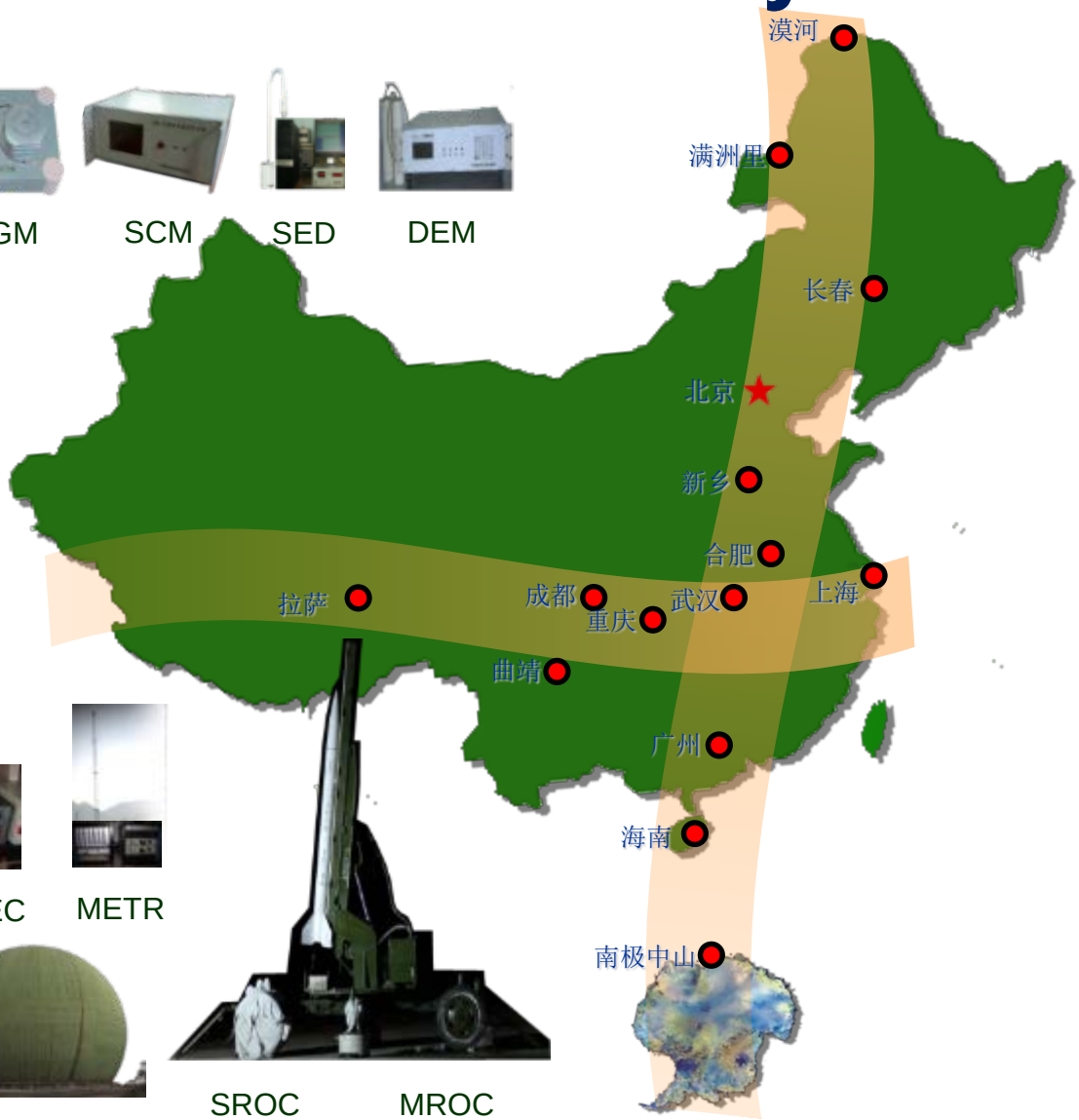
HFR

MST

VHF

ISR

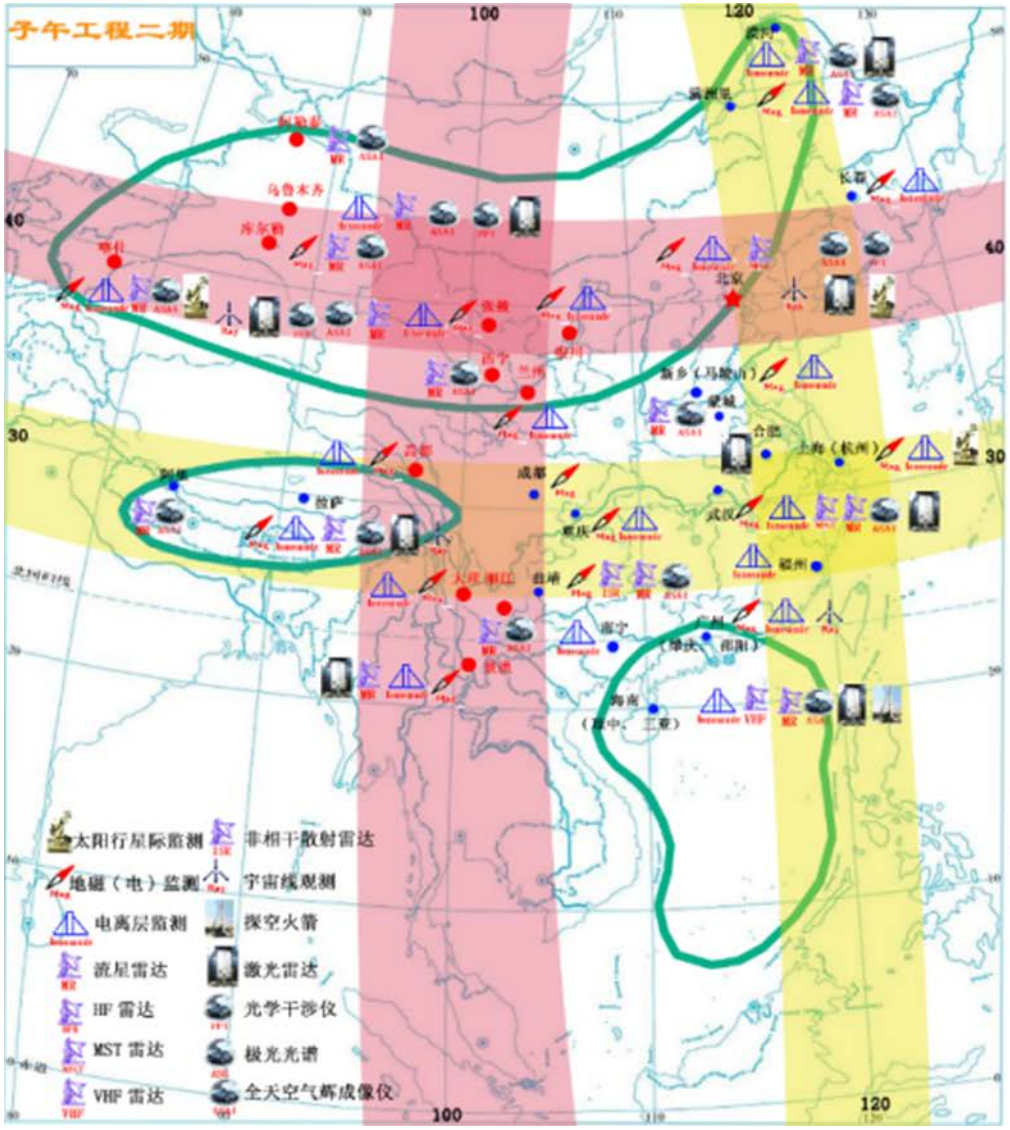
SROC MROC

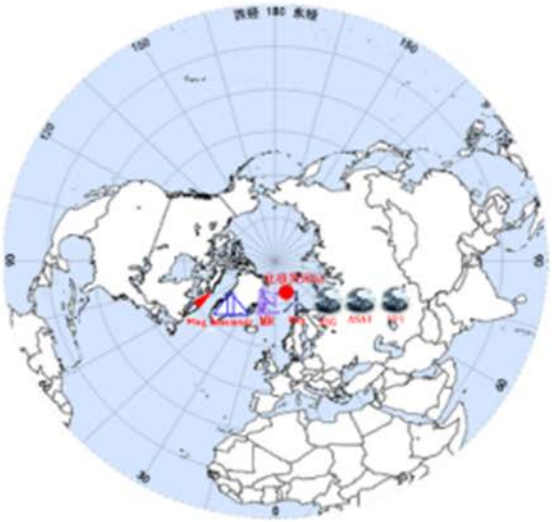


Status

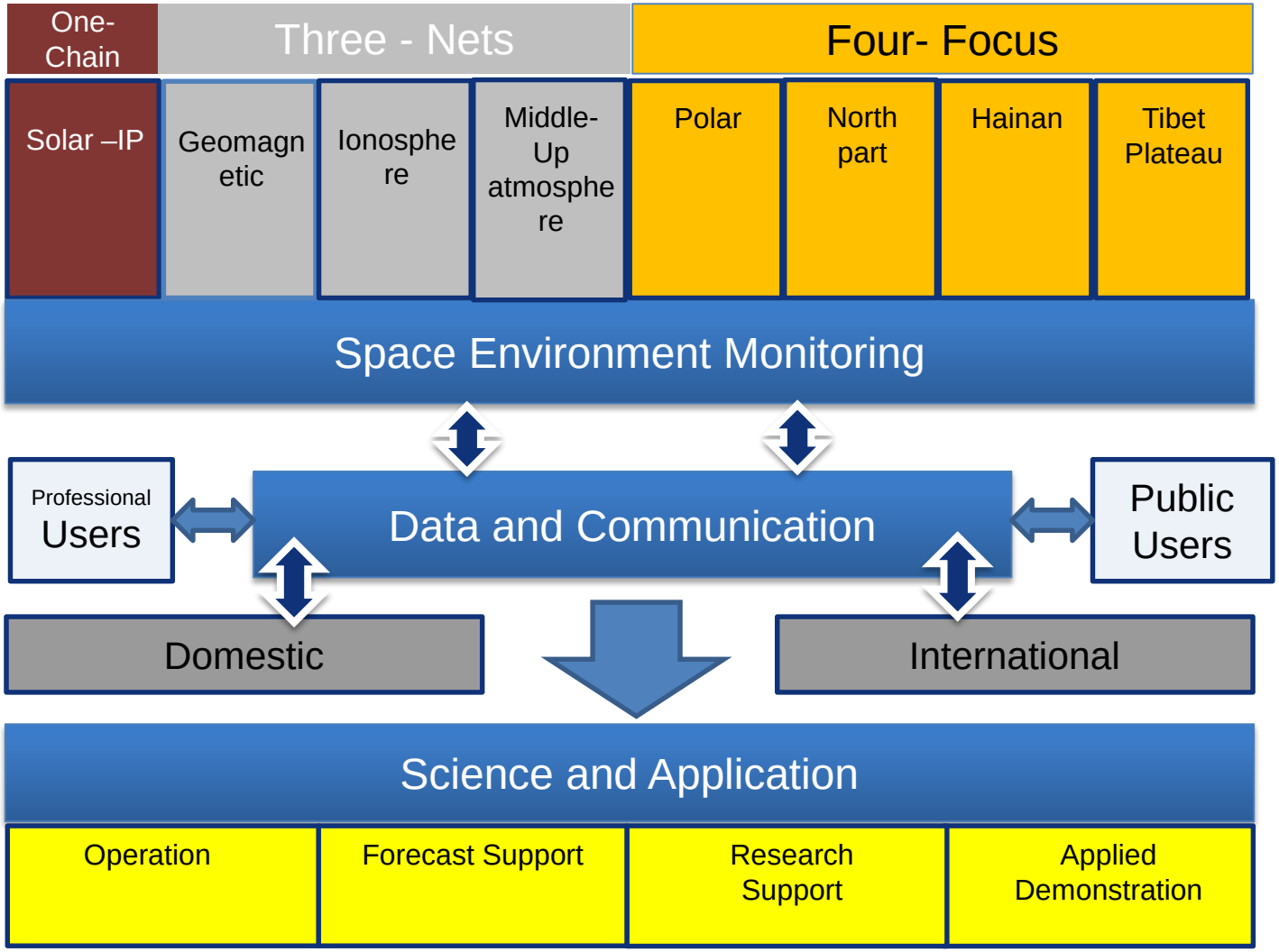
- Chinese Meridian Project started data collection in Oct. 2012
