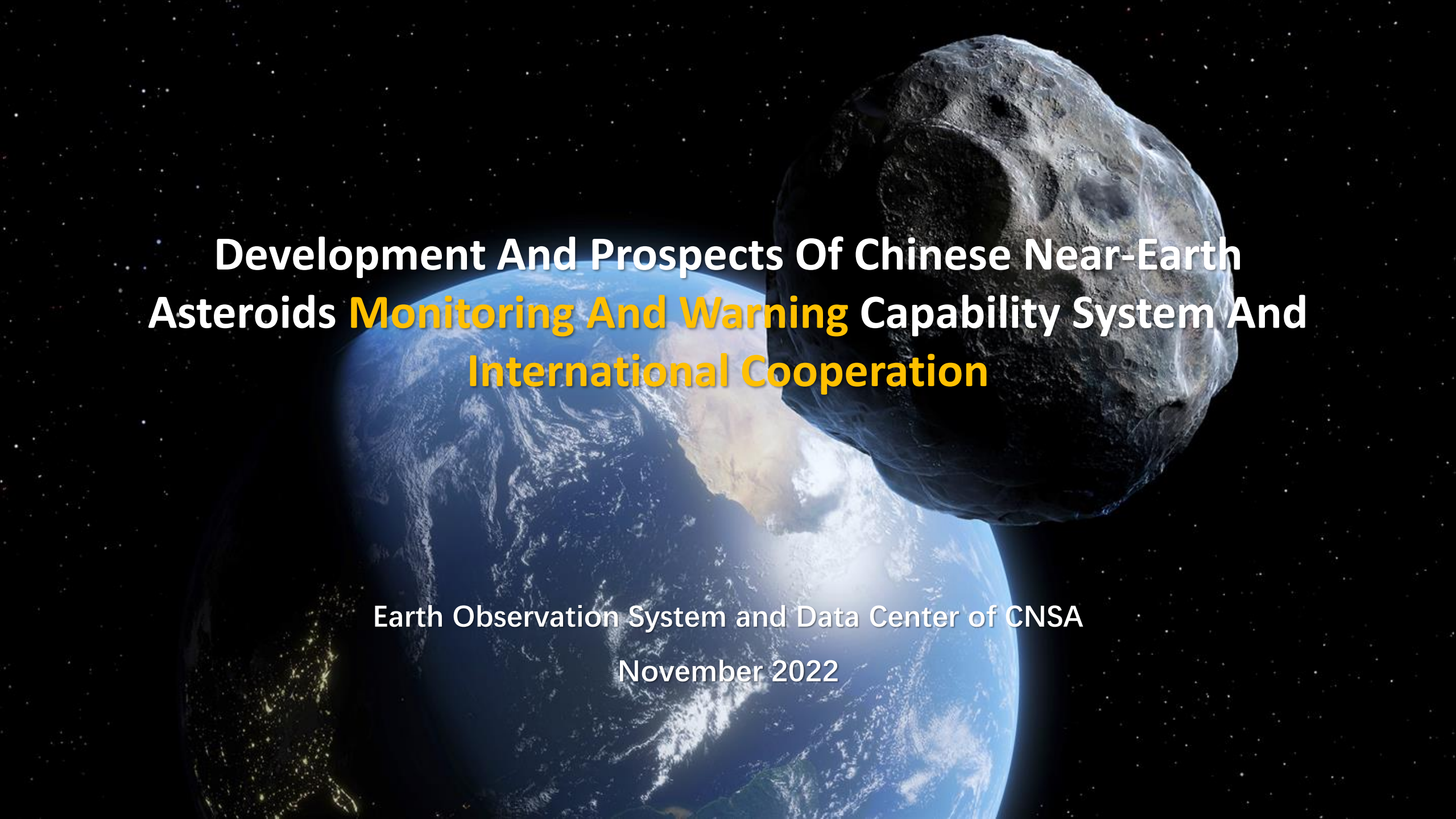

Development And Prospects Of Chinese Near-Earth Asteroids Monitoring And Warning Capability System And International Cooperation

Earth Observation System and Data Center of CNSA

November 2022

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1 Background and Significance

2 Requirements Analysis

3 Latest Status

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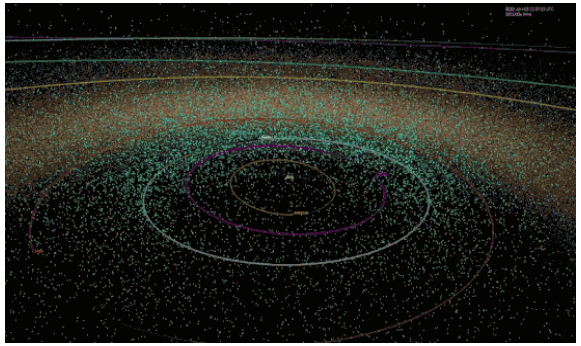
5 Prospect

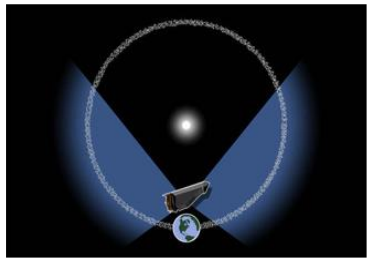
1. Background and Significance

Near-Earth Asteroids (NEAs)

NEAs with perihelion radius less than 1.3 astronomical units have the opportunity to come within 45 million kilometers of Earth's orbit and are at risk of impacting the Earth.



Preventing and resolving the risk of NEAs impacts is a common task for all of humanity



Monitoring And Early Warning

In-orbit Disposal

International Cooperation

Monitoring and early warning is a prerequisite for preventing and resolving NEAs impact risks, and international cooperation is the main grip throughout the response process, so it is especially important to carry out NEAs monitoring and early warning and international cooperation.

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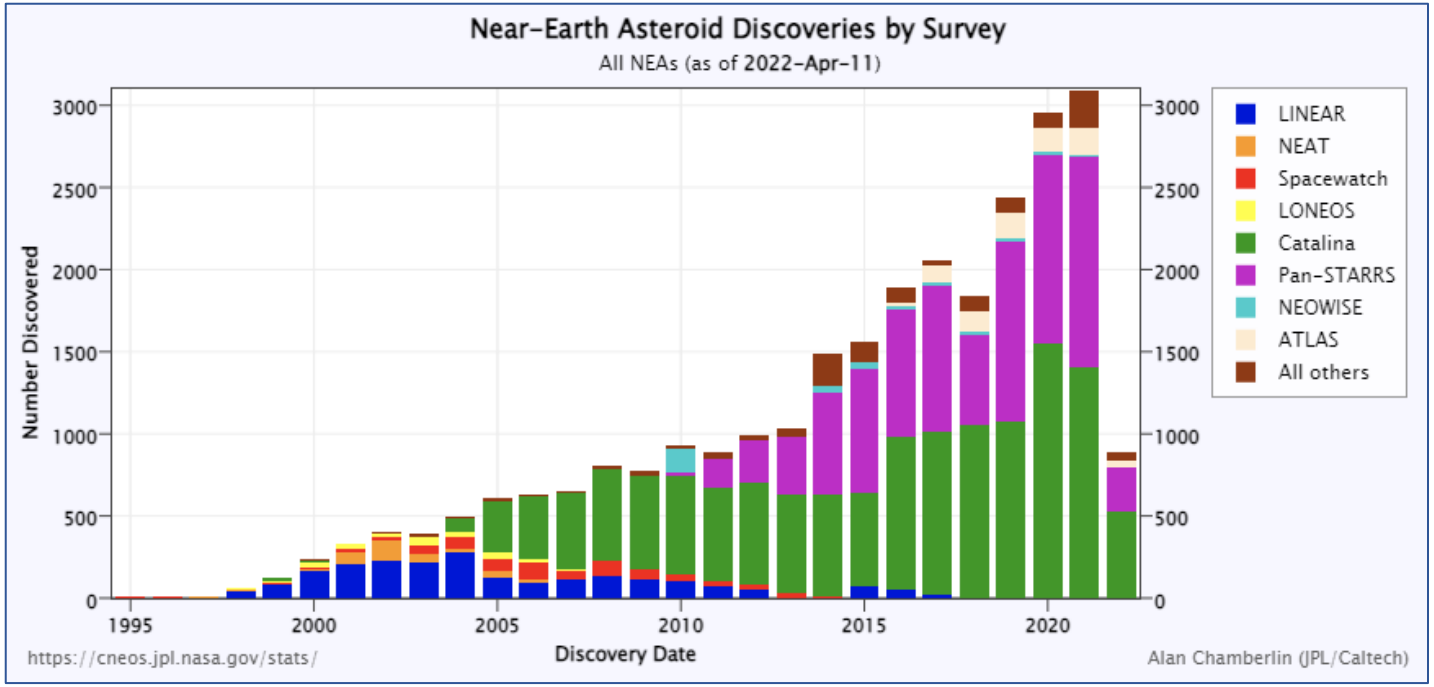
2. Requirements Analysis

