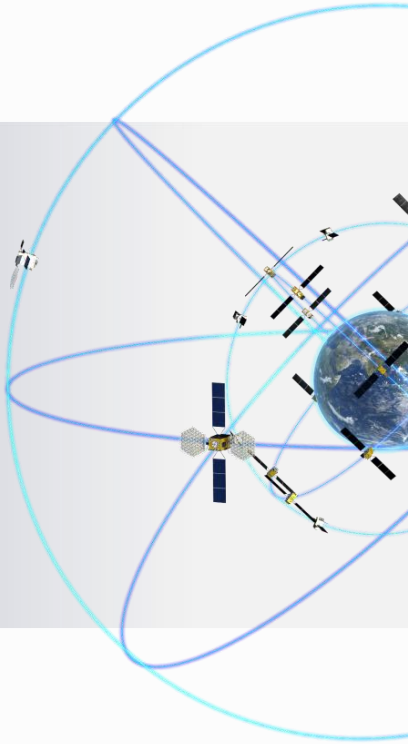
BeiDou Navigation Satellite System Development and High-Accuracy Applications



LU Xiaochun
Jan. 11, 2022

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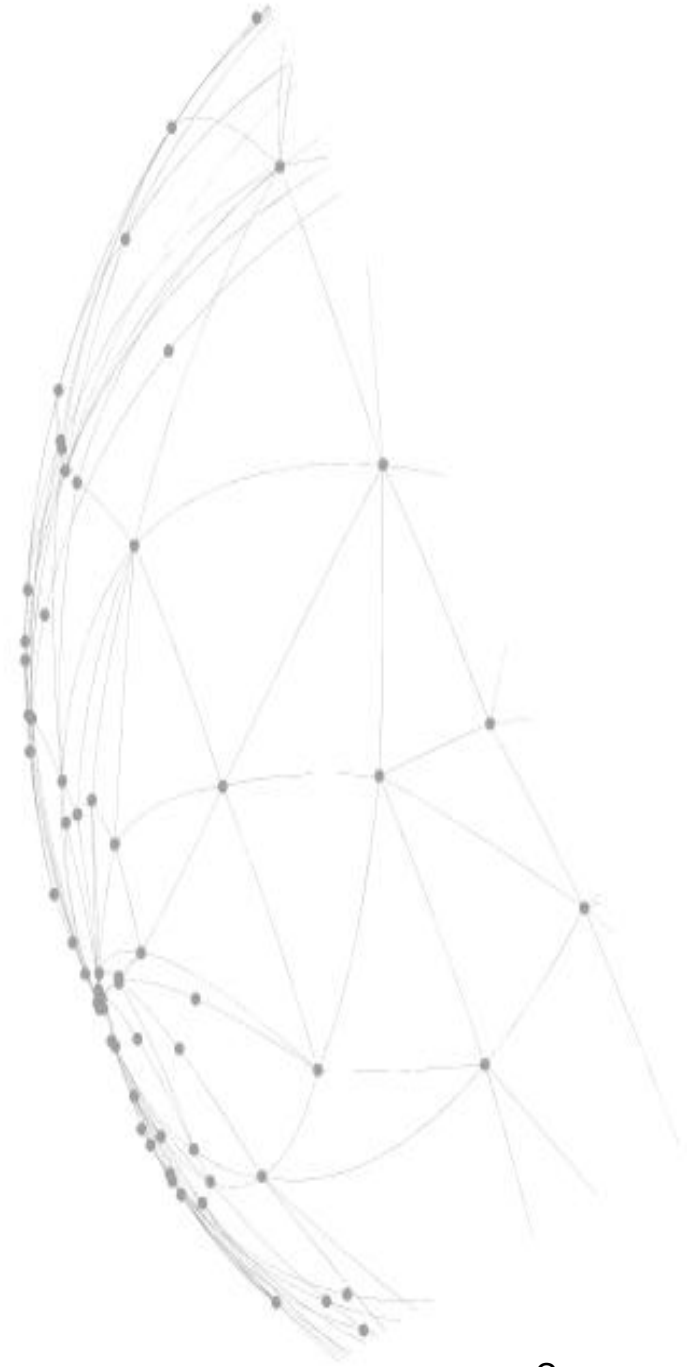
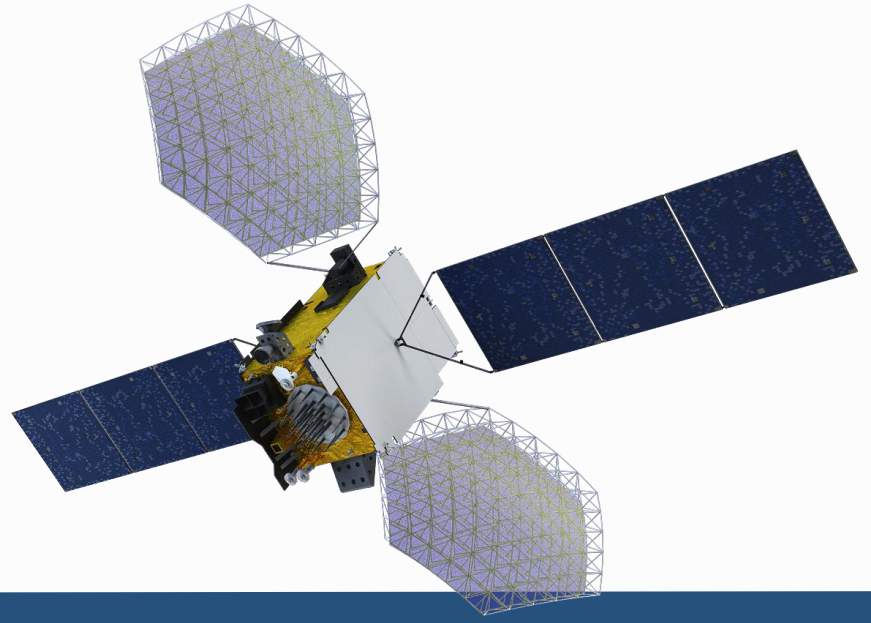




