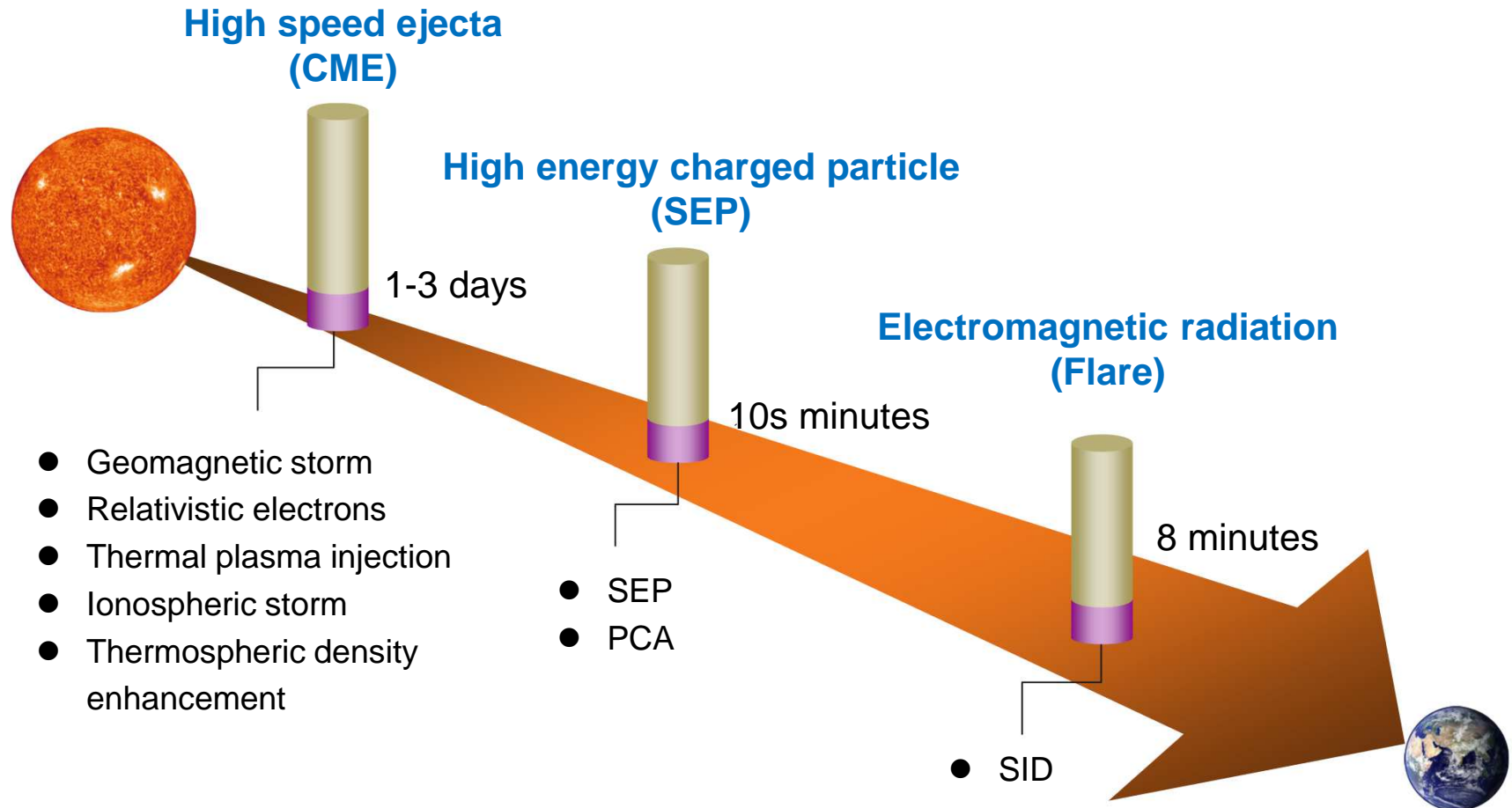# The Requirement Analysis for User-oriented Space weather Products and Services

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National Space Science Center, CAS

Three Rounds of Solar Attack!

High speed ejecta (CME)

High energy charged particle (SEP)

1-3 days

Electromagnetic radiation (Flare)

10s minutes

- Geomagnetic storm
- Relativistic electrons
- Thermal plasma injection
- Ionospheric storm
- Thermospheric density enhancement