(1) Status of Near-Earth Asteroids Cataloging

- The ground-based optical system is the main equipment for asteroid survey and cataloging.
- As of November 1st, 30,435 NEAs have been discovered, but there are still a large number of uncatalogued NEAs that could endanger life and property on Earth.

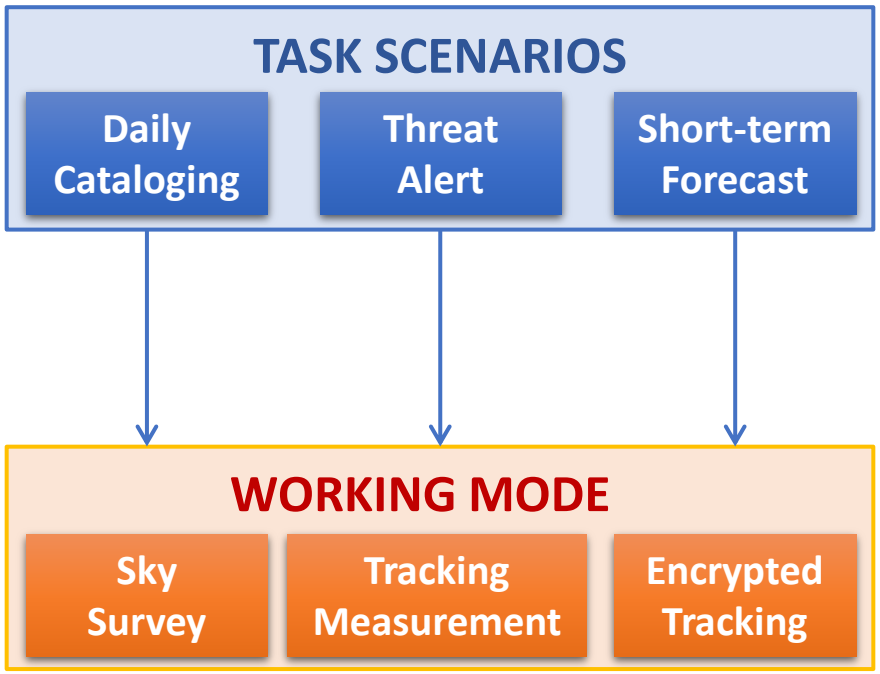


Near-earth asteroid discovery

Equivalent Diameter	Rank of Disaster	Theoretical Quantity	Discovered Rate
1000m	Global	940	94%
140m	Region	27k	34%
50m	Large City	**210k**	**3.7%**
20m	City	**500k**	**1.3‰**

(2) Analysis of Requirements for Monitoring and Early Warning

Through the analysis of the process of coping with the collision risk, the task scenario and corresponding working mode are sorted out.



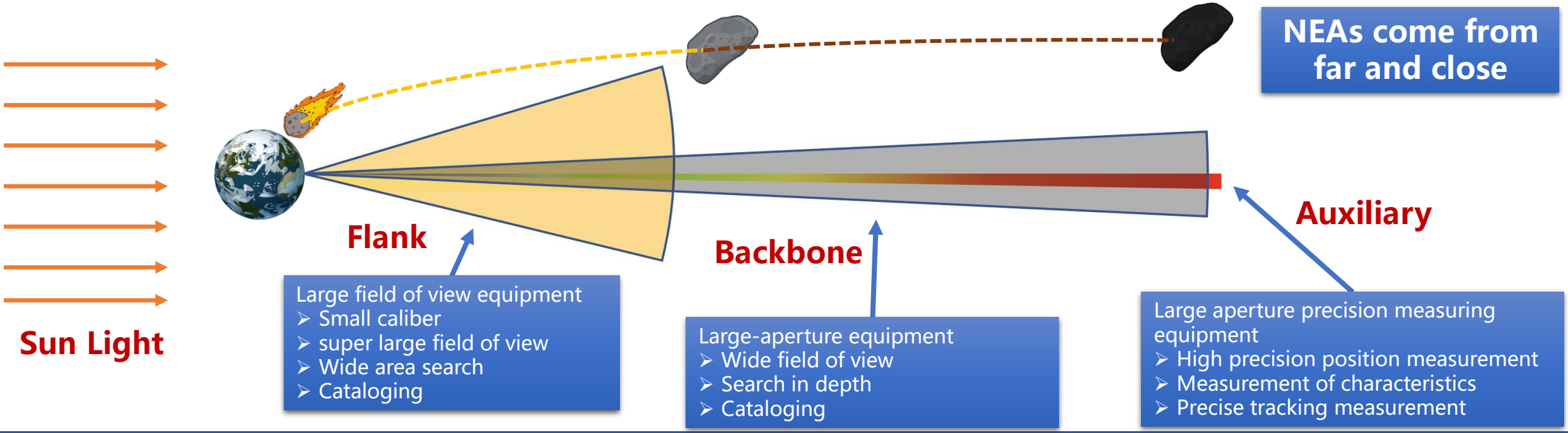
Integrated task scenario and working mode, the mission of the monitoring and early warning system are:

① For unknown NEAs, carry out a wide-area **sky survey** to catalog the discovery of larger asteroids at longer distances and alert the proximity of uncatalogued asteroids at closer distances to achieve "**comprehensive monitoring**" of NEAs.

② For discovered NEAs, we will carry out tracking and precise measurement to warn the risk and hazard of their impact on Earth, and start **encrypted tracking** when necessary to realize "**precise warning**" of NEAs impact risk.