01 System Status

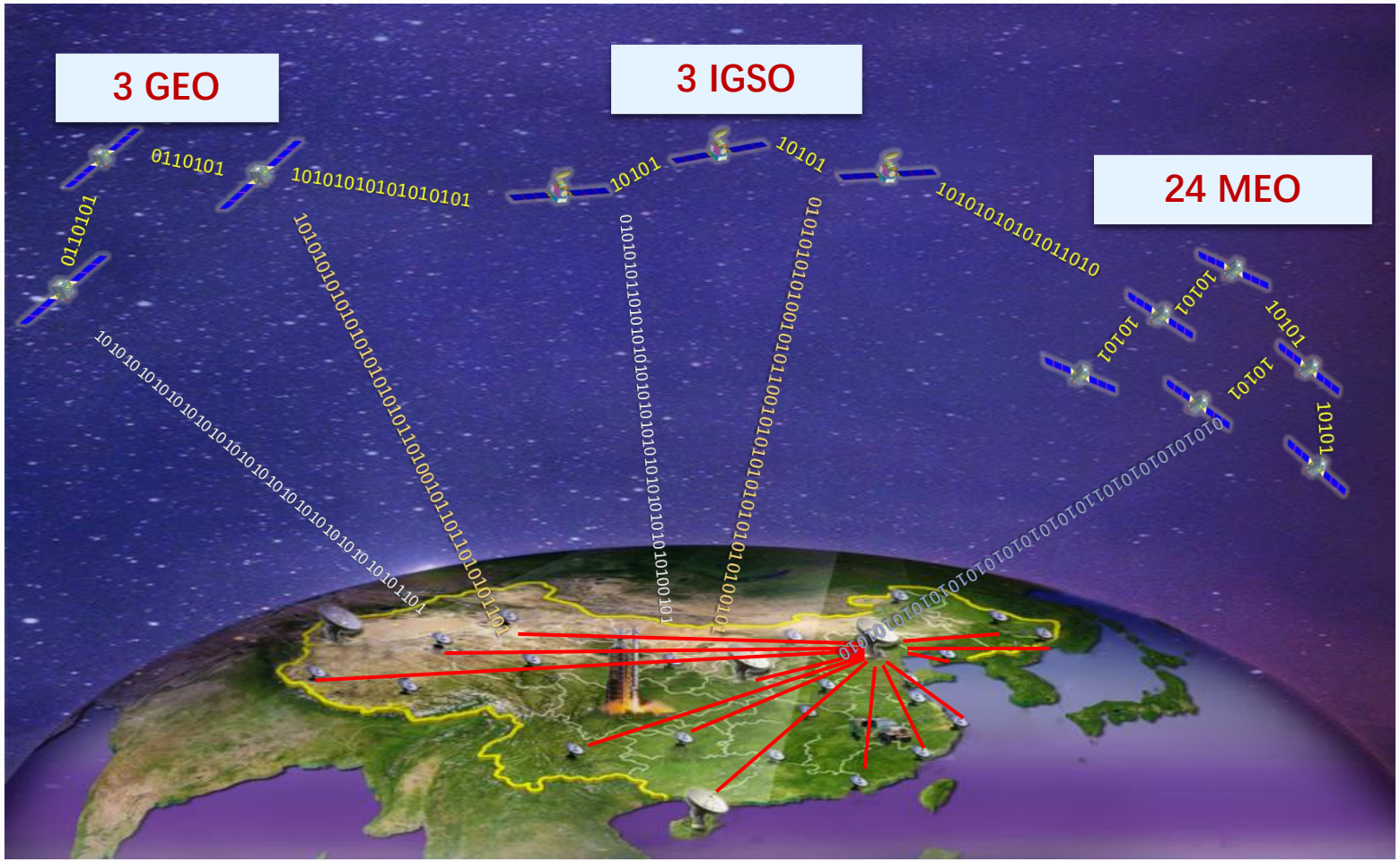
1. System Status

——Completion and Commissioning

On July 31, 2020, General Secretary XI Jinping of the CPC Central Committee announced to the world that BDS-3 was formally commissioned and provided seamless coverage passive navigation, positioning, and timing services for the global users. BDS becomes a proud Chinese innovation for the world.

1. System Status

——System Components



BDS is mainly comprised of three segments: a space segment, a ground segment and a user segment.

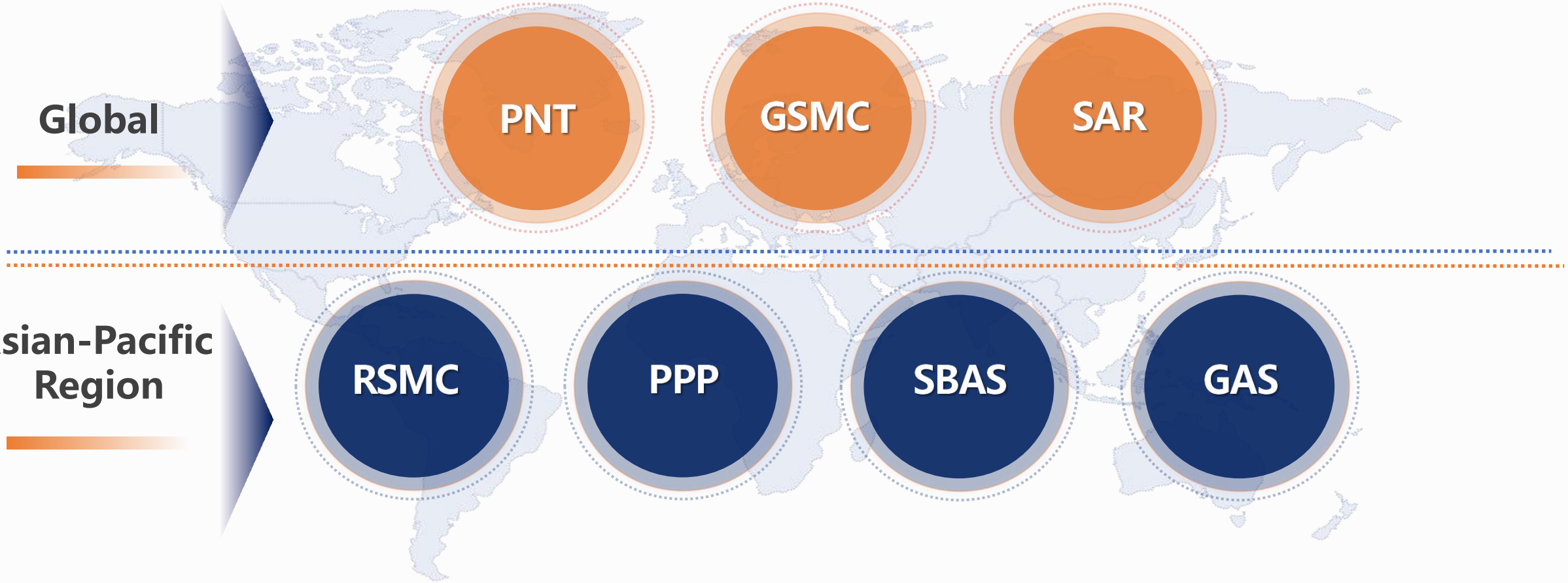
Up to now, BDS-3 constellation consists of 3 GEO satellites, 3 IGSO satellites, and 24 MEO satellites.

The BDS ground segment consists of various ground stations, including master control stations, time synchronization/uplink stations, monitoring stations, etc.

The BDS user segment consists of various kinds of the BDS terminals.