8 minutes

- SEP
- PCA

- SID

Technology Systems Vulnerable to Space Weather

SATELLITES

COMMUNICATIONS

PEOPLE

NAVIGATION SYSTEMS

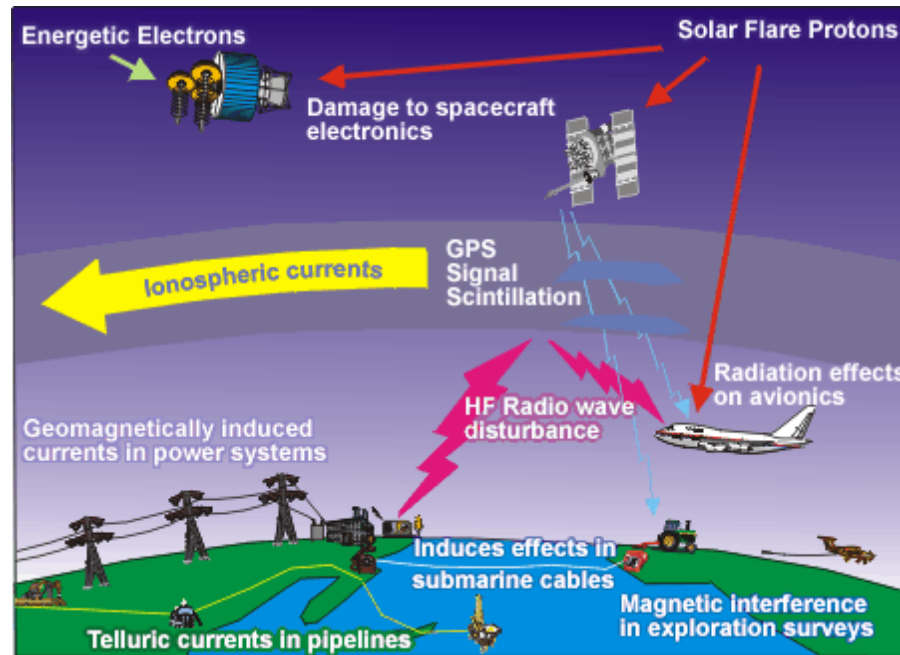**GEOLOGIC EXPLORATION**

ELECTRIC POWER

PIPELINES

THEY NEED TO BE PROTECTED AGAINST SPACE WEATHER!
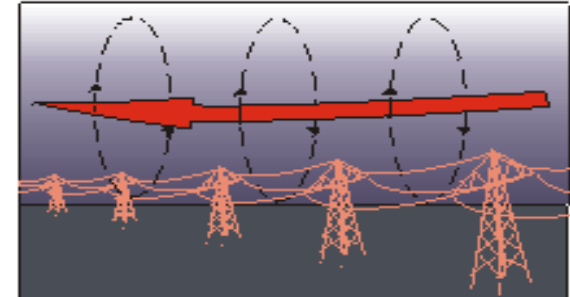
The questions are:

- Space weather providers: what space weather events may impact these systems?

- Technology system operators: what space weather events may impact our technology system?

The user requirements should be identified (user-centric analysis).

Power Grid

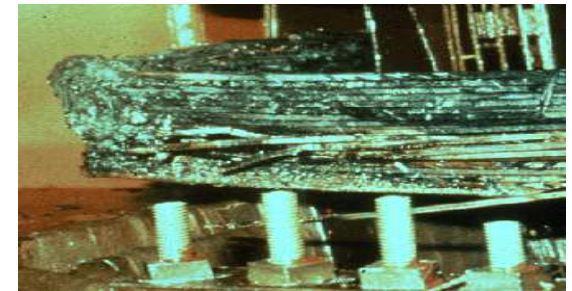**What environment cause what effects?**

- Geomagnetic field
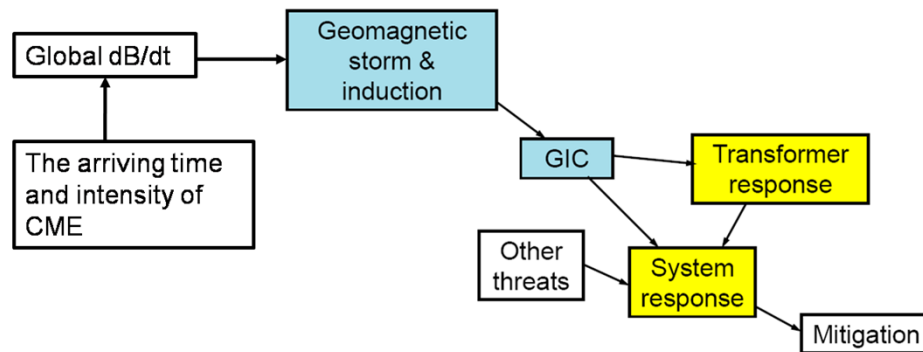 - Geomagnetic induced current (GIC)

NEED TO BE ANSWERED:

(1) What space weather information are needed?

- Events forecast: CME, CIR, geomagnetic storm, ……
- Indices forecast: Ap, Kp, Dst, ……
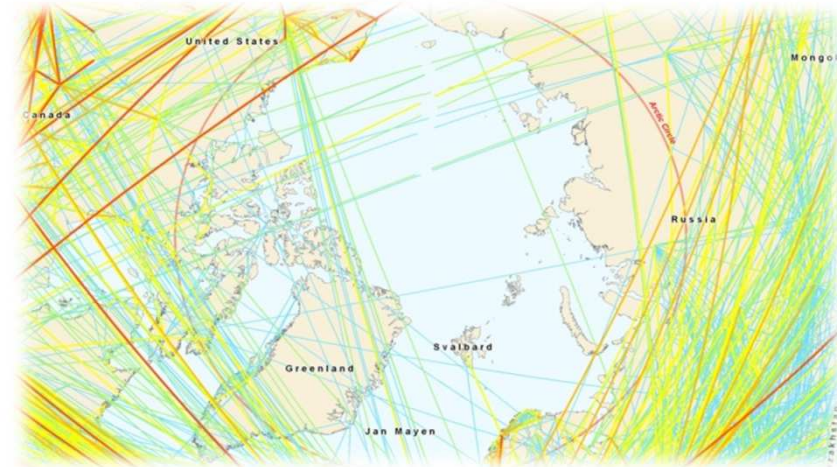- Environment specifications: dB/dt, Electric Field, …… ?

(2) How space weather information should be provided?

Aviation

What environment cause what effects?

- Ionosphere
  - Communication – radio blackout
  - Navigation
- Particle Radiation
  - Human health
  - SEE: Single Event Effects

NEED TO BE ANSWERED:
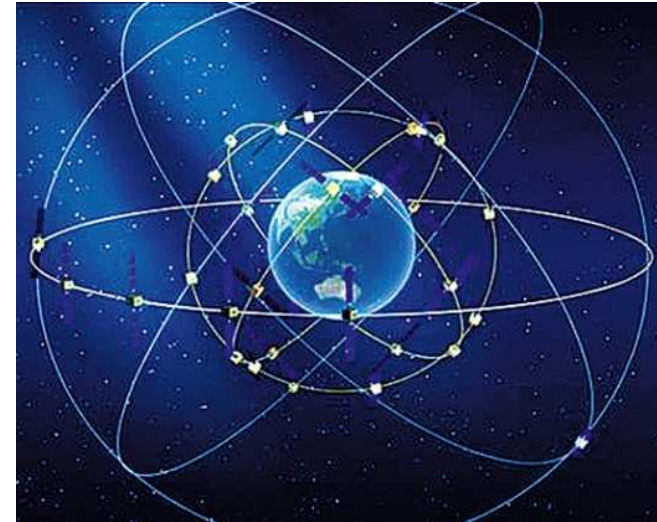
(1) What space weather information are needed?