(3) Ground-based monitoring requirements

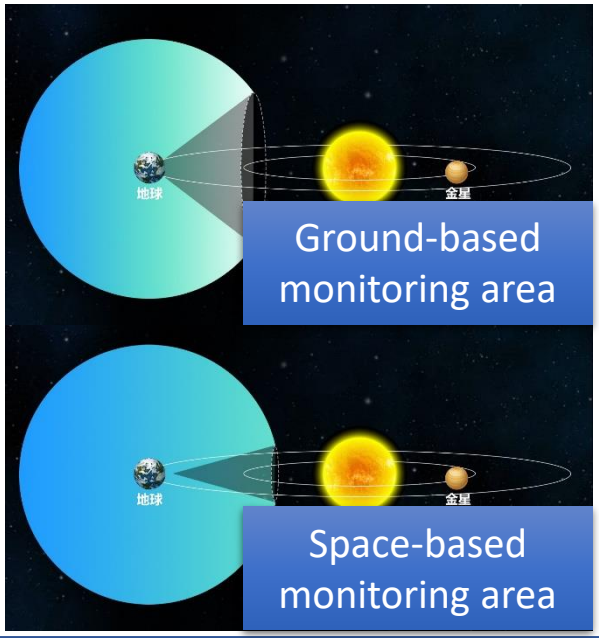
- For **daily cataloging** scenarios, using **large-aperture, large-field optical equipment** as the backbone to achieve the depth of the patrol search.
- For **daily cataloging** scenarios, using **large-aperture optical equipment** as a flanker to realize the breadth of patrol search.
- For **threat warning and short-range forecast** scenarios, we improve the accuracy of position, physical and chemical property measurements with the aid of **large-aperture precision measurement equipment**.



2.Requirements Analysis

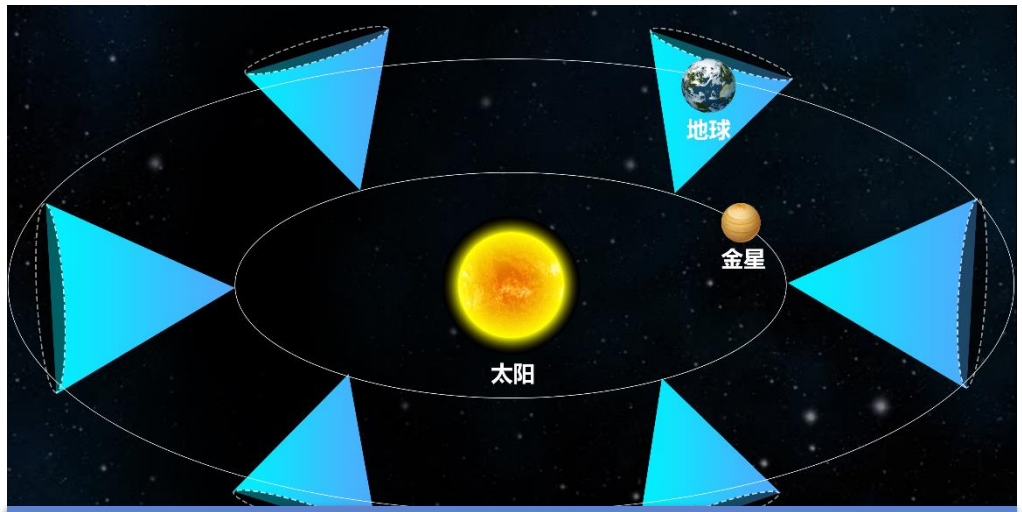
(3) Space-based monitoring requirements

- For daily cataloging scenarios, the rapid deployment of space-based integrated test satellites as a starting point to collaboratively compensate for ground-based blind areas, blind spectra and interference.
- For daily cataloging scenario, the deployment around the day-earth network patrol orbit is the main focus to expand the depth, breadth and frequency of monitoring and warning.
- For threat warning and short prognosis scenarios, through satellite application mode design, the deployment of stable watch points relative to the sun and earth is the main focus, expanding the accuracy, speed, and dimension of monitoring and warning. Realize Short-term Forecast of incoming uncatalogued asteroids and explore new modes of watch over the sky zone.

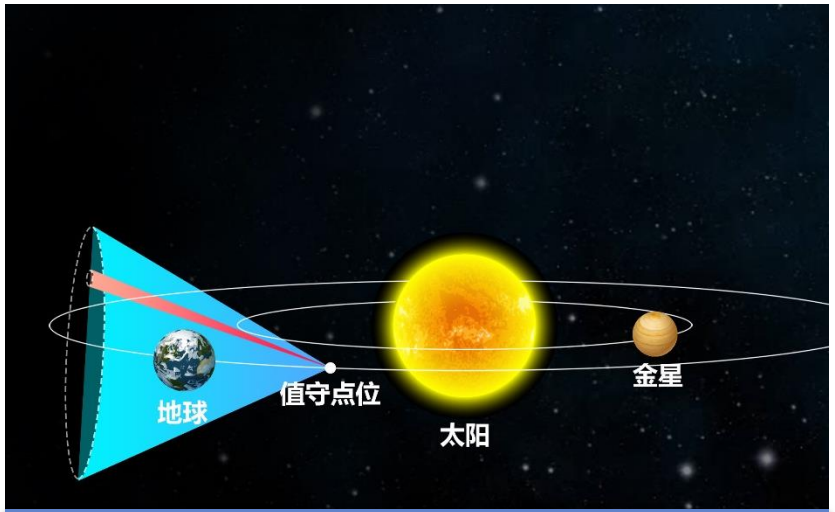


Ground-based monitoring area

Space-based monitoring area



the deployment around the day-earth network patrol orbit



the deployment of stable watch points relative to the sun and earth

(5) Early warning service requirements

For the risk of an asteroid impact, we provide "**Five Precise**" early warning services in terms of precise orbit determination, Precise portrayal characteristics, precise rendezvous prediction, precise risk warning and precise hazard assessment, and form a regular early warning operation capability.

Asteroids Impact Risk Early Warning

Precise Orbit Determination	**Precise** portrayal characteristics	**Precise** Rendezvous Prediction	**Precise** Risk Warning	**Precise** Hazard Assessment
To determine the initial orbit of near-Earth asteroids and precise orbit determination.	To describe multi-dimensional characteristics such as rotation, shape and material.	To accurately forecast the Earth's rendezvous event within 200 years.	To accurately calculate the asteroid impact probability and impact area.	To accurately assess air burst and surface impact hazards.

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3.Latest Status

(1) Overview of Monitoring and Early Warning system

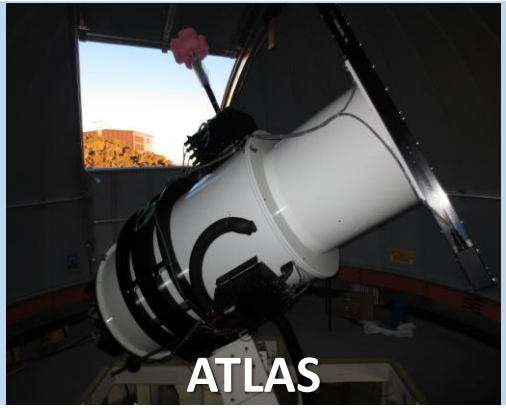
In the international community, resources are pooled to strengthen coordination, the system capacity of space and ground integration and the early warning software system are simultaneously in developping. Currently, **the United States and Europe** are able to calculate and analyze the **short, medium, and long-term impact risks** of NEAs, and **the United is in a leading position** in monitoring and warning.

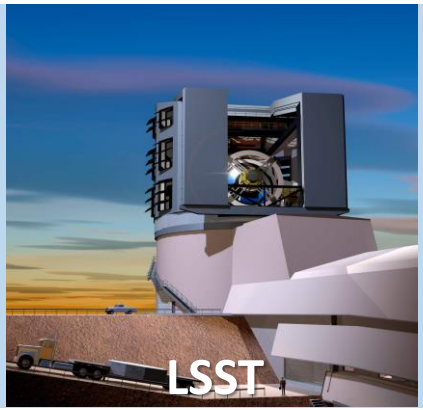
Ground-based and space-based monitoring and early warning equipment and facilities

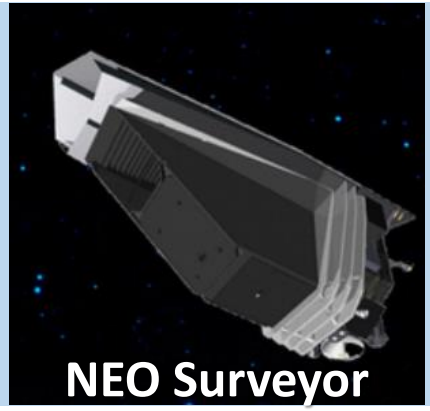
- The US has started several ground-based optical sky survey programs, such as Catalina, Pan-STARS, and LSST, **contributing more than 98% to international cataloging**, far more than other countries.
- The US is actively supporting the Near-Earth Object Explorer **space-based infrared telescope**, which is expected to double the proportion of potential targets found.