- Up to Jan. 2017, it has collected 4.8TB of scientific data for 23 space environment key parameters
- More than 200 peer–reviewed papers have been published

Meridian Project 2

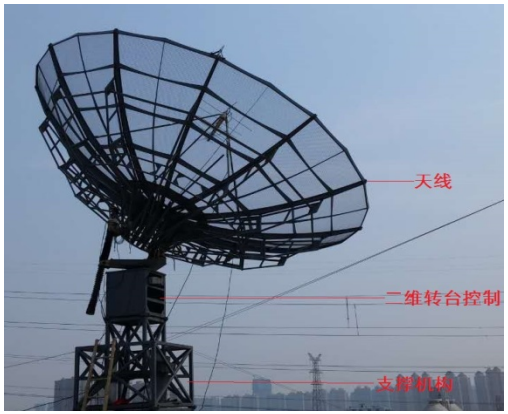




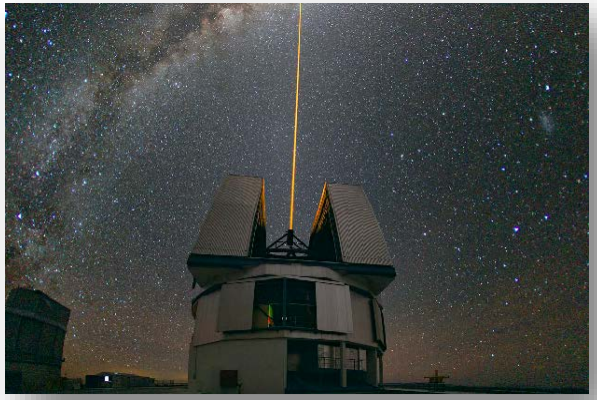
Framework


One-Chain
Three - Nets
Four- Focus
Solar –IP
Geomagnetic
Ionosphere
Middle-Up atmosphere
Polar
North part
Hainan
Tibet Plateau
Space Environment Monitoring
Professional Users
Data and Communication
Public Users
Domestic
International
Science and Application
Operation
Forecast Support
Research Support
Applied Demonstration