- Events forecast: Flare, SEP, REF enhancements, SID, PCA, ……
- Indices forecast: **?**
- Environment specifications: TEC, ……**?**

(2) How space weather information should be provided?

What environment cause what effects?

- Ionosphere
  - Propagation effect cause errors of PNT
- Particle Radiation
  - SEE: Single Event Effects
  - Surface charging
  - Deep dielectric or bulk charging
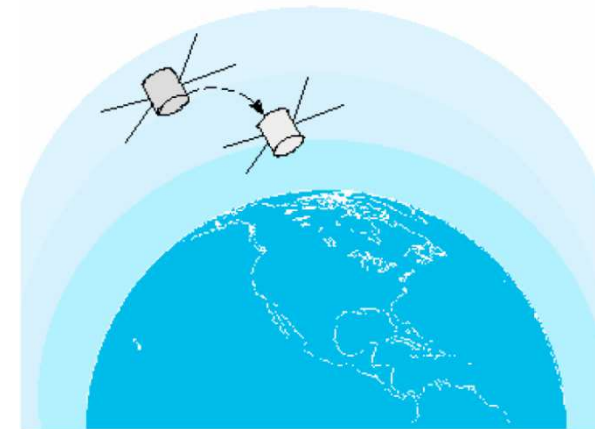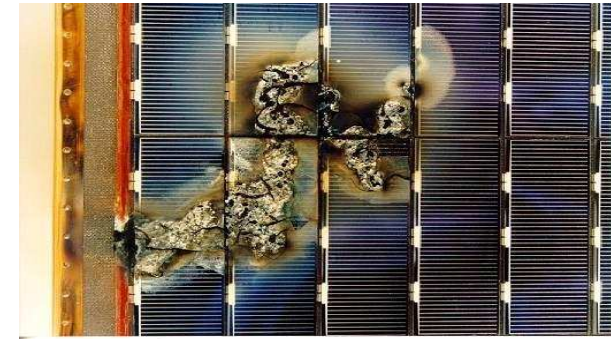 - Total dose effects

NEED TO BE ANSWERED:

(1) What space weather information are needed?

- Events forecast: flare, CME, ionospheric storm, SID, PCA,   Scintillation……
- Indices forecast: foF2, Ap, Kp, Dst, ……
- Environment specifications: TEC, electron density, ……

(2) How space weather information should be provided?

Satellites (orbit dependent)

What environment cause what effects?

- Particle Radiation
  - SEE: Single Event Effects
  - Surface charging
  - Deep dielectric or bulk charging
  - Total dose effects
- Geomagnetic Field Disturbance
  - Spacecraft orientation
- Neutral density
  - Spacecraft drag (<1000 km)
- Meteoriode / Debris
  - Collision damage

NEED TO BE ANSWERED:

(1) What space weather information are needed?

- Events forecast: SEP, Geomagnetic storm, REF enhancements ……
- Indices forecast: F10.7, Ap, Kp, Dst, ……
- Environment specifications: electrons, protons, neutral density, ……

(2) How space weather information should be provided?
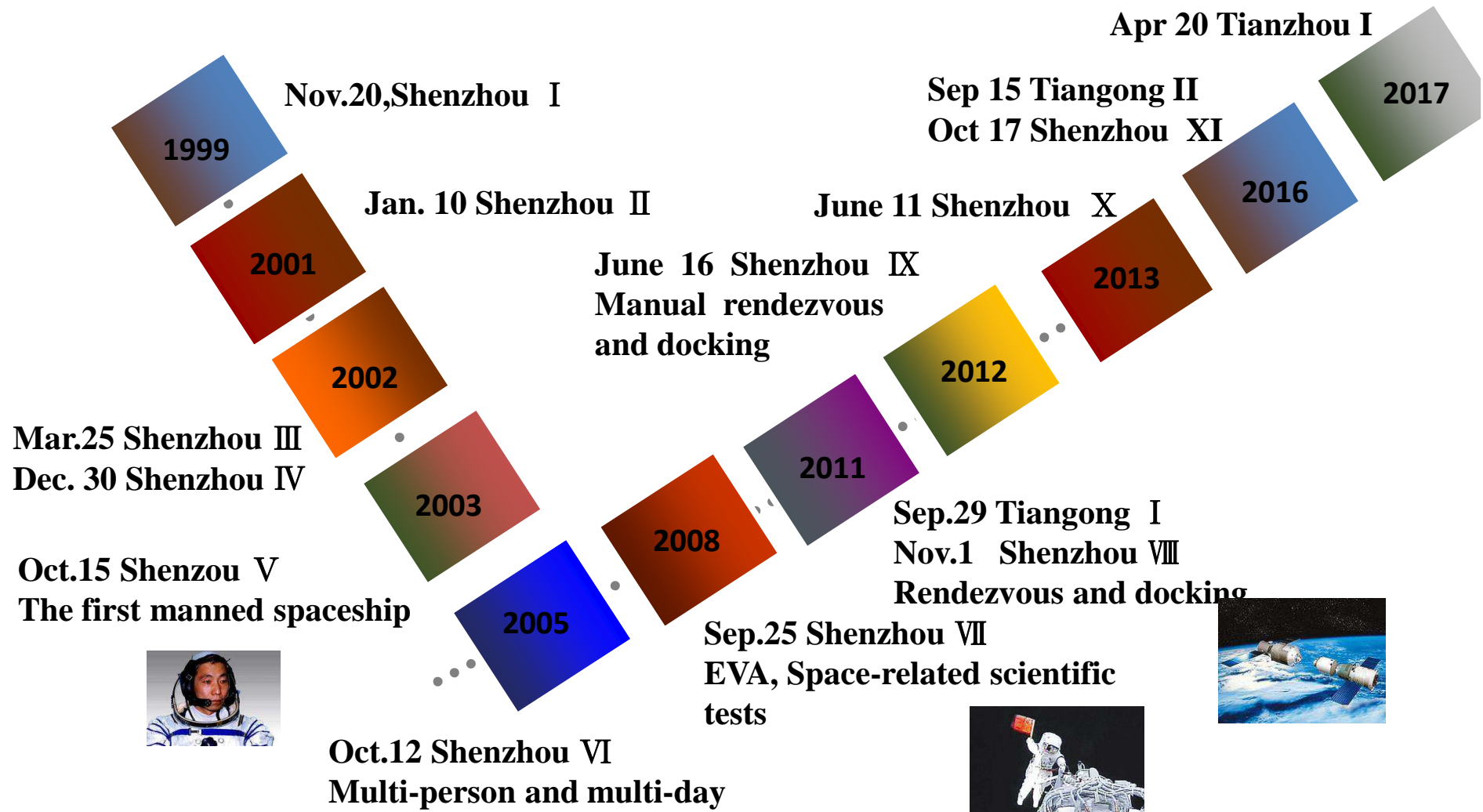
Users requirements are different!