1. System Status

——Various Services with Powerful Functions



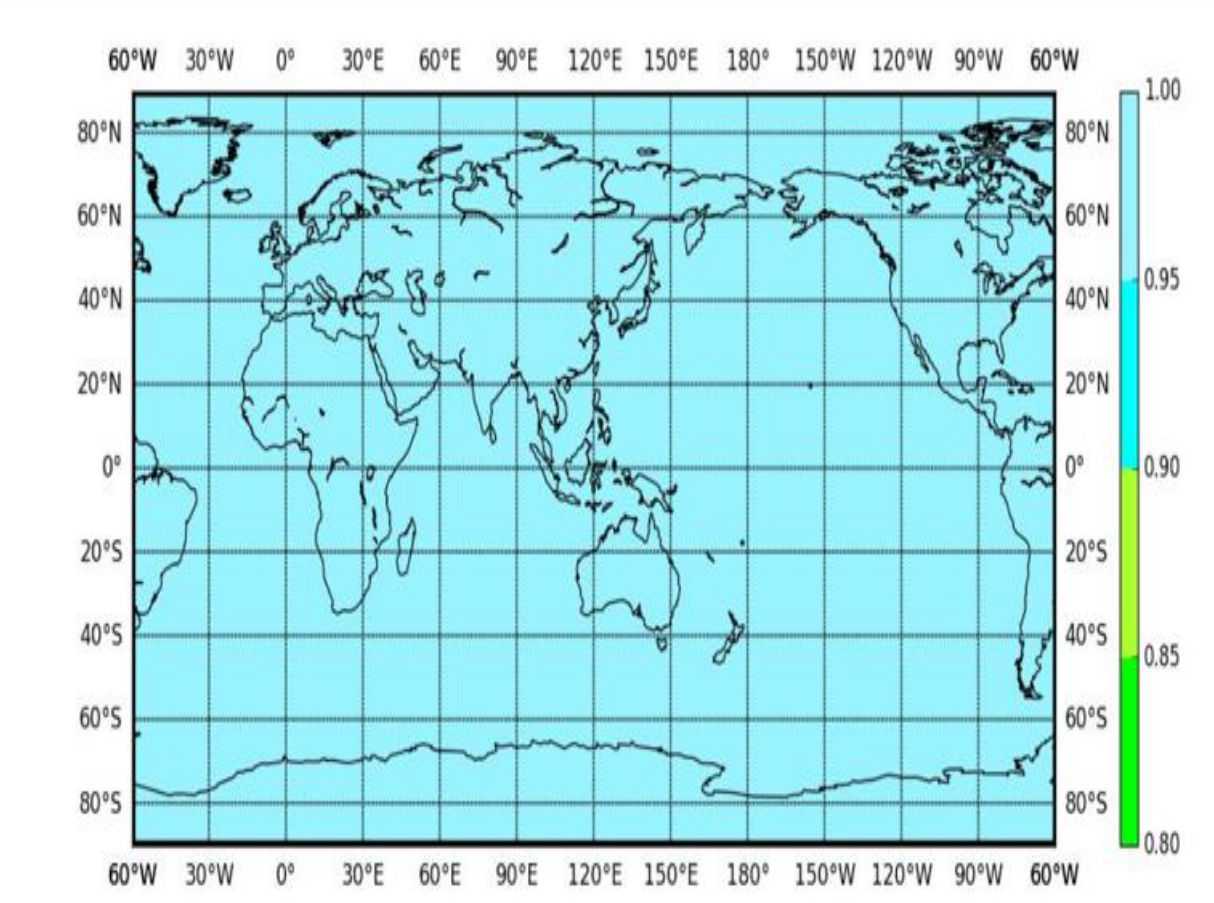
1. System Status

——Positioning, Navigation and Timing (PNT)

BDS Service Performance Indicator

Performance Characteristics	Performance Specification
Global Positioning Accuracy (95%)	Horizontal≤2.5m Vertical≤5m
Global Velocity Measurement Accuracy (95%)	≤0.2m/s
Global Timing Accuracy (95%)	≤20ns
Space Signal Continuity	99.996%
Space Signal Availability	≥99%

BDS Availability (5° Elevation Mask, PDOP≤6)



1. System Status

——Positioning, Navigation and Timing (PNT)

01. Space Signal Quality

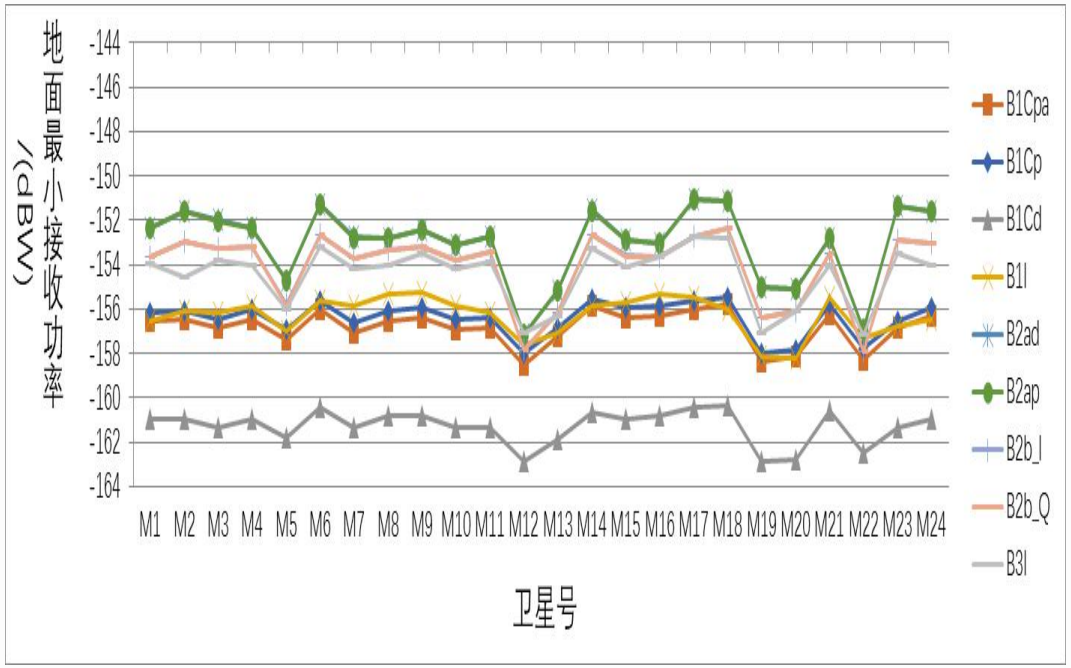


Figure 1 Minimum Ground Received Power of Signal Components

02. Space Signal Precision

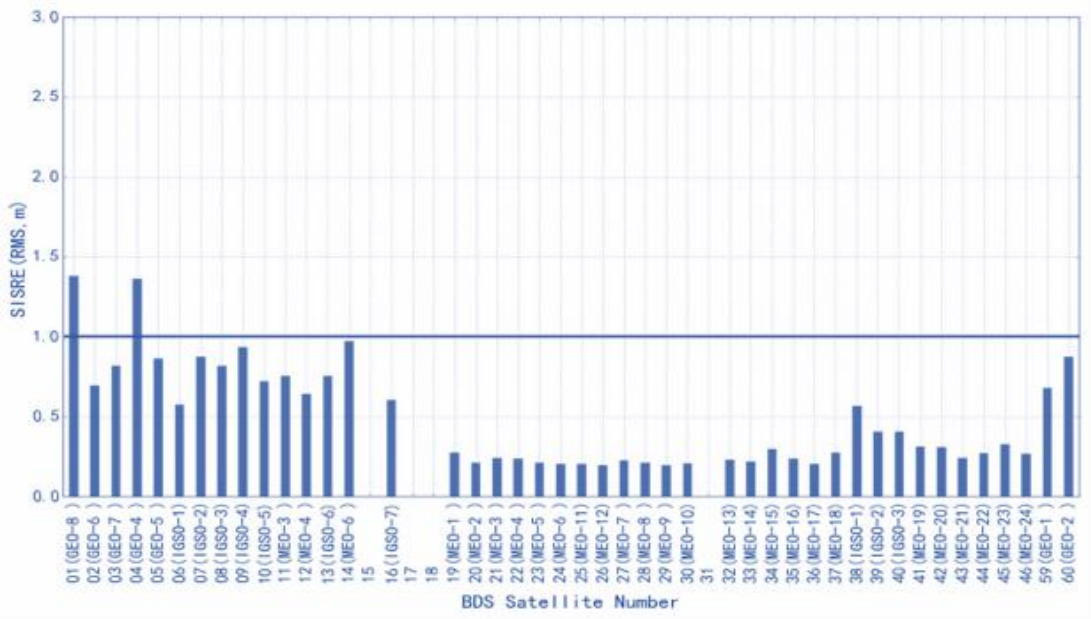


Figure 2 URE of the BDS Satellites

1. System Status

——Positioning, Navigation and Timing (PNT)