Key Instruments

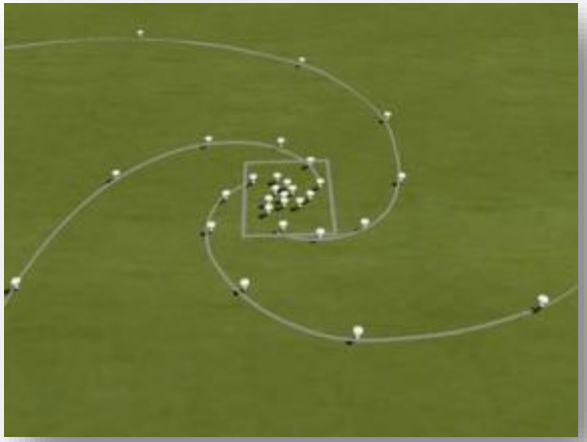


SWRT



Multi-function LIDAR

SuperDAWN Radar

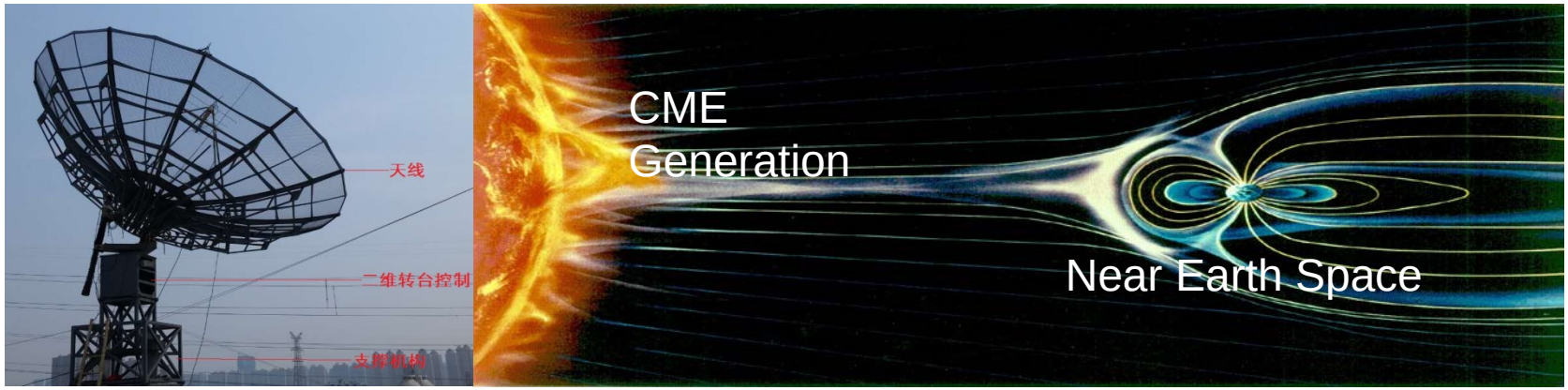


Solar Radio Heliograph

Solar Wind Radio Telescope (SWRT)

——one major instrument of Meridian Project 2

- The objective of SWRT is to detect and track the whole process of CME from the generation to the near earth space.
- The CME imaging on VHF/UHF band can provide important detection method for space weather forecast and early warning.
- SWRT will be the first UHF/VHF CME radio imaging project in China.