- Not every space weather event impact all these systems.

- Not every technology system faces impacts of all these space weather events.

Space weather services for individual technology system should be identified accordingly!
(ICAO has provided an good practice.)

Services for China Manned Spaceflight Project

Apr 20 Tianzhou Ⅰ

Nov.20,Shenzhou Ⅰ

1999

Sep 15 Tiangong Ⅱ
Oct 17 Shenzhou Ⅺ

2017

Jan. 10 Shenzhou Ⅱ

2001

June 11 Shenzhou Ⅹ

2016

June 16 Shenzhou Ⅸ
Manual rendezvous
and docking

2013

2002

2012

Mar.25 Shenzhou Ⅲ
Dec. 30 Shenzhou Ⅳ

2011

2003

Sep.29 Tiangong Ⅰ
Nov.1 Shenzhou Ⅷ
Rendezvous and docking

Oct.15 Shenzou Ⅴ
The first manned spaceship

2008

2005

Sep.25 Shenzhou Ⅶ
EVA, Space-related scientific
tests

Oct.12 Shenzhou Ⅵ
Multi-person and multi-day

SEPC/NSSC has supplied space weather service in each step of China Manned Space Program for 11 Shenzhou space ships, Tiangong I & II, and cargo vessel Tianzhou I.

The Space Environment Related to LEO Spacecraft

Environments

- **High energetic particle**
- **Plasma**
- Solar radiation
- Geomagnetic field
- Upper atmosphere
- Meteoroide and debris

Effects

- **Radiation damage**
- **Charging**
- Orbital decay
- Collision effects

The Space Weather Forecast Requirements for Manned Spaceflights

I. Indices

- Solar F10.7 (the predictions in advance of 3 days, 30 days, 6 months, 11years, etc.)
- Ap (the predictions in advance of 3 days, 30 days , 6 months, 11years, etc.)

II. Space weather Events (occurrence probabilities)

- Solar proton event
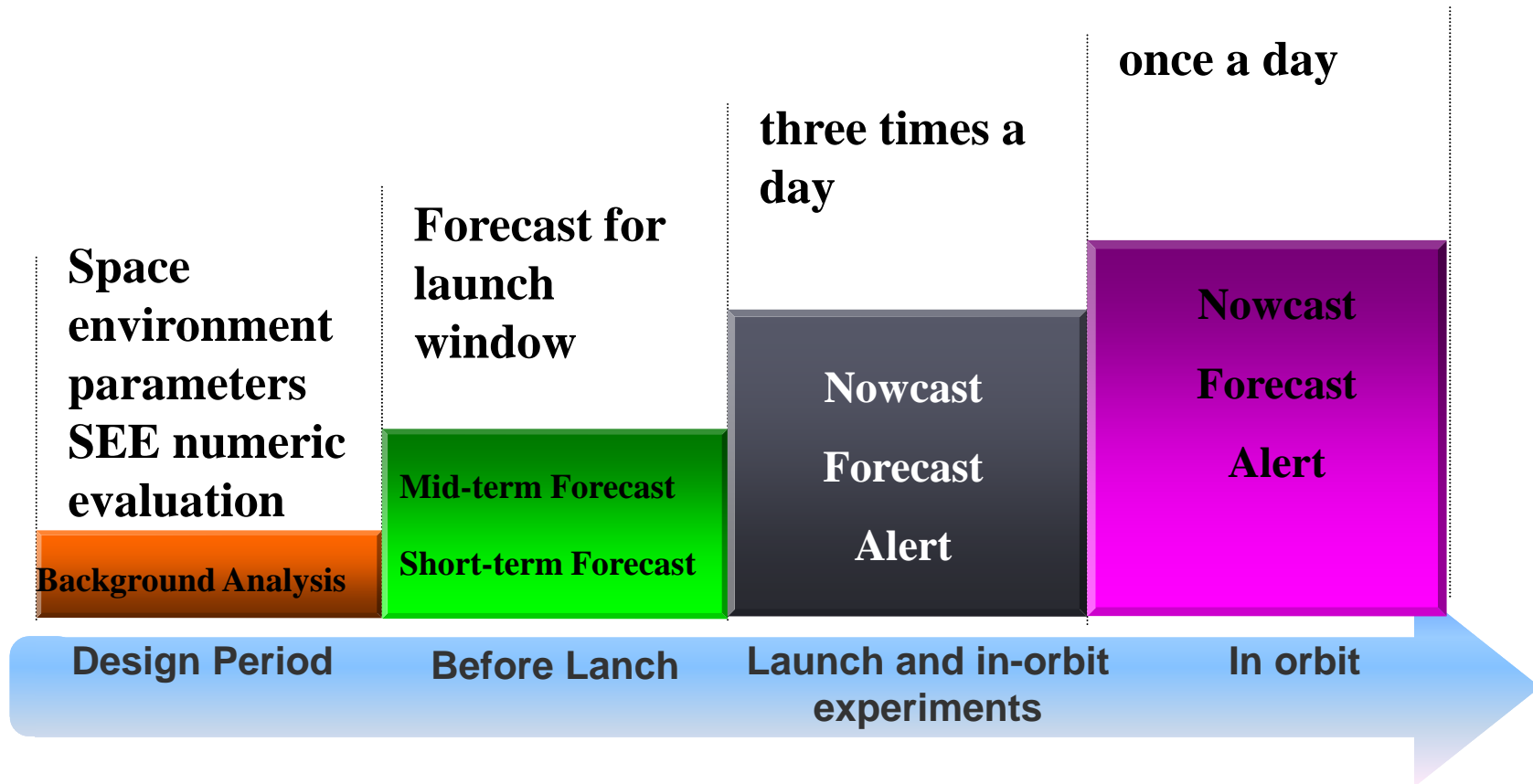- Solar flare
- Geomagnetic storm