03. BDS Coordinate Reference Frame

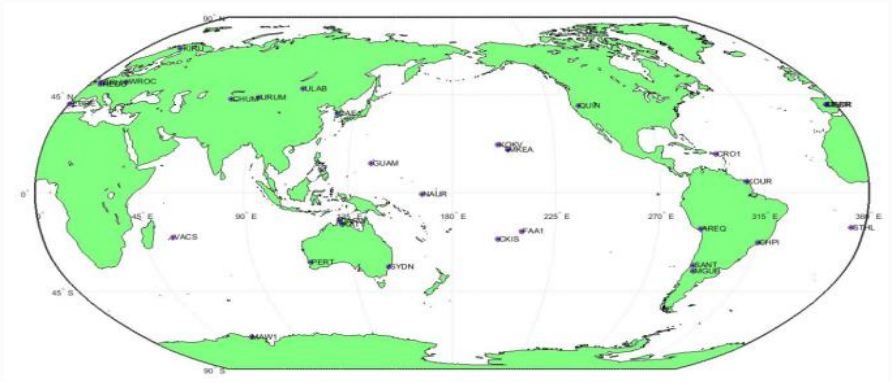


Figure 3 BDS Monitoring Stations and Globally Deployed IGS Monitoring Stations

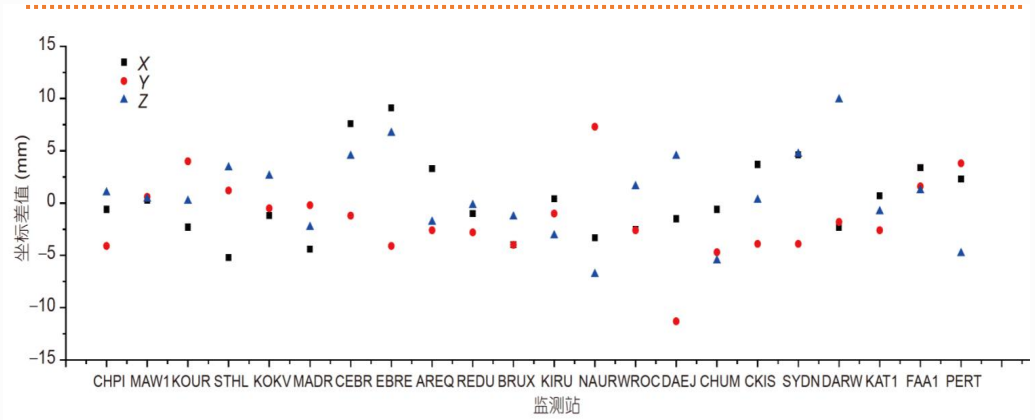


Figure 4 Difference between BDCS and ITRF 2014

04. Stability of BDT

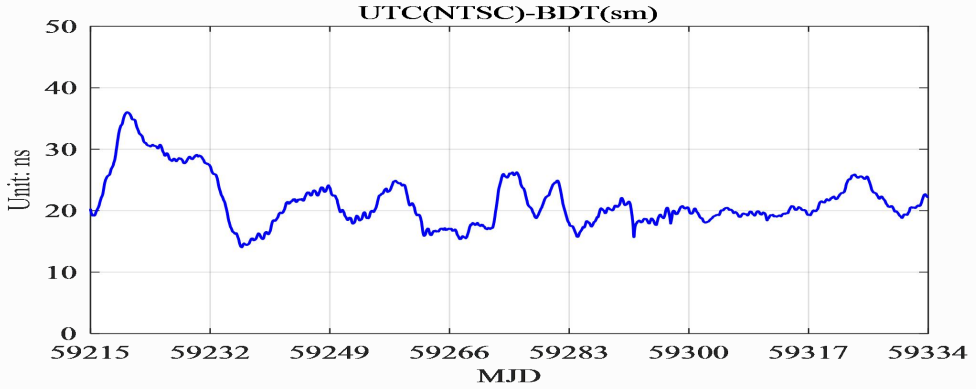


Figure 5 Time Deviation between BDT and UTC(NTSC)

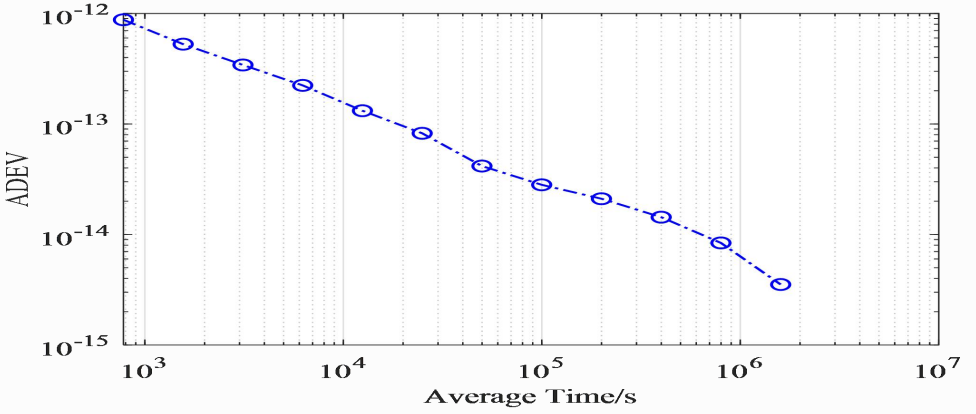
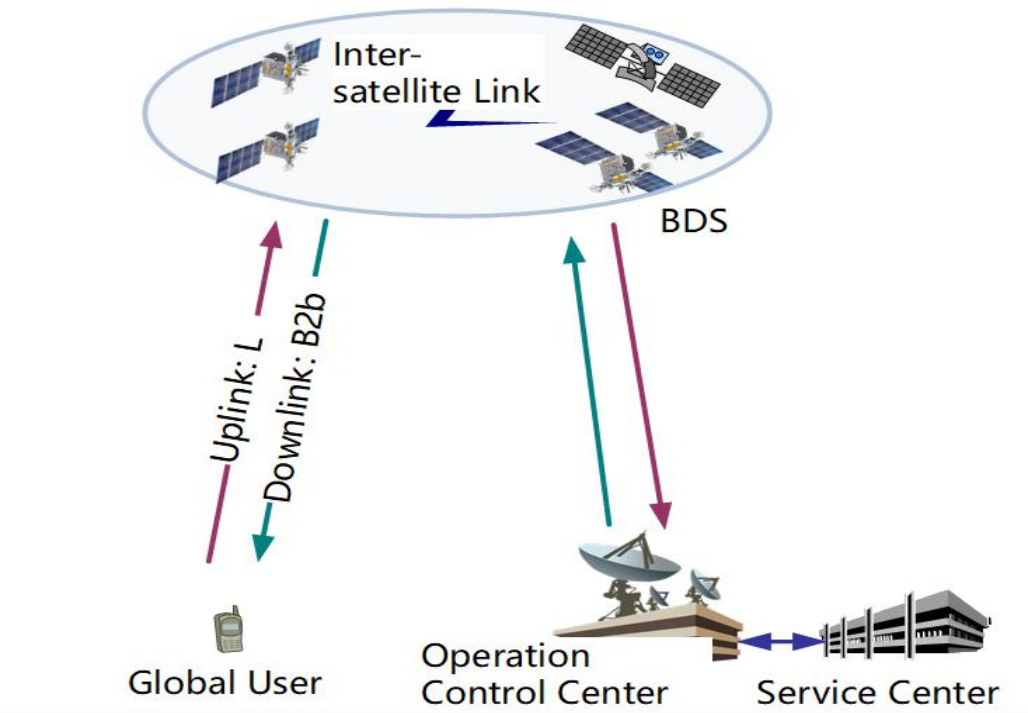


Figure 6 Stability of Clock Bias between BDT and UTC(NTSC)

1. System Status

——Global Short Message Communication (GSMC)