Catalina


Pan-STARRS

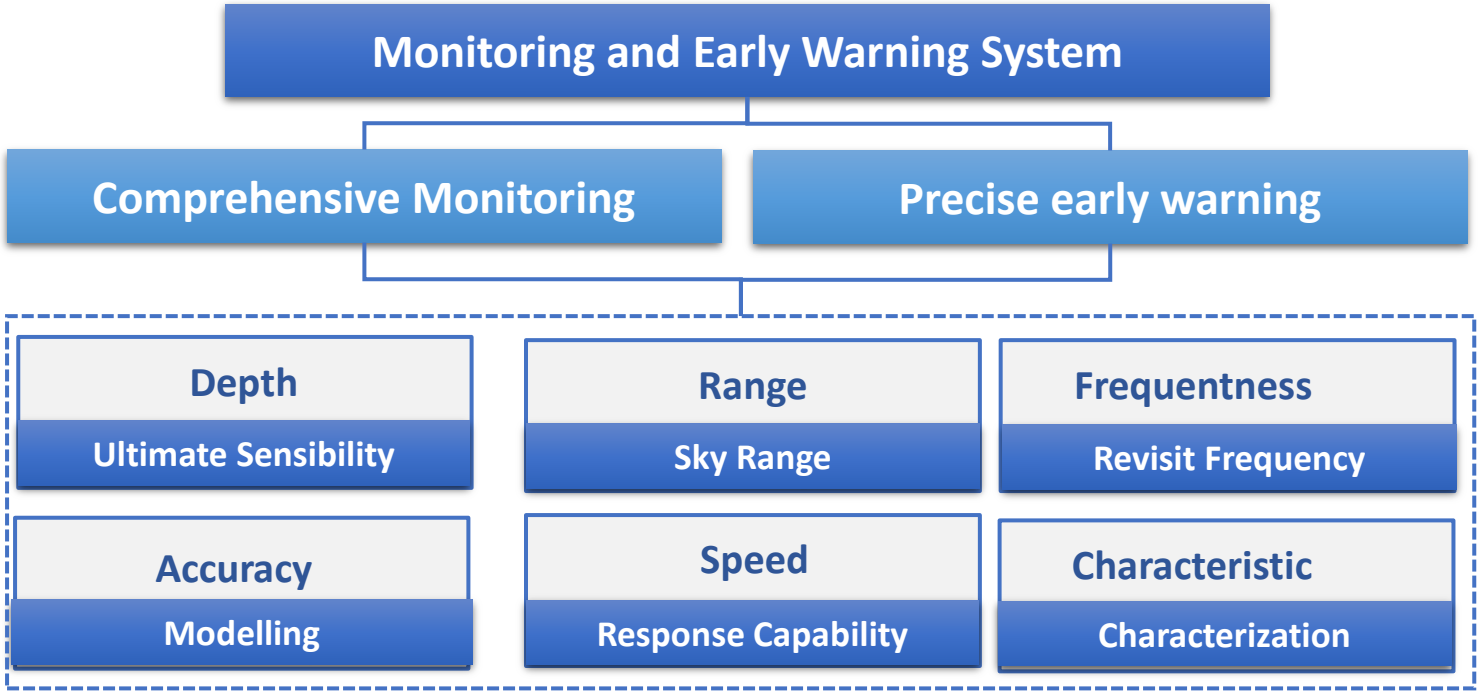

ATLAS

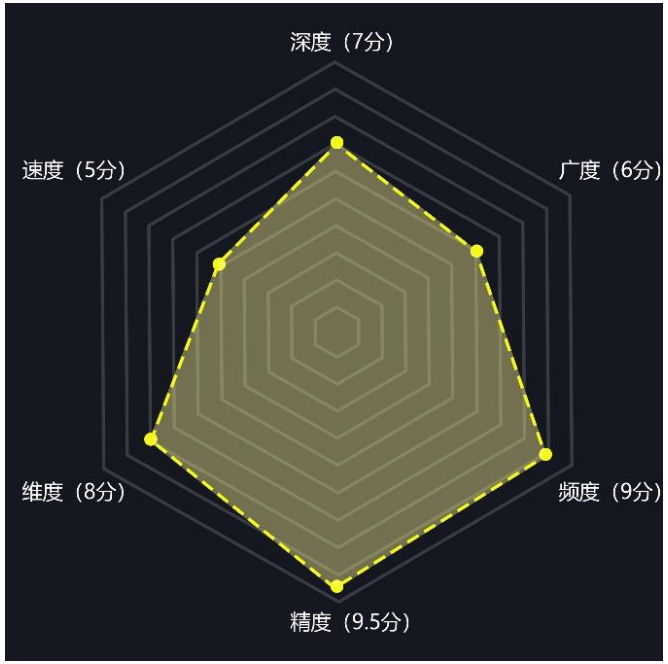

LSST


NEO Surveyor

(2) Chinese monitoring and early warning system

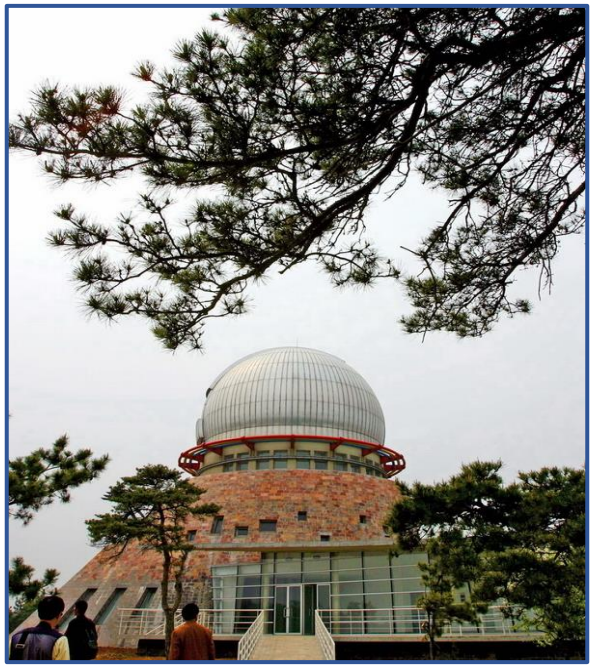
- For the three mission scenarios, a **six-degree analysis theoretical framework** is proposed around the mission orientation of "comprehensive monitoring" and "accurate warning".
- Through **the capability value diagram**, a comprehensive evaluation of the capability systems of different architectures is conducted to support the construction of the NEAs monitoring and warning system.





The Capability Value Diagram

(3) China's monitoring and early warning capabilities - Specialized



At present, China has only one specialized **1-meter aperture** monitoring equipment at the Purple Mountain Observatory of the Chinese Academy of Sciences. **More than 30** near-Earth asteroids have been discovered, ranking sixth in the world.

Chineses Specialize Capability

At present, the system layout has not been formed, the early warning algorithm model needs to be promoted.

There is a **big gap**.