III. Space environment specification

- Radiation belt
- Neutral density

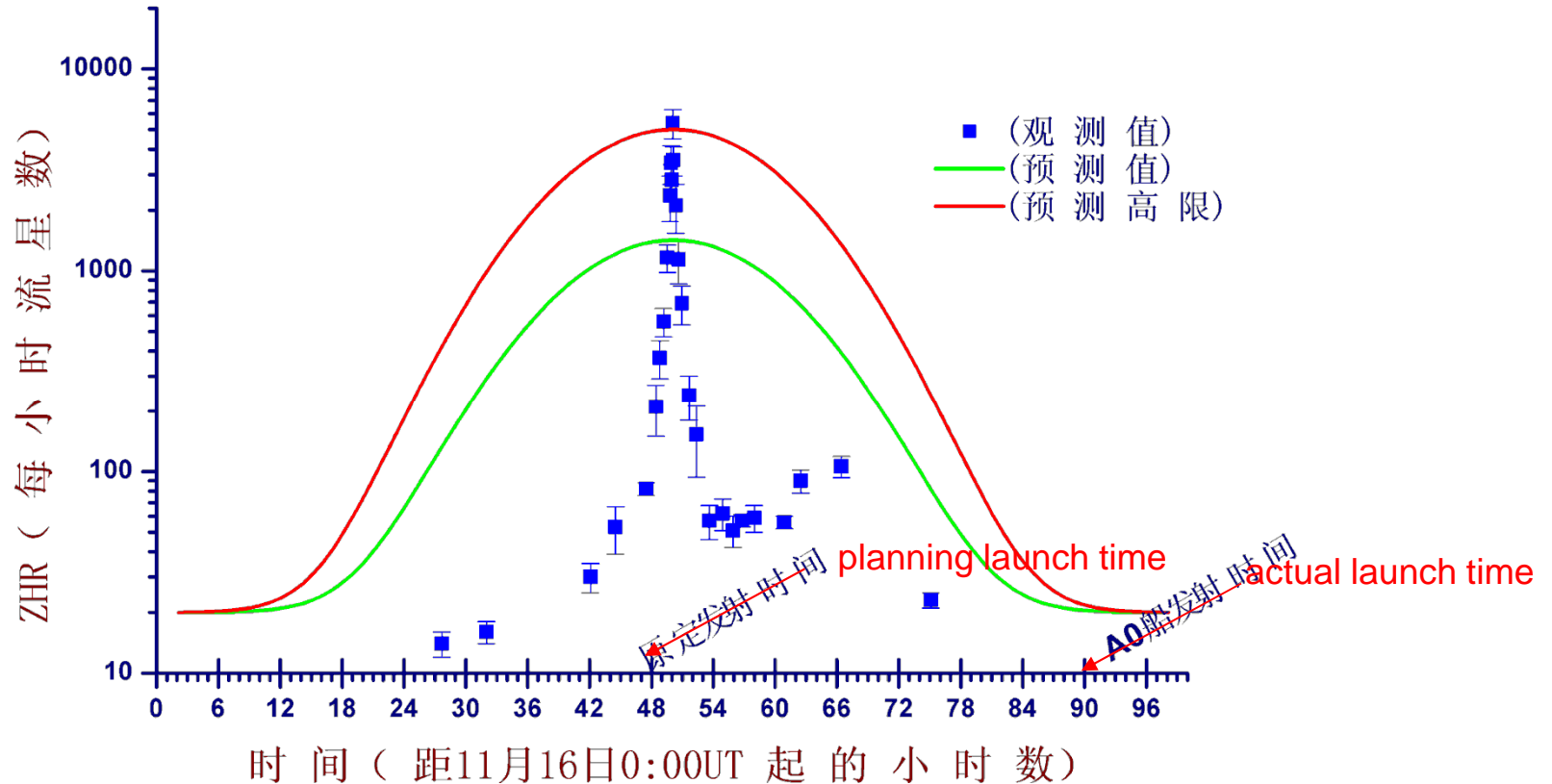## IV. Space environment effect analysis

- SEE numeric evaluation (Single event effect, Surface Charging…)
- Collision probability calculation