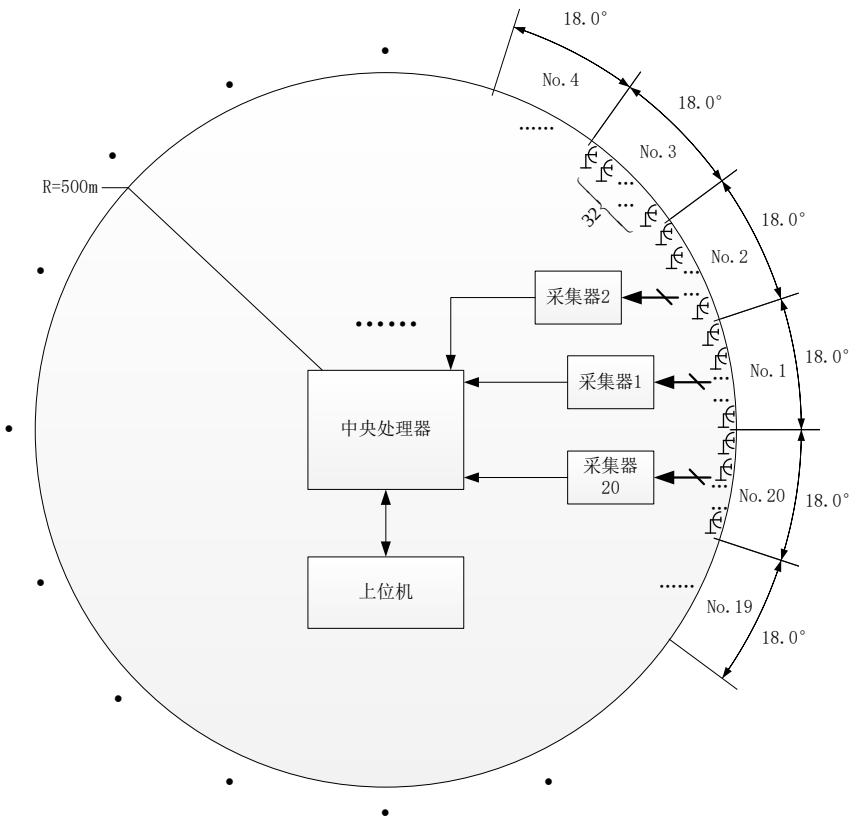
Technical Specification

Technical specification	Value
Frequency	50MHz – 450MHz
Antenna array	Circular Array with 1km diameter
Element number	≈400
AF-FoV	45°(150MHz) ; 15°(450MHz)
Spatial Resolution	≈5 ‘4 “(150MHz) ; ≈1'42" (450MHz) ;
Timing resolution	~ ms (special event), ~1s – 1min (normal observation)
Imaging Radiometric sensitivity	474K
Antenna aperture size	~6m
Receiver noise	150K
Dynamic Range	>45dB
ADC resolution	8bit
Polarization	I/Q/ U/ V

Overall SWRT System

- Uniformly distributed circular array : undistorted image reconstruction
- Sweep-frequency receivers: wide-band spectrum measurement and imaging
- Distributed data acquisition and processing: decentralized massive data processing pressure
- digital correlation technique:

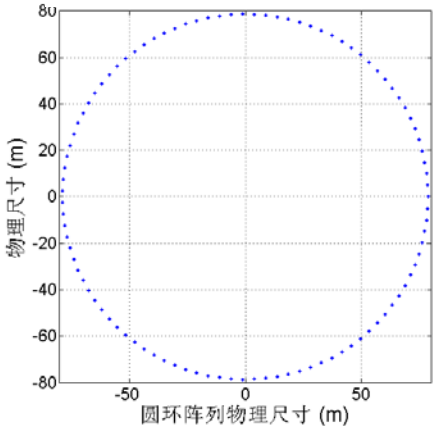
balance performance and processing ability