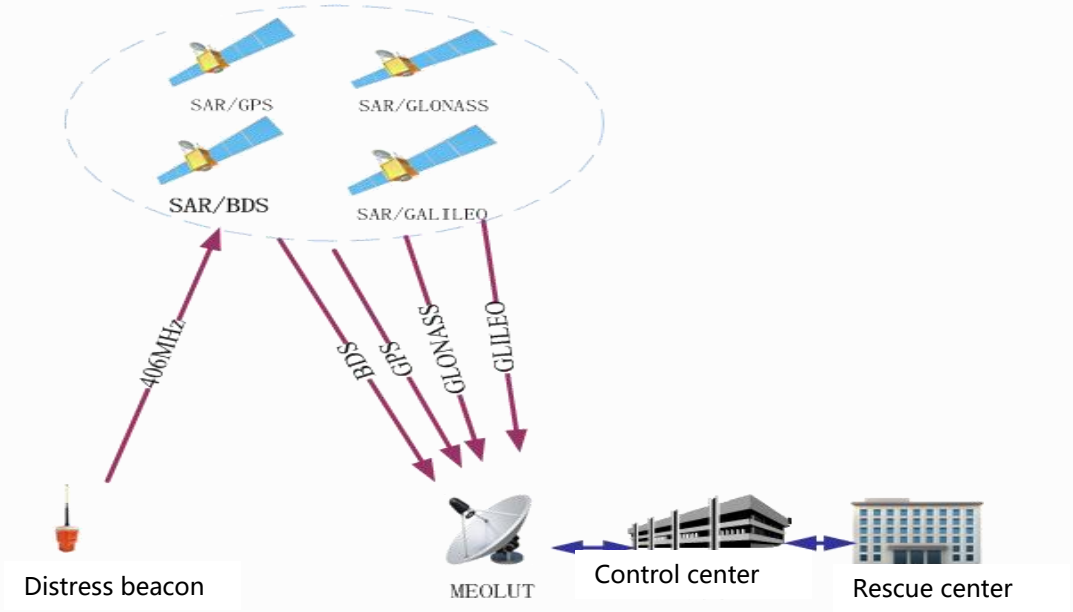


- **Satellites：14 MEO Satellites**
- **Method：Global Random Access**
- **Maximum length of a single message: 560 bits (40 Chinese characters per message)**

Performance Characteristics	Performance Specification
Service Capability	Uplink 300,000 times/hour Downlink 200,000 times/hour
Service Success Rate	≥95%

1. System Status

——Search and Rescue (SAR)

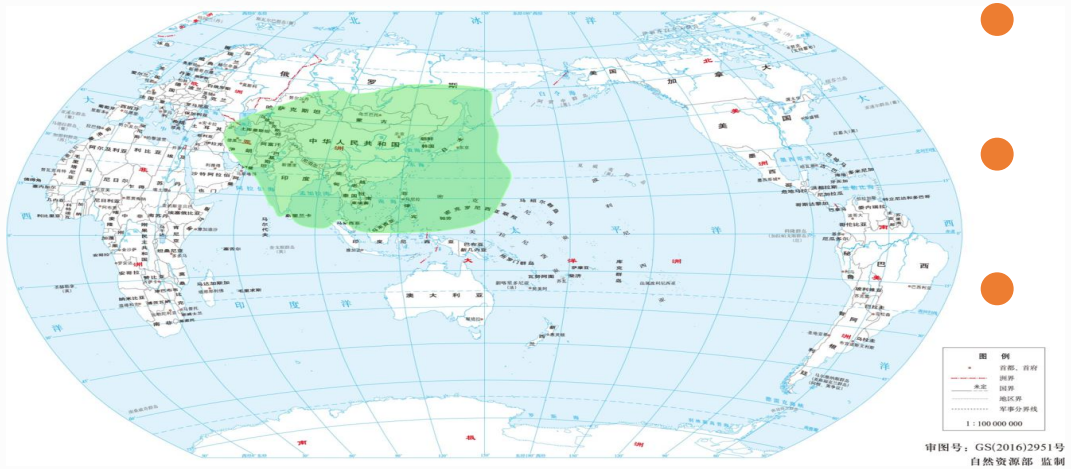


- **Satellites：6 MEO&SAR Payloads**
- **Standard：COSPAS-SARSAT**
- **Characteristics：Return Link Service**

Performance Characteristics	Performance Specification
Positioning Accuracy	≤5km
Detection Probability	≥99%
Availability	≥99%
Return Link Time Delay	≤2 min
Return Link Success Rate	≥95%

1. System Status

——Regional Short Message Communication (RSMC)

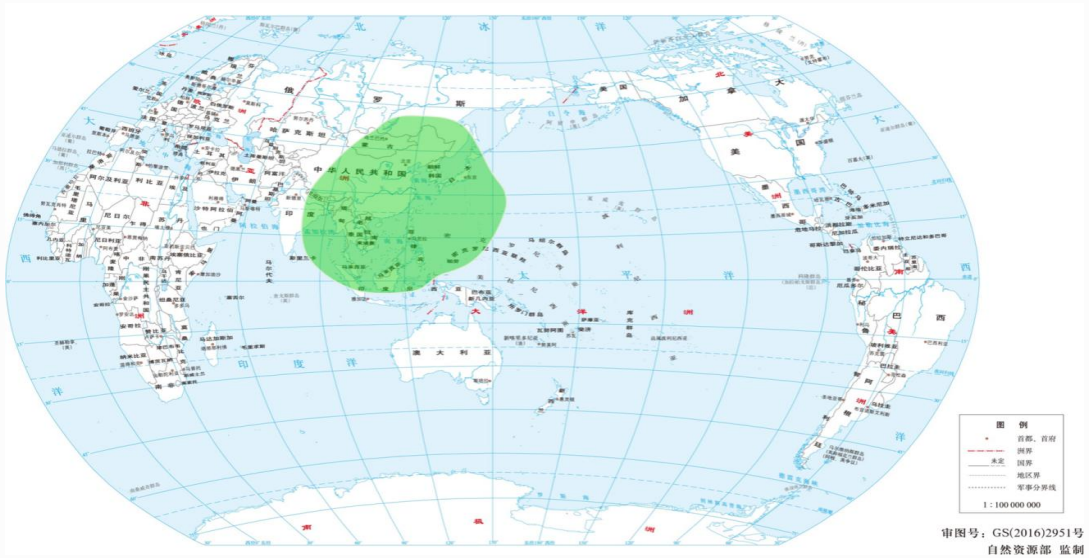


- **Satellites：3 GEO Satellites**
- **Coverage Area：China and surrounding areas**
- **Maximum length of a single message : 14,000 bits (around 1,000 Chinese characters)**

Performance Characteristics	Performance Specification
Service Success Rate	≥95%
Service Time Delay	better than 2s on average
Service Frequency	30s per time
Capability per Message	≤14000 bits

1. System Status

——Precise Point Positioning (PPP)