The Whole Process of Space Weather Forecast Service

Space environment parameters SEE numeric evaluation

Background Analysis

Forecast for launch window

Mid-term Forecast

Short-term Forecast

three times a day

Nowcast

Forecast

Alert

once a day

Nowcast

Forecast

Alert

Design Period

Before Lanch

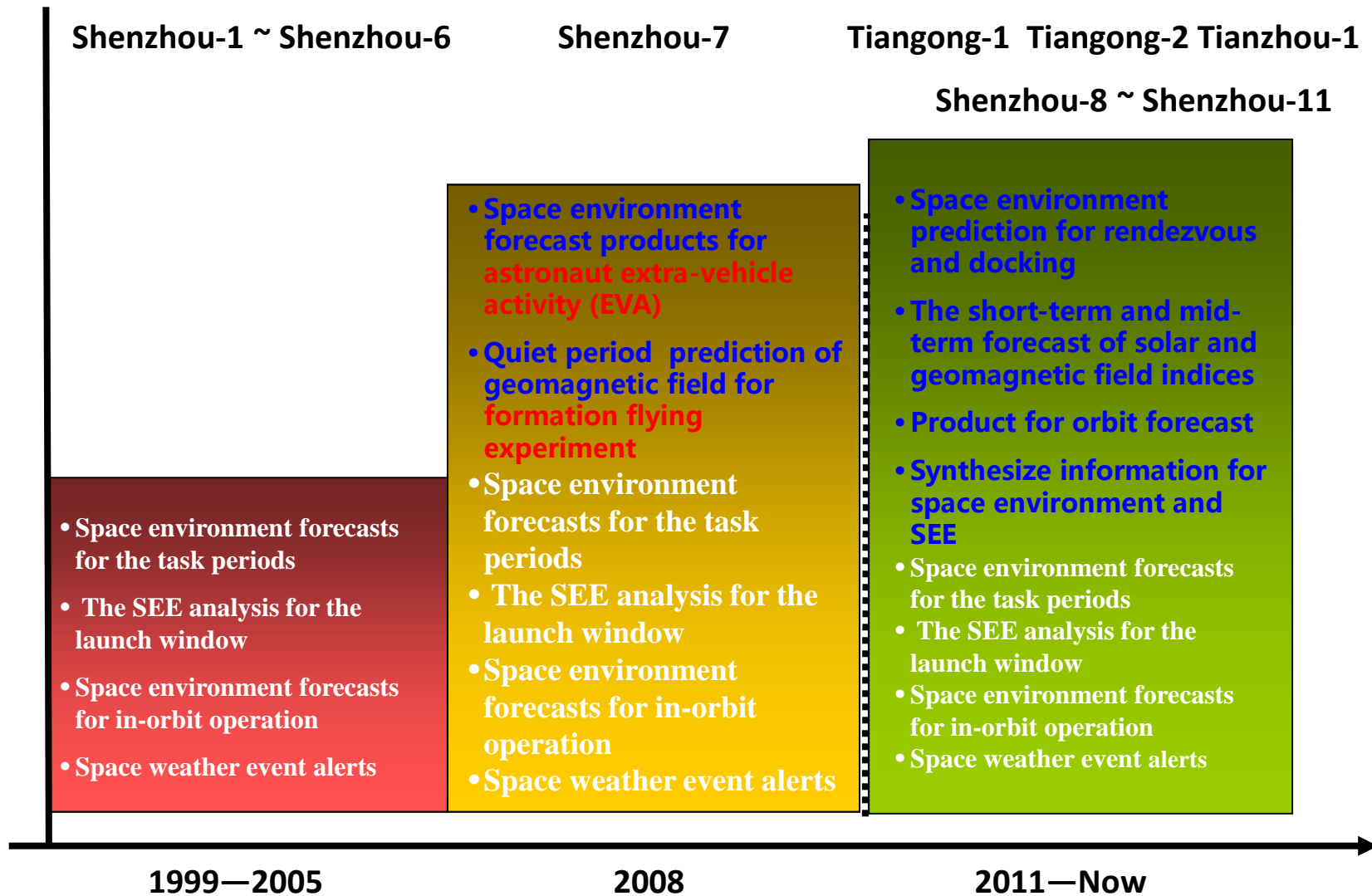Launch and in-orbit experiments

In orbit

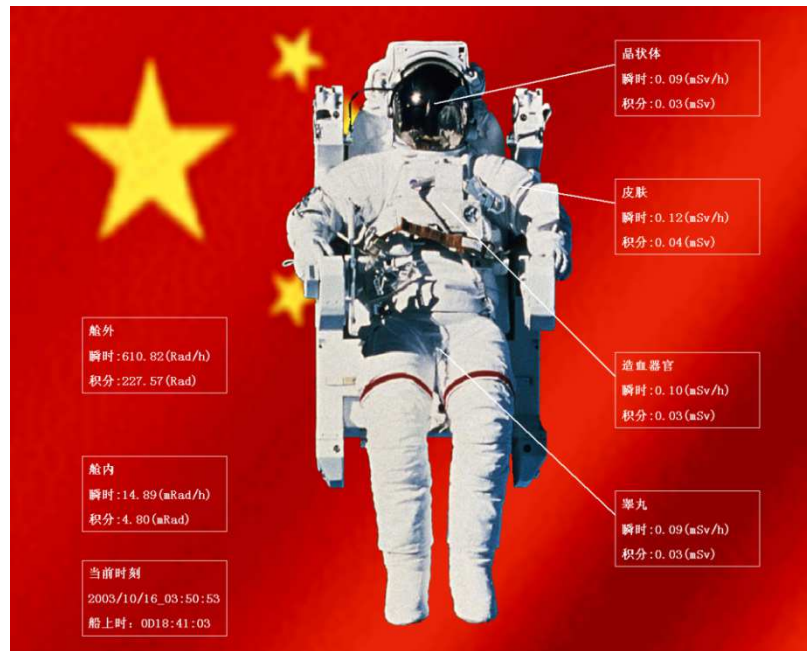# Leonid Burst Prediction for Shenzhou-1

- In 1999, in order to avoid Leonid burst, Shenzhou-1 delayed its launch time from Nov.18 to Nov. 20 for 48 hours . This is the first time to change launch plan due to the space environment in China.