(4) China's monitoring and early warning capabilities - mainly for dual use

The Lijiang (2.4m), Xinglong (2.16m) and Yao ‘an (0.8m) telescopes are mainly used for asteroid observation and research. They are capable of spectral measurement and multicolor metering.

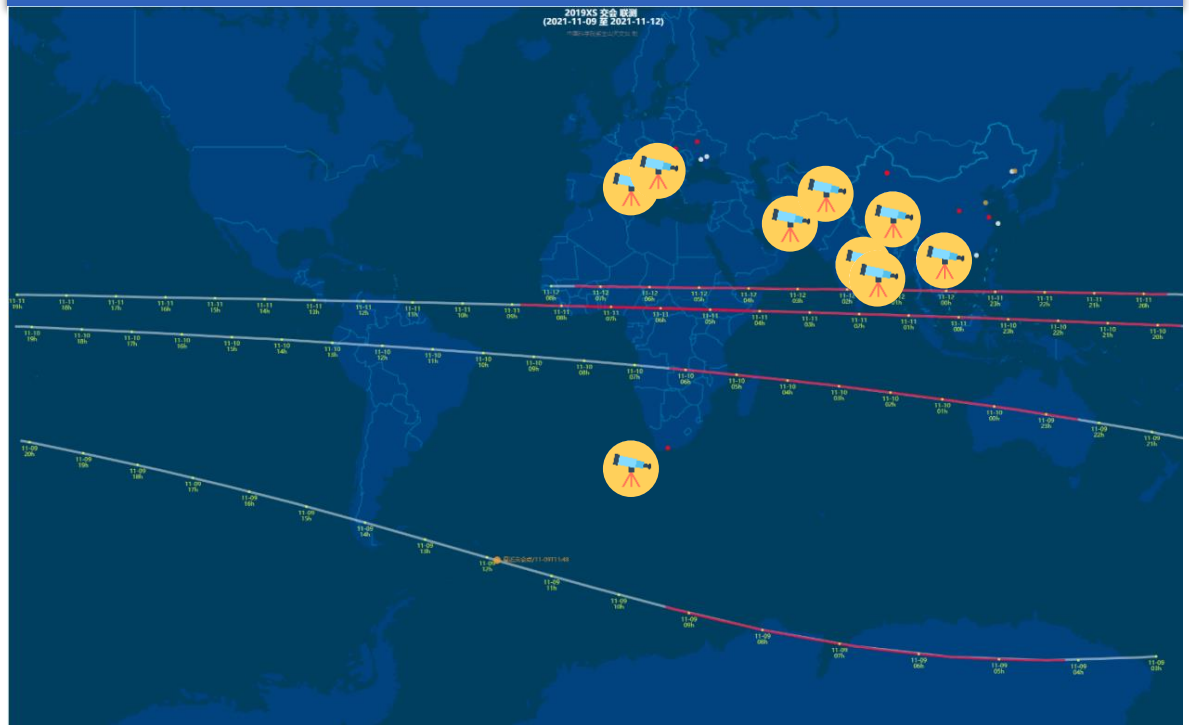
Dual-use Telescope capabilities

The existing telescopes is with relatively small apertures. The time that can be used for asteroid observation and research is not much. And the perception of the physical characteristics of the asteroid is not strong.

3.Latest Status

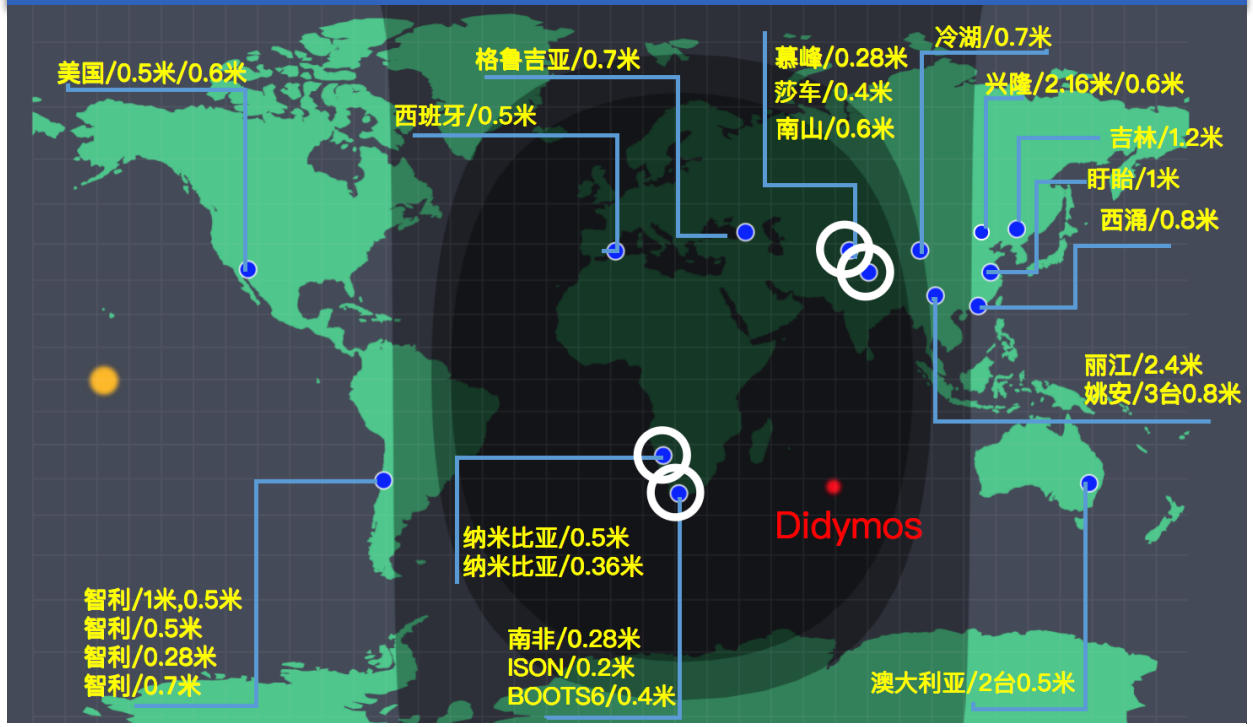
(5) Chinese major international cooperation - international joint survey