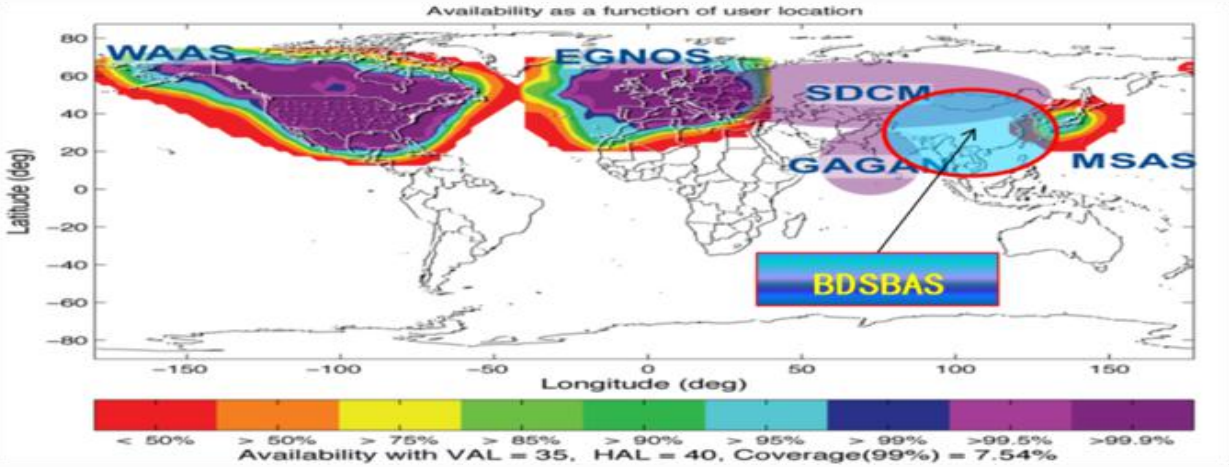


- **Satellites：3 GEO Satellites**
- **Coverage Area：China and surrounding areas**
- **Accuracy：decimeter (dynamic), centimeter (static)**

Performance Characteristics	Performance Specification	
Accuracy（95%）	Horizontal	≤20cm
Accuracy（95%）	Vertical	≤35cm
Convergence Time	≤20 min	

1. System Status

——Satellite-based Augmentation System (SBAS)



- **Satellites: 3 GEO Satellites**
- **Standard: ICAO**
- **Coverage Area: China and surrounding areas**
- **Services Mode: Single-Frequency or Dual Frequency Multi-Constellation**

Performance Characteristics	Performance Specification
Dual-Frequency Positioning Accuracy for Civil Use (95%)	Horizontal 1m Vertical 1.5m
Warning Time	Single Frequency for Civil Use 10s Dual Frequency for Civil Use 6s
Integrity Risk	$2x10^{-7}$/150s
Continuity	$1-8x10^{-6}$/15s(99.992%)
Avaliability	99%

1. System Status

——Ground-based Augmentation System (GAS)

- **Service is provided through mobile communication networks or the Internet, with positioning accuracy at meter, decimeter, centimeter and millimeter levels**

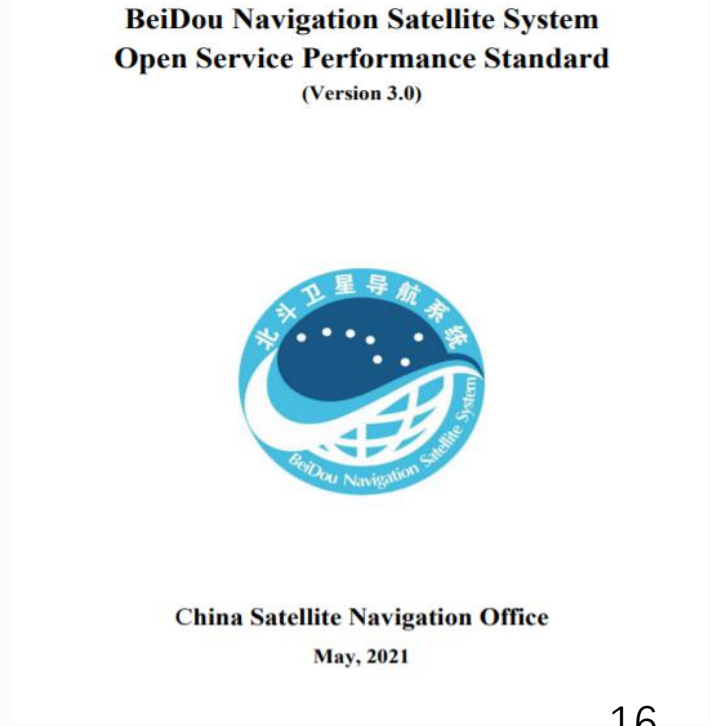
Dual-Frequency Static Post-Processing Service	Performance Specification
Horizontal Positioning Accuracy (RMS)	≤5mm+1mmx10^{-6}xD D means baseline length.
Vertical Positioning Accuracy (RMS)	≤10mm+2mmx10^{-6}xD D means baseline length.
Relative positioning accuracy of repeated baseline length measurements	better than 3X10^{-8}

1. System Status

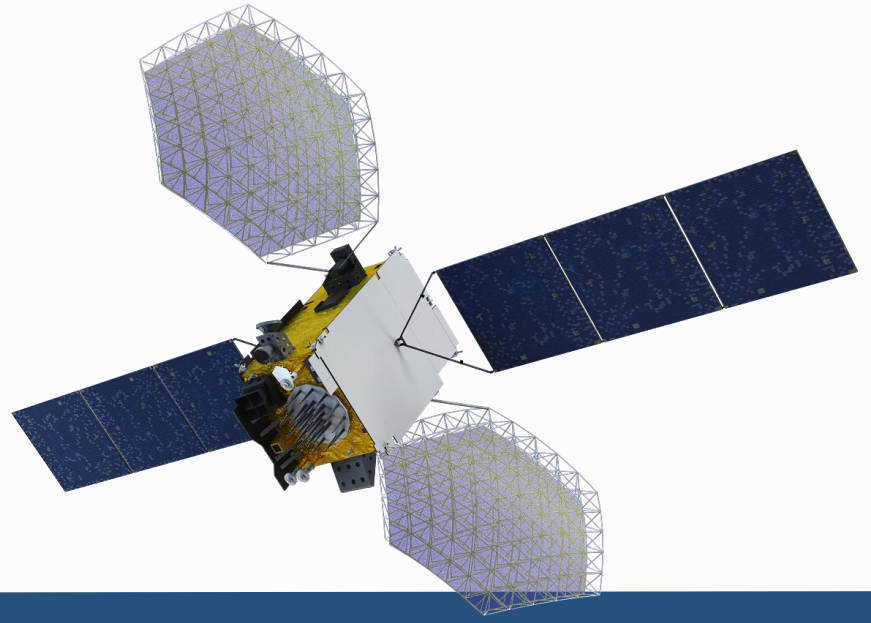
——Information Dissemination

- **The latest released documents of Open Service Performance Standard, Signal In Space Interface Control Document are shown as followings.**
- **More information is available at: en.beidou.gov.cn**

Document	Date
BeiDou Navigation Satellite System Open Service Performance Standard (Version 3.0)	2021.05
BeiDou Navigation Satellite System Signal In Space Interface Control Document Open Service Signal B2b (Version 1.0)	2020.08
BeiDou Navigation Satellite System Signal In Space Interface Control Document Precise Point Positioning Service Signal PPP-B2b (Version 1.0)	2020.08
BeiDou Navigation Satellite System Signal In Space Interface Control Document Satellite Based Augmentation System Service Signal BDSBAS-B1C (Version 1.0)	2020.08
BeiDou Navigation Satellite System Signal In Space Interface Control Document Search and Rescue Service (Version 1.0)	2020.08
BeiDou Navigation Satellite System Ground-based Augmentation Service Interface Control Segment	2020.08
Development of the BeiDou Navigation Satellite Syste (Version 4.0)	2019.12
The Application Service Architecture of BeiDou Navigation Satellite System	2019.12


BeiDou Navigation Satellite System
Open Service Performance Standard
(Version 3.0)