- According to the observation, Meteoroid flux had declined to the safe level at the launch time.

Forecast Products for Manned Spaceflights

Shenzhou-1 ~ Shenzhou-6　　**Shenzhou-7**　　**Tiangong-1 Tiangong-2 Tianzhou-1**

Shenzhou-8 ~ Shenzhou-11

- Space environment forecast products for **astronaut extra-vehicle activity (EVA)**

- Space environment prediction for rendezvous and docking

- Quiet period prediction of geomagnetic field for **formation flying experiment**

- The short-term and mid-term forecast of solar and geomagnetic field indices

- Product for orbit forecast

- Synthesize information for space environment and SEE

- Space environment forecasts for the task periods

- Space environment forecasts for the task periods

- Space environment forecasts for the task periods

- The SEE analysis for the launch window

- The SEE analysis for the launch window

- The SEE analysis for the launch window

- Space environment forecasts for in-orbit operation

- Space environment forecasts for in-orbit operation

- Space environment forecasts for in-orbit operation

- Space weather event alerts

- Space weather event alerts

- Space weather event alerts

1999—2005　　　　　**2008**　　　　　**2011—Now**
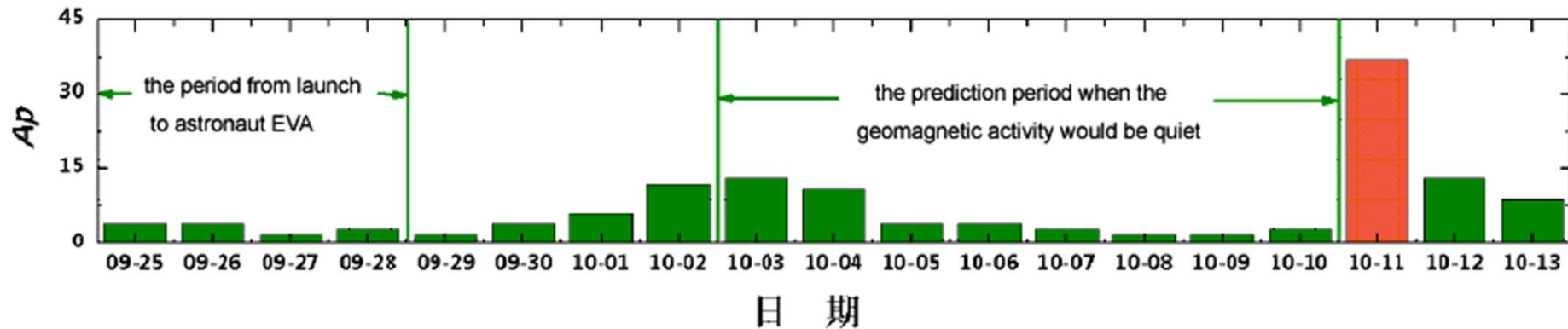
Radiation Environment and Dose Calculation