IAWN-2019XS Joint Survey



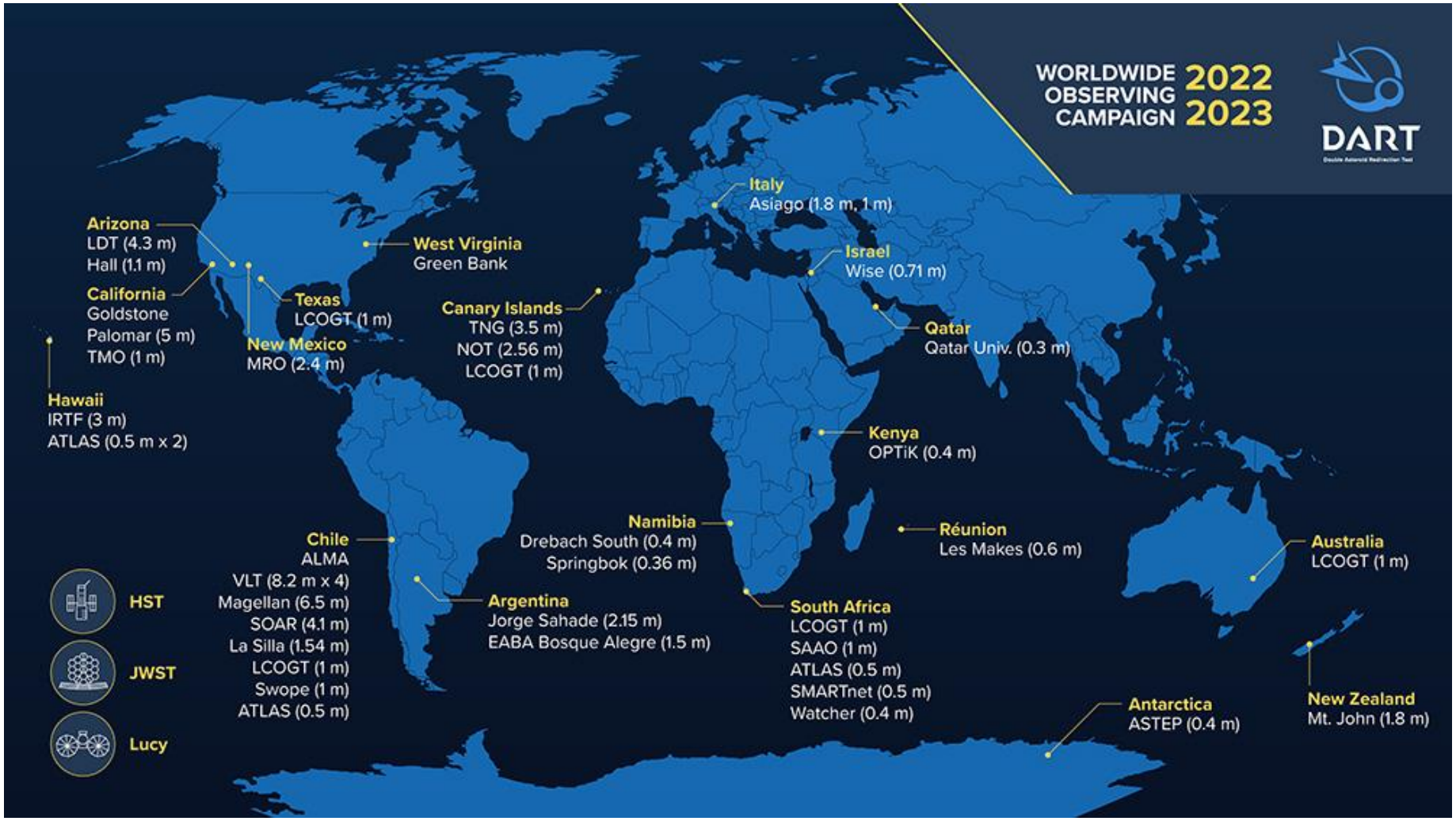
- Participate in conducting IAWN 2019XS joint survey activities.

DART-Didymos Joint Survey



- A total of 43 domestic and foreign telescopes were organized to conduct joint measurements of the DART mission.

(6) DART Mission -- Distribution of monitoring equipment outside China

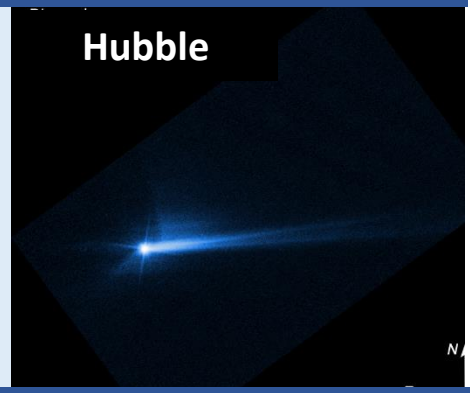


List of equipment

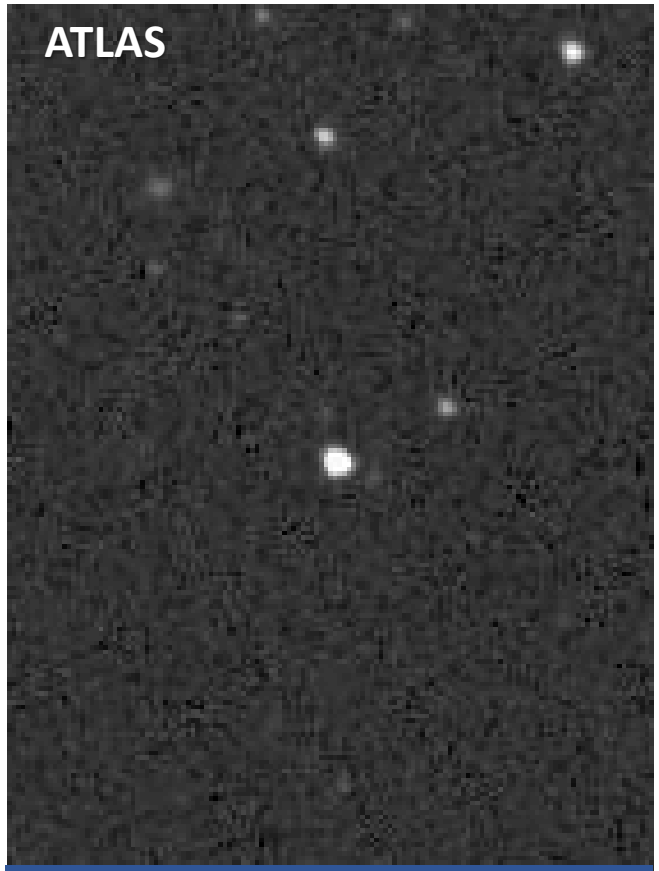
- **Space-based,** HS, JWST, Luc, Liciacube;
- **Ground-based**, LDT, Hall, Palomar, MRO, TMO, ATLAS, VLT, Magellan…
- **Ground-based Infrared,** IRTF, SOAR
- **Ground-based Radar,** Goldstone, GreenBank

(7) DART Mission - Collaborative monitoring and Evaluation

Post-collision observations with space-based visible and infrared telescopes



Ground and space-based telescopes observe sputtering dust images



Ground-based telescope image of the impact process

Monitoring and Evaluation

- During the mission, the US deployed **dozens of** ground-based telescopes and radars, as well as four spacecraft in orbit, to continuously monitor the impactor and the target asteroid and assess the impact.
- With its **strong collaborative monitoring capability**, the United States has been able to predict the way and probability of asteroid impact, which has laid a solid foundation for identifying and preventing the risk of near-Earth asteroid impact.

(8) DART Mission - China

Under the leadership of the **CNSA**, the **Purple Mountain Observatory** of the CAS took the lead in mobilizing more than **40** equipments of international and domestic equipment to carry out the joint DART mission measurements.