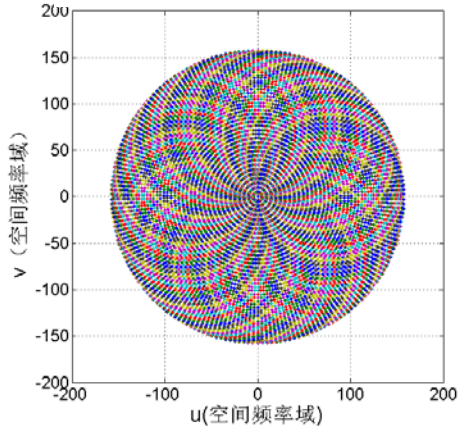
SWRT Array Design

- Array configuration

Circular array



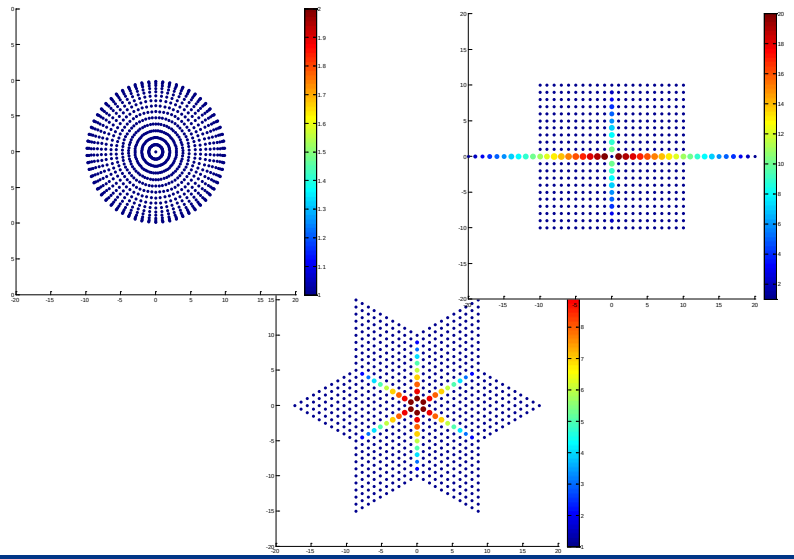
u-v coverage

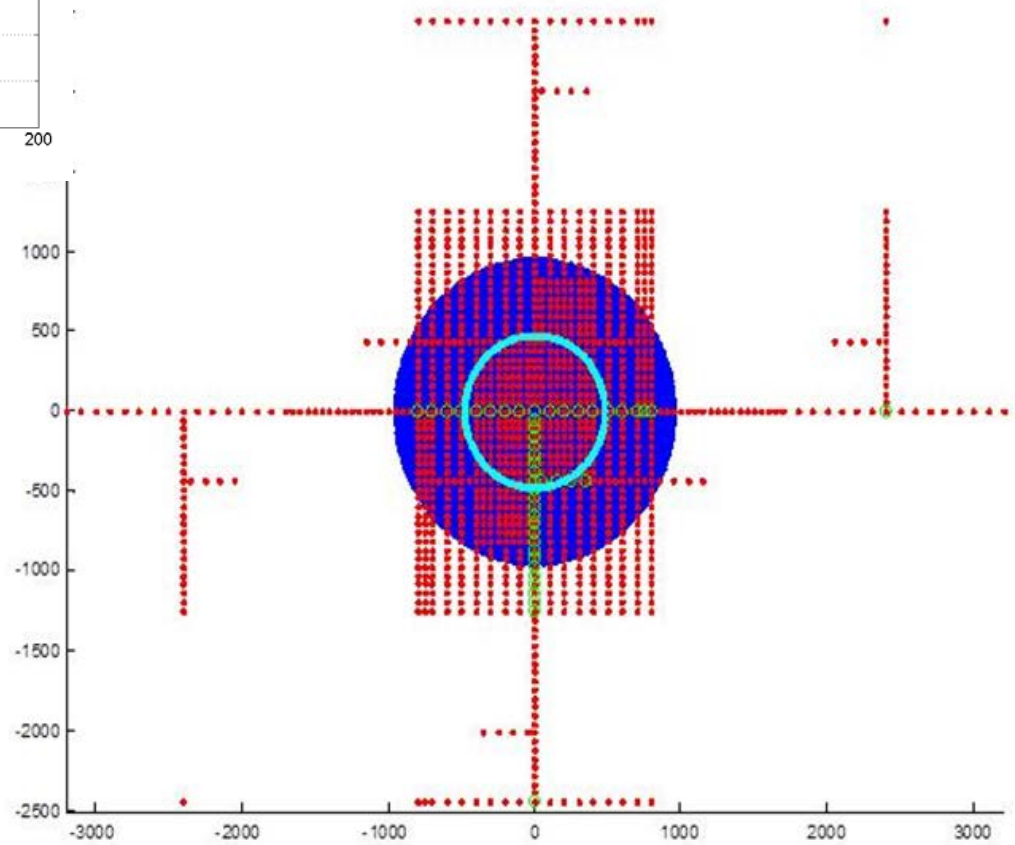


Comparison of u-v coverage between circular array and T-array of NRH:

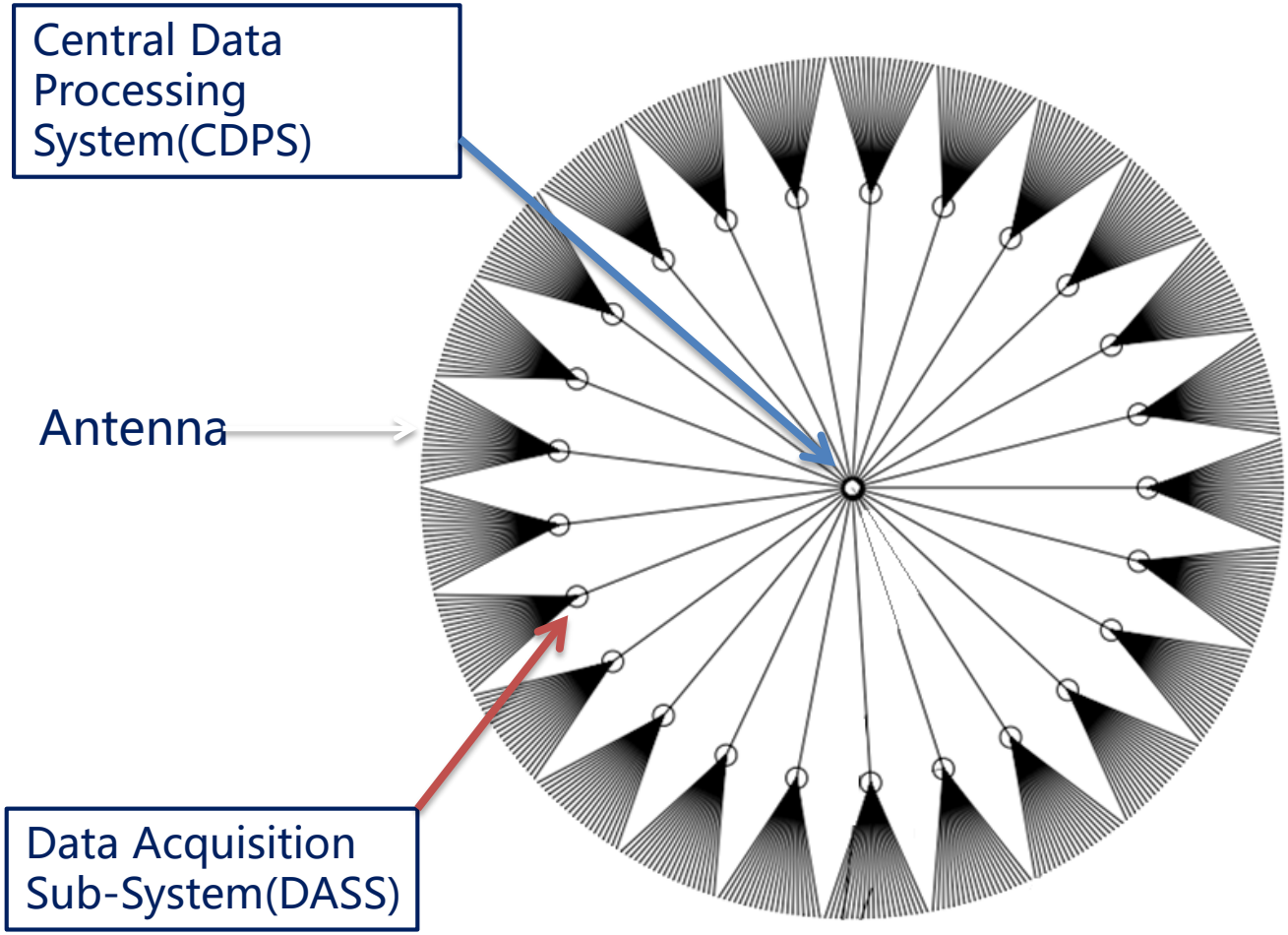
- Circular array: full u-v coverage
- T-array : thinned u-v coverage