Radiation dose received by the astronaut on the orbit
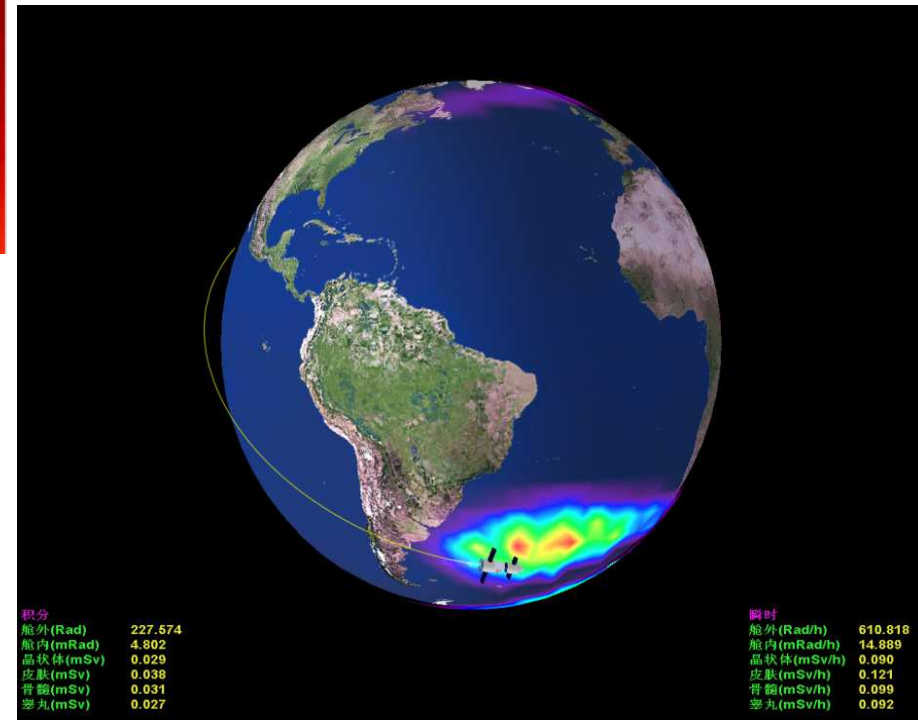
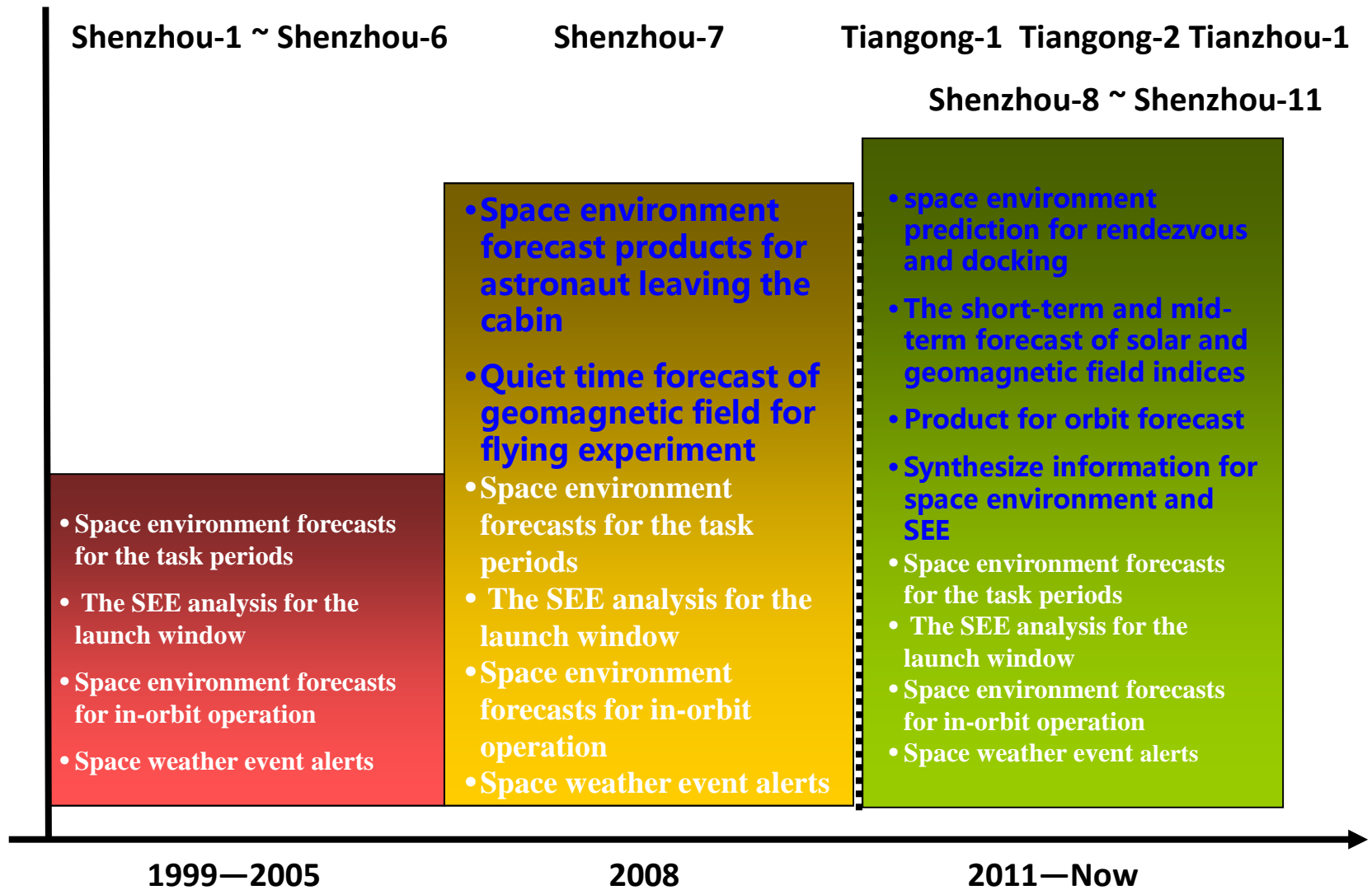The time prediction for Crossing the SAA for Shenzhou spacecraft

Geomagnetic Quiet Period Prediction for Formation Flying Experiment

The geomagnetic Ap index during SZ-7 launch, EVA and companion microsatellite experiment

- Shenzhou Ⅶ made formation flying experiments.
- We gave the Ap index mid-term forecast and selected the experiment window when the geomagnetic activity was quiet.

Forecast Products for Manned Spaceflights

Shenzhou-1 ~ Shenzhou-6 **Shenzhou-7** **Tiangong-1 Tiangong-2 Tianzhou-1**

Shenzhou-8 ~ Shenzhou-11

- Space environment forecasts for the task periods
- The SEE analysis for the launch window
- Space environment forecasts for in-orbit operation
- Space weather event alerts

- **Space environment forecast products for astronaut leaving the cabin**
- **Quiet time forecast of geomagnetic field for flying experiment**
- Space environment forecasts for the task periods
- The SEE analysis for the launch window
- Space environment forecasts for in-orbit operation
- Space weather event alerts

- **space environment prediction for rendezvous and docking**
- **The short-term and mid-term forecast of solar and geomagnetic field indices**
- **Product for orbit forecast**
- **Synthesize information for space environment and SEE**
- Space environment forecasts for the task periods
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- Space environment forecasts for in-orbit operation
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1999—2005 **2008** **2011—Now**

The Real-time Neutral Density Error Correction for Rendezvous and Docking Tasks

The neutral density prediction for Tiangong -1
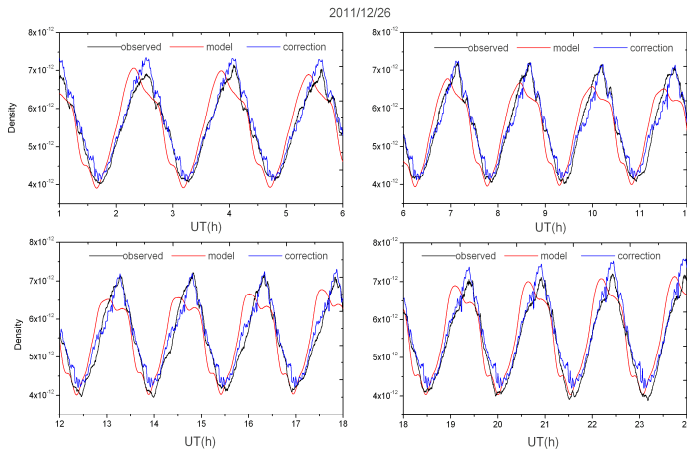
How about Other Technology Systems?

- We recommend that experiences and achievements in other practices around the globe can be shared.
- It will be useful for :
  - improving service quality;
  - establishing an international frame work for space weather services.

Thanks for your attention!