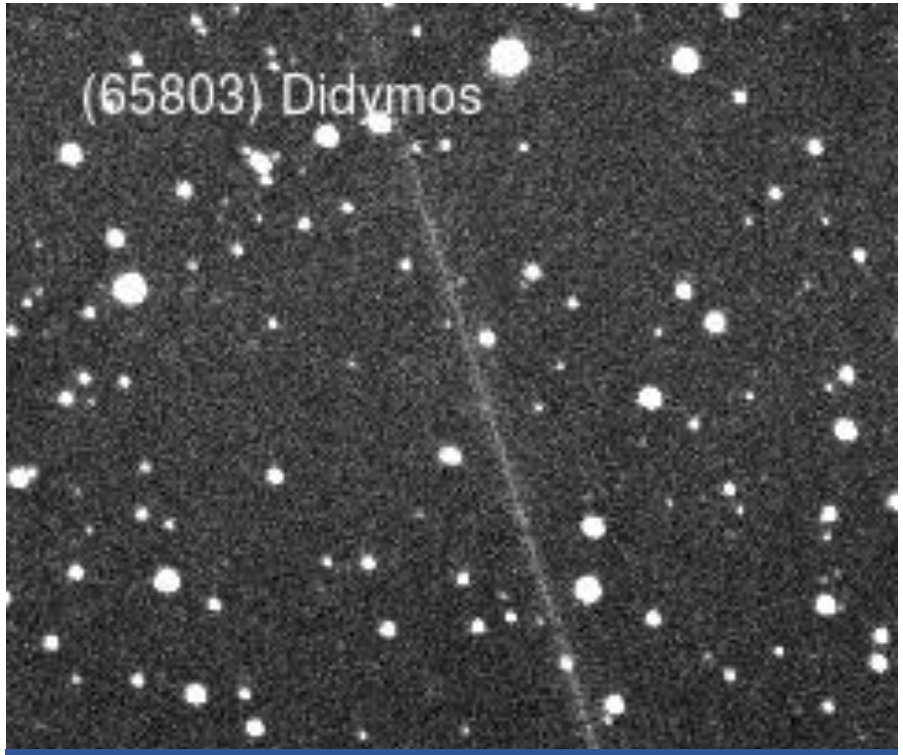
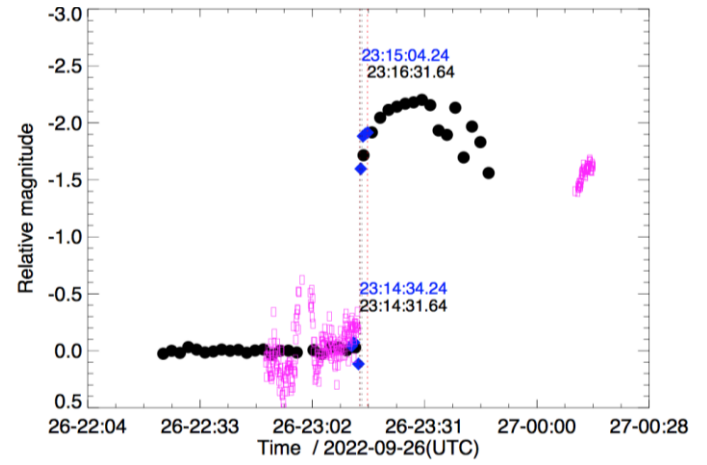
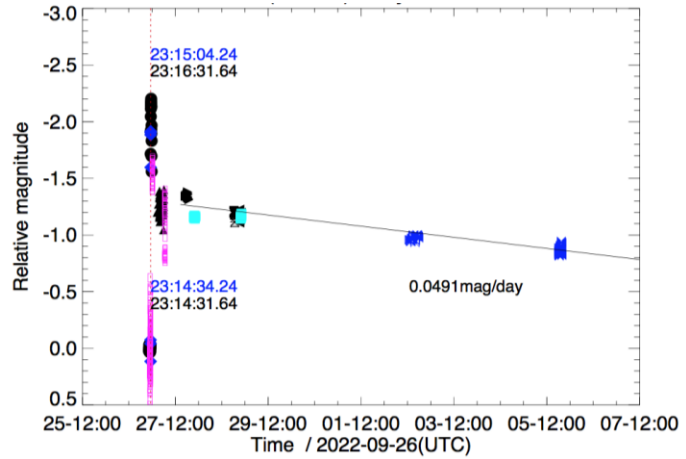


Image of the impact acquired by the Muztagh Telescope





Impact Effect Assessment

- A dust explosion of the binary system was observed, resulting in a brightness increase of about 7.6 times and a magnitude brightening of 2.2 magnitudes. **It can be judged that DART successfully impacted the asteroid.**
- Due to the insufficient acquisition of observational data, the results of the assessment of **the orbital period change are yet to be determined and analyzed**.

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4.Requirements and Objectives of the Development

Requirements of Development

- In 2018, China National Space Administration joined the IAWN and SMPAG.
- In 2021, Administrator Zhang Kejian proposed to **demonstrate the construction of an asteroid defense system**; Hosting the first National Conference on Planetary Defense; The white paper "China's Space in 2021" proposes to "**Demonstrate the construction of a defense system for near-Earth small objects and improve the capabilities of monitoring, cataloging, early warning, response, and disposal**".
- In 2022, Wu Yanhua said in an interview that "**China will start to build a near-Earth asteroid defense system**."

Since 2020, Administrator Zhang Kejian and Deputy Administrator Wu Yanhua of CNSA have made it clear on different occasions that China will demonstrate the construction of a Chinese Asteroid Defense System, in which **monitoring and early warning, and international cooperation** are an indispensable part of planetary defense.

Mission Objective: To build a community of shared future for mankind in the field of planetary defense

Monitoring and Early Warning

- **In the near term**, the focus will be on building a monitoring and early warning network, which will be capable of independent discovery and continuous cataloging of **140-meter asteroids**.
- **In the medium term**, a joint earth-earth monitoring and early warning network should be established to enable the autonomous discovery and continuous cataloging of **50-meter asteroids**.
- **In the long term**, a comprehensive and reliable monitoring and early warning network will be established, with the capability of self-discovery and continuous cataloging of **30-meter asteroids**.

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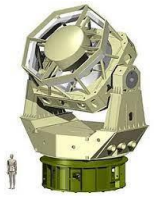
5.Prospect

(1) the development of ground-based monitoring capacity system vision

A ground-based monitoring network of a "**combination of survey and accurate measurement, relay between the eastern and western hemispheres, and coverage of the northern and southern sky areas**" will eventually be formed.