The structure of the circular array and redundancy distribution are more reasonable.





Distributed Data Acquisition and Processing Subsystem

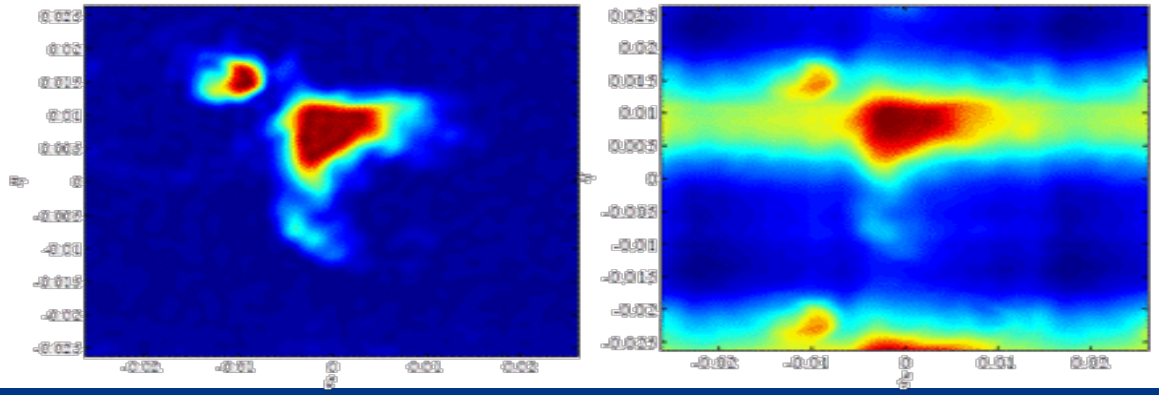


- 1 CDPS located in the center of the array;
- 20 DASS located near to the antennas;
- Every 20 receiving channels share 1 DASS;

Massive data processing (~400 channels) requires distributed data acquisition and processing

Significance

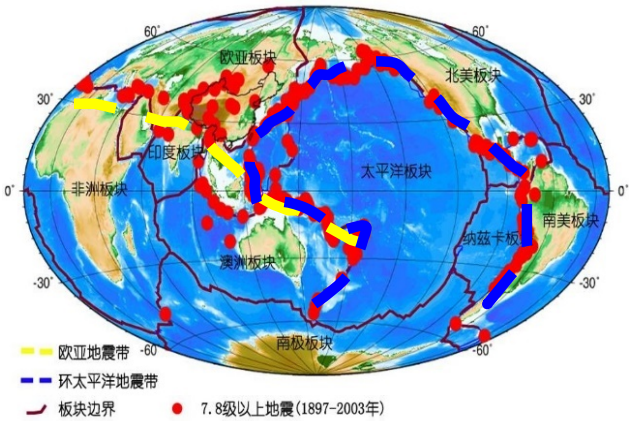
- SWRT Uniformly distributed circular antenna array lead to a full u-v coverage and undistorted reconstructed image;
- Perfect RFI environment for SWRT in Tibet;
- SWRT will play an important role in space science research and space weather forecast;
- SWRT will provide standard image for CME to improve the performance of the other system;
- SWRT will be the first VHF/UHF CME imaging and tracking system focused on the CME propagation in the Sun-Earth space in the world.



Status

- Chinese Meridian Project II has been listed as one of the national key mega scientific infrastructure in 2016-2020 in China (Ranked #1 from 10).
- The construction is expected to start before the end of 2018.

2. International Space Weather Meridian Circle Plan (IMCP)



Overview

- To connect 120ºE and 60ºW meridian chains of ground based monitors worldwide, in order to provide a global picture of unfolding space weather events.

Status

- The Ministry of Science and Technology (MOST) of China is going to set up a few mega international science plans within coming two years.
- MOST has hosted a discussion meeting with us, and encouraged us to submit a proposal.
- A NOI (Notice of Intention) to make a proposal was submitted to MOST on April 23, 2017.