China Satellite Navigation Office
May, 2021



02 Application Promotion

2. Application Promotion

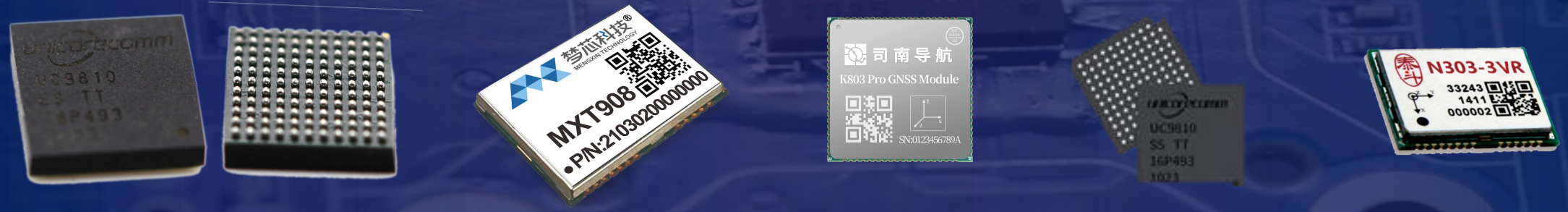
——Industrial Applications

Establishment of full industrial chain and breakthroughs in basic products innovation

Making **breakthroughs** in the key technologies of basic products

Performances and techniques greatly improved, and **large-scale** applications **enter into market**

Sales volume domestic BDS-supported chips and modules has exceeded **100 million**



2. Application Promotion

——Industrial Applications

Entry into Mass Market, Sharing Economy and People's Livelihood

79% smart phones sold in China in the Q1 and Q2 of 2021 supported BDS positioning function

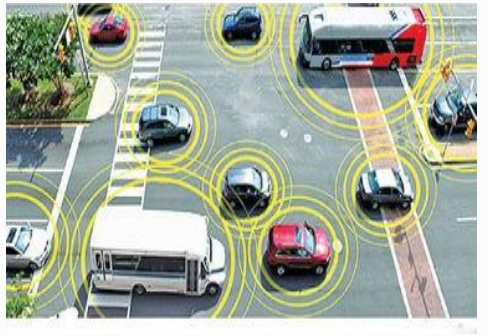
Meter-level positioning is available based on BDS ground-based augmentation service signal

Smart phone supporting BDS short message service and information interconnection to be launched

2. Application Promotion

——Industrial Applications

Industrial and regional applications of BDS have been significantly improved



- **Focus on BDS/GNSS Large-scale Applications**
- **Widely used in Transportation, Public Security, Disaster Relief and Mitigation, Fishery, Agriculture, Forestry, Smart City, and Precise Digital Construction**
- **Quick Fusion with Power, Finance, and Communication Industries**

2. Application Promotion

——Smart City Building

BDS Smart Medicine and fighting against COVID-19

- Travel record monitoring
- Epidemic prevention
- Tele medicine
- Rapid hospital building
- Personal health management
- Material distribution
- Precise disinfection through UAV

Real time data and decision support have been provided

2. Application Promotion

——Smart City Building

BDS improves infrastructure construction

- Intelligent operation and maintenance of BDS charging pile
- Smart operation and maintenance and centralized meter reading based on IoT
- BDS Intelligent tourism information service system
- The big data service platform of scenic spots

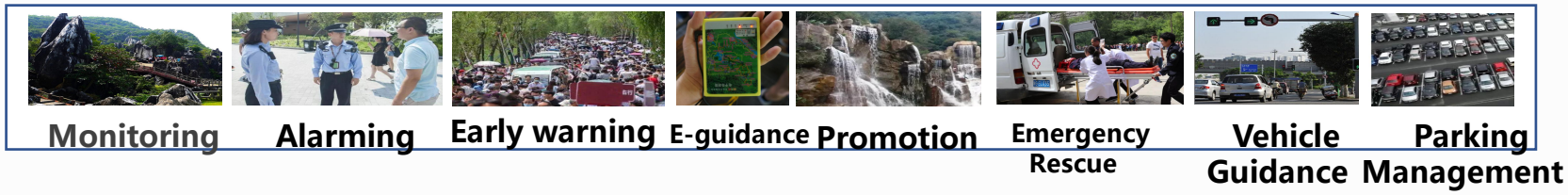
Charging Piles of State Grid EV Service--Construction Site

Improving urban power infrastructure and making tourism more smart, informationalized, and modernized

2. Application Promotion

——Smart City Building

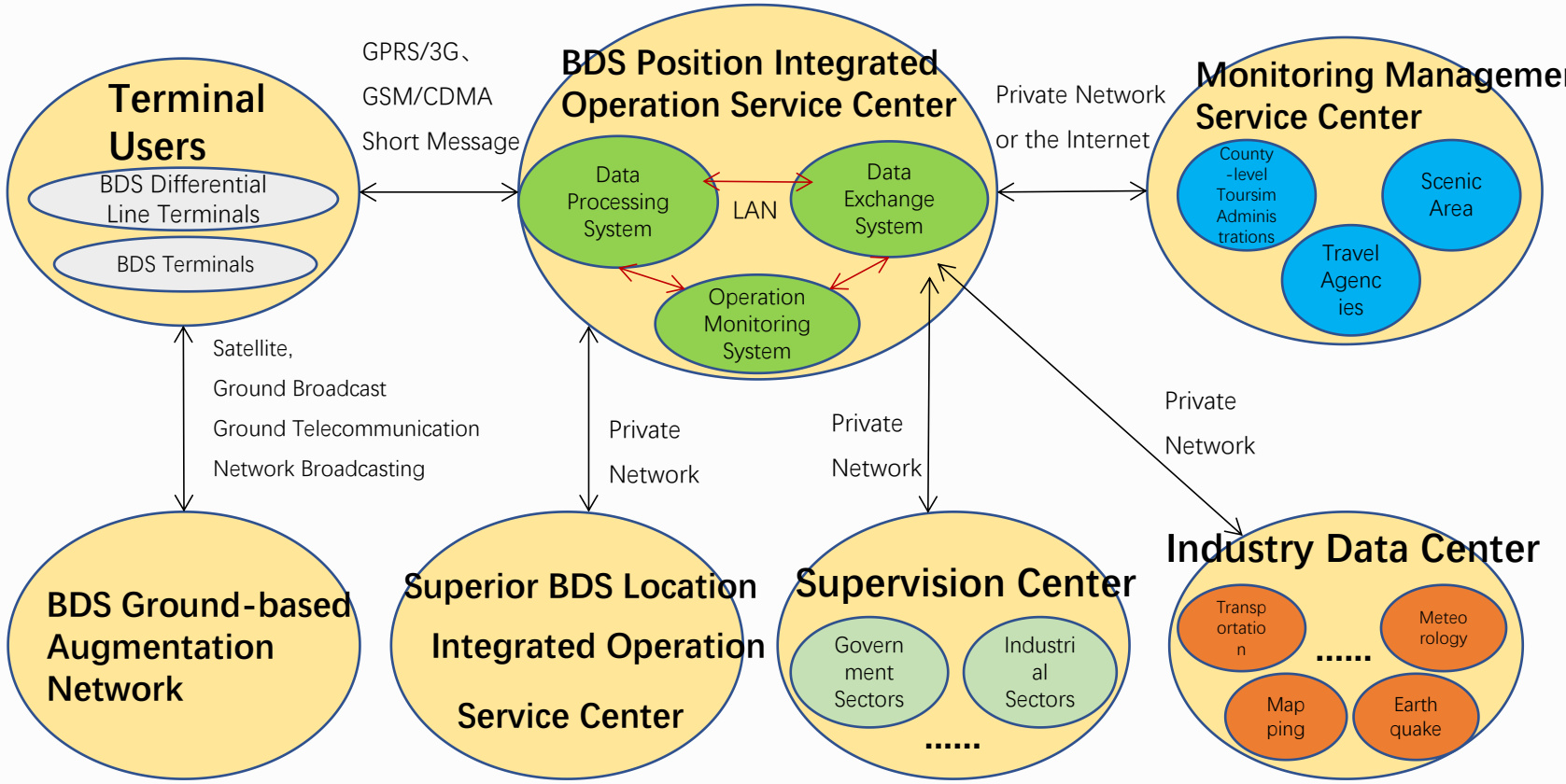
Based on BDS, a tourism information system with multimedia, multi-form, multi-service and multi-terminal support should be established. In order to realize the standardization, fine management, and personalized service of tourism industry, the brand value of local featured products should be improved, and the marketing model should be innovated with the help of tourism information.