Daily Cataloging



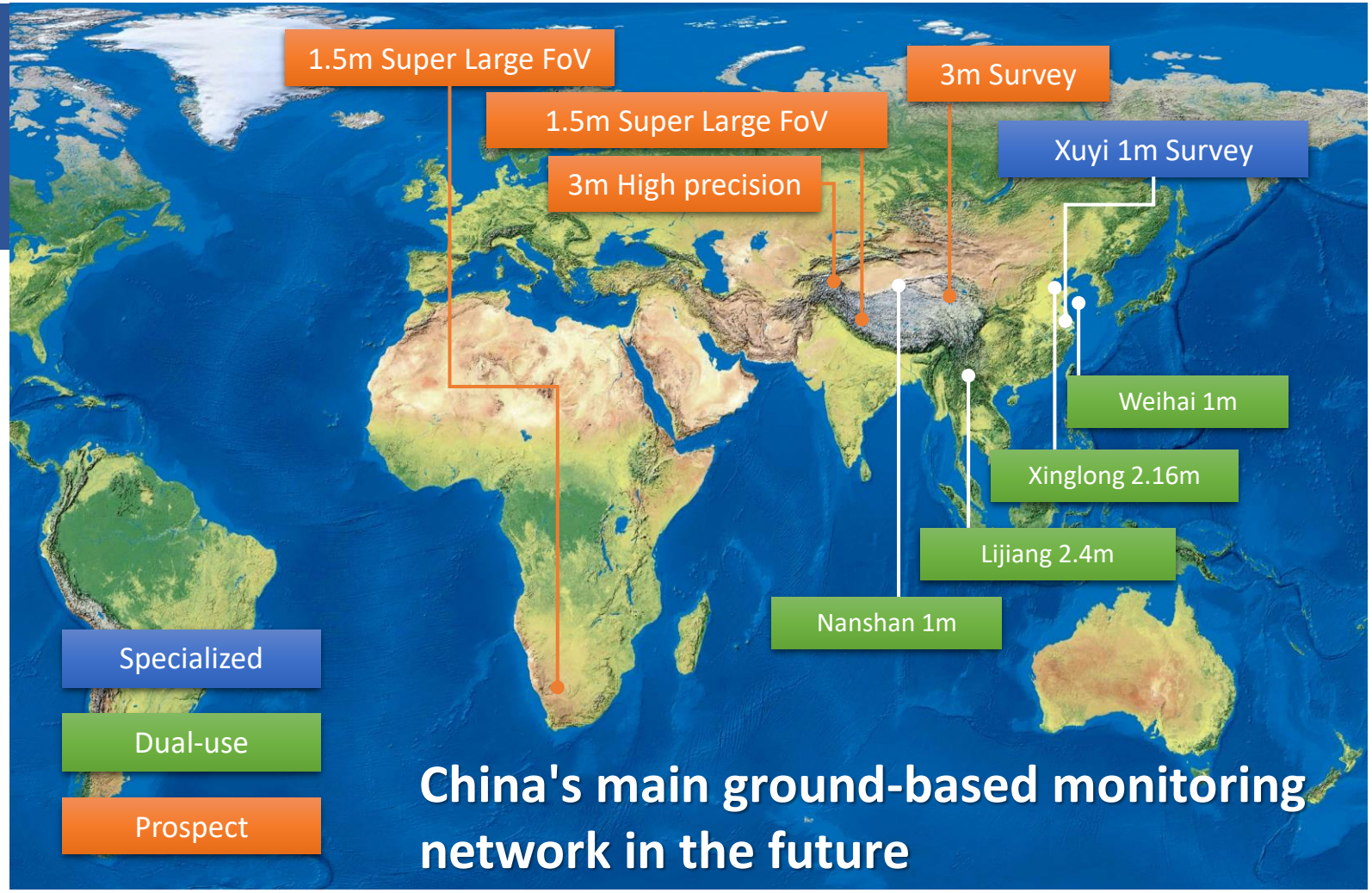
Large-Aperture Survey
One 3-m 9 Deg2

Threat Alert

Super Large FoV
Two 1.5-m
36 Deg2

Short-term Forecast

Large-Aperture
High precision
One 3-m spectrum

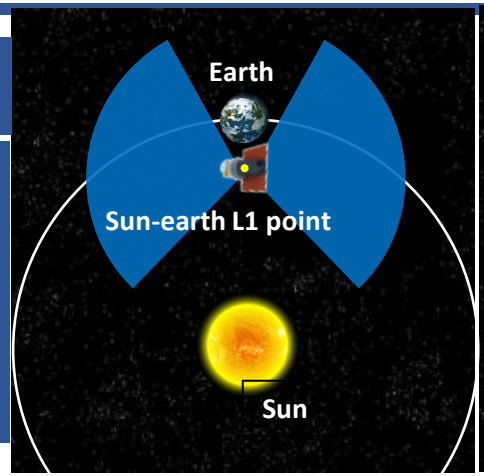


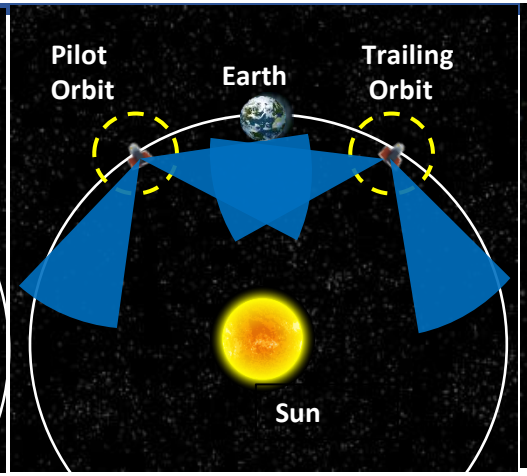
China's main ground-based monitoring network in the future

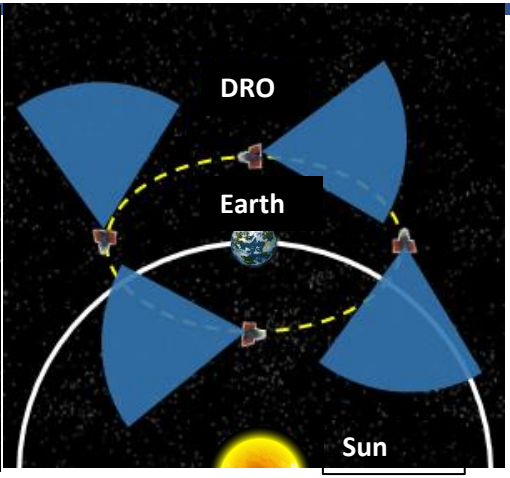
5.Prospect

(2) spaced-based monitoring vision

Through the development steps of test optimization, network deployment, and expansion and enhancement, a space-based monitoring network with "**heaven and earth coordination, wide area coverage, and time-sensitive response**" will eventually be formed.







Daily Cataloging

Threat Alert

Short-term Forecast

Multi-orbit Multi-scene Integrated Test Satellite (1)

Stable Watch Points Relative To The Sun And Earth Monitoring And Warning Satellite

Orbit Around The Solar-terrestrial Network Monitoring And Warning Satellite

Concurrent Satellites And Payloads

China's main space-based monitoring network in the future

Solar-Terrestrial L1 Orbit

Earth Pilot / Trailing Orbit

Venus-like orbit

Earth Accompanying Flight DRO Orbit

Earth-Moon L3/L4/L5 point

Others

Orbit

VL, IR, etc

VL, IR, etc

VL, IR, MUX

VL, IR, MUX

Radar、Laser

Other Spectra

Band

(3) Prospect of Early Warning System

- Based on the "**Five Precise**" warning services, we will develop the capability of generating, disseminating and providing warning information on the risk of near-Earth asteroid impact at 140m, 50m and 30m diameters in a phased manner.

Asteroid impact risk Early warning

Precise Orbit Determination
- Initial orbit determination
- Precise orbit determination

Precise portrayal characteristics
- Characteristic of light variation
- Characteristic of spectrum

Precise Rendezvous Prediction
- Short-term forecast
- Long-term forecast

Precise Risk Warning
- Probability of impact
- Corridor of impact

Precise Hazard Assessment
- Air burst
- Surface impact hazards.

(4) International Cooperation and Opening-up Initiative

1. To accelerate diversified cooperation in monitoring and early warning

- African and South American countries are preferred to set up overseas monitoring stations to expand ground-based sky area coverage. We will enrich cooperation styles in space-based development such as payload carrying and joint development with major space-based countries, and strive to promote mission-level cooperation.
- China has carried out ground-based joint observation missions with Russia, Europe, South America and other countries to improve its emergency monitoring capacity.
- Relying on specialized agencies, China will set up international data centers, establish track cataloging databases, and carry out international data exchange and sharing.

2. Advance the process of advancing international rules

- We will strengthen cutting-edge research on international planetary defense policies, regulations, mechanisms and processes.
- China is deeply involved in relevant international organizations such as IAWN and SMPAG, exploring and launching international big science programs, and making China's contribution to jointly addressing long-term threats and challenges facing all mankind.

5.Prospect

(5) Specialized Organizations/Entities

The Establishment Of A **National Asteroid Monitoring And Early Warning Research Center** Is A Necessary Measure For China To Quickly And Effectively Promote The Progress Of Monitoring And Early Warning And International Cooperation.

Focus

- **Monitoring And Early Warning:** we will strengthen the organization and guidance of relevant domestic departments, coordinate to explore the potential of domestic monitoring resources, and promote the design of monitoring system capacity, early warning technology research and operation service platform construction, monitoring and early warning business operations.
- **International cooperation:** we will actively participating in missions of the IAWN and the SMPAG, connecting with institutions of major space countries such as the US and Europe, establishing a multi-tiered cooperation system, and promoting diversified cooperation.

Thank you!

Earth Observation System and Data Center of CNSA

November 2022