International Participation

- 21 institutes covering over 13 countries have showed their interest in cooperation

Russia

US

Brazil

Australia

UK

Finland

Norway

Malaysia

Sweden

South Korea

Peru

Thailand

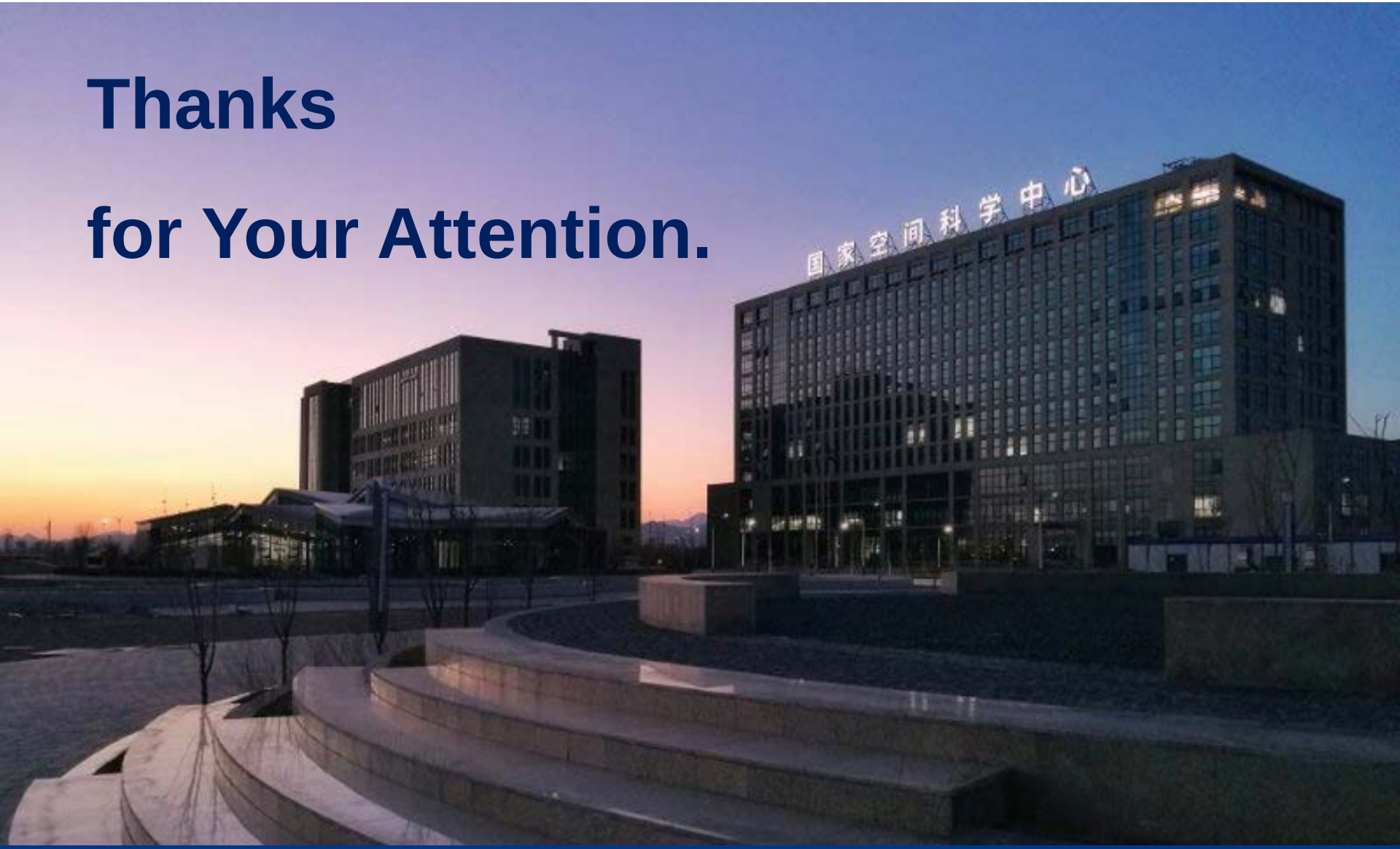
Japan

International Participation

- The international organization willing to participate:
  - International Space Weather Initiative (ISWI)
  - Scientific Committee on Solar Terrestrial Physics (SCOSTEP)
  - Asia-Pacific Space Cooperation Organization (APSCO)
  - Committee on Space Research (COSPAR)
  - European Institute for the Study of Contemporary Antisemitism(EISCAT)
  - The International Union of Geodesy and Geophysics (IUGG)
  - International Scientific Radio Union (URSI)
  - Scientific Committee on Antarctic Research (SCAR)
  - World Federation of Engineering Organisations (WFEO)
  - International Centre for Theoretical Physics (ICTP)

Final Remarks

- .
- Solar and space physics in China has been developing quickly over a dozen years.
- Both space missions and ground-based projects have been implemented and will be constructed in near future, aiming to build comprehensive capacity for scientific output.
- International cooperation is a key to our success and very much welcomed in our future programs.

Thanks

for Your Attention.