2. Application Promotion

——Smart City Building

BDS Intelligent Tourism Information Service System can provide remote information services for all levels of tourism agencies, scenic spots, tourism service centers, and tourists.



Network Topology Diagram

2. Application Promotion

——Smart City Building

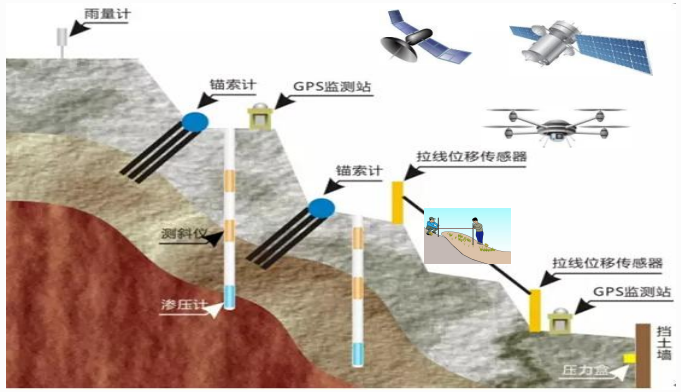
The big data service platform of scenic spots can collect data through multiple channels such as video data, mobile phone signal data, BDS location data and infrared acquisition data, which is convenient for the scenic spots to make accurate decisions, safety monitoring management and emergency treatment for their construction.

The tourism quality management and law enforcement platform uses BDS positioning, voice, video intercommunication, and data upload to manage scenic patrol law enforcement personnel. When abnormalities occur, patrol and law enforcement personnel can quickly report incidents and talk in real time.

The standardized service platform for travel agencies provides travel agencies with noise-free explanation terminals for teams and dynamic route management services.。

2. Application Promotion

——BDS High Precision Deformation Monitoring

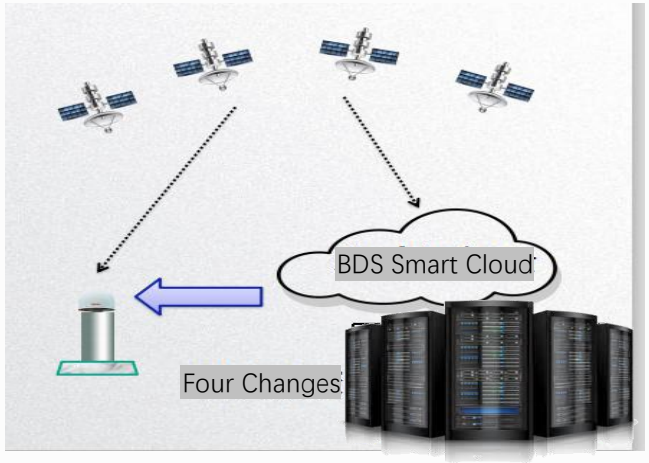


- **Difficulties in Construction**
- **High Cost of Hardware**
- **Low Real-time Accuracy**

Invalid Monitoring Work

Four Changes

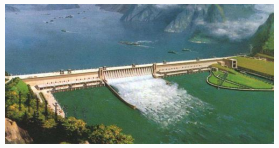
Realization



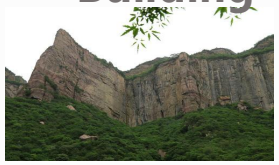
- **Uni-processing→Cloud Computing**
- **Hysteretic Observation→Real-time Monitoring**
- **Decimeter→Centimeter**
- **Outdoor manual work→Automatic collection**
- **Lower cost, Higher Precision, Lighter Construction**

2. Application Promotion

——BDS High Precision Deformation Monitoring


Dam


Building


Slope


Earthquake


Bridge

Satellite- and Ground-based Data Collection System


GNSS

4G 5G 2G 3G Mobile Internet


NB-Client

seismometer

NB-IoT

Real-time Transmission


GNSS


NB-Client

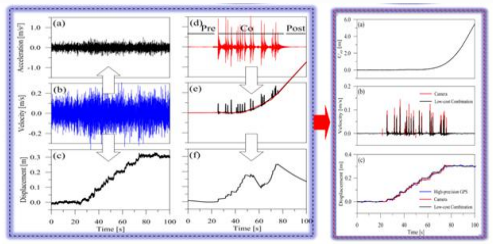
4G 5G 2G 3G Mobile Internet

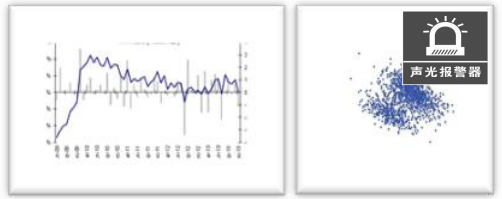

seismometer


"The Belt and Road" Service Center

Cloud Platform Data Processing System

Intelligent Analysis and Early Warning System


Data Processing System



Intelligent Analysis and Early Warning System


Operation and maintenance management display system

Simple Terminal, Low Power Consumption, High Integration, Cloud Services

2. Application Promotion

——BDS High Precision Deformation Monitoring

BDS High Precision Deformation Monitoring

Landslide Deformation Monitoring

Static:3D<5mm

Active:3D<1cm

Slope and Dam monitoring

Static:3D<5mm

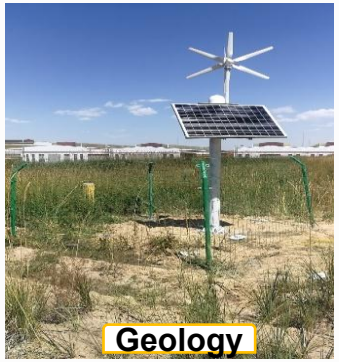
Active:3D<1cm

Urban Land Subsidence Monitoring

H<2mm

V<5mm

Applications



2. Application Promotion

——BDS High Precision Deformation Monitoring

BDS safeguards the security of the dam across the world’ s highest quake lake

Sarez Lake: Located in the Pamir region of 3263 meters above sea level in eastern Tajikistan. It is a natural lake formed by the collapse of the mountain after a strong earthquake occurred in the area on February 18, 1911.

Sarez Lake and Usoi Dam

An earthquake may damage the dam.

The whole area of Tajikistan is in a seismically active zone, and now it has entered a dangerous period of another earthquake.

If the dam collapses after an earthquake, the lake water will engulf parts of Tajikistan, affecting millions of people in Tajikisatan, and even people in Afghanistan and Uzbekistan . The ecological environment in Central Asia will be destroyed, and the loss of life and property will be immeasurable.

2. Application Promotion

——BDS High Precision Deformation Monitoring

BDS safeguards the security of the dam across the world’ s highest quake lake

The dam deformation real-time monitoring system customized for the special harsh environment of the Sarez Lake Dam in Tajikistan has the functions of real-time collection, transmission, calculation, and analysis of BDS data, thus realizing the stability monitoring of dam reference station and deformation monitoring service for body monitoring points in the dam area.

BDS integrated monitoring terminal

Solar photovoltaic power supply system

VSAT satellite communication system

Real-time data solution system

2. Application Promotion

——BDS High Precision Deformation Monitoring

BDS safeguards the security of the dam across the world’ s highest quake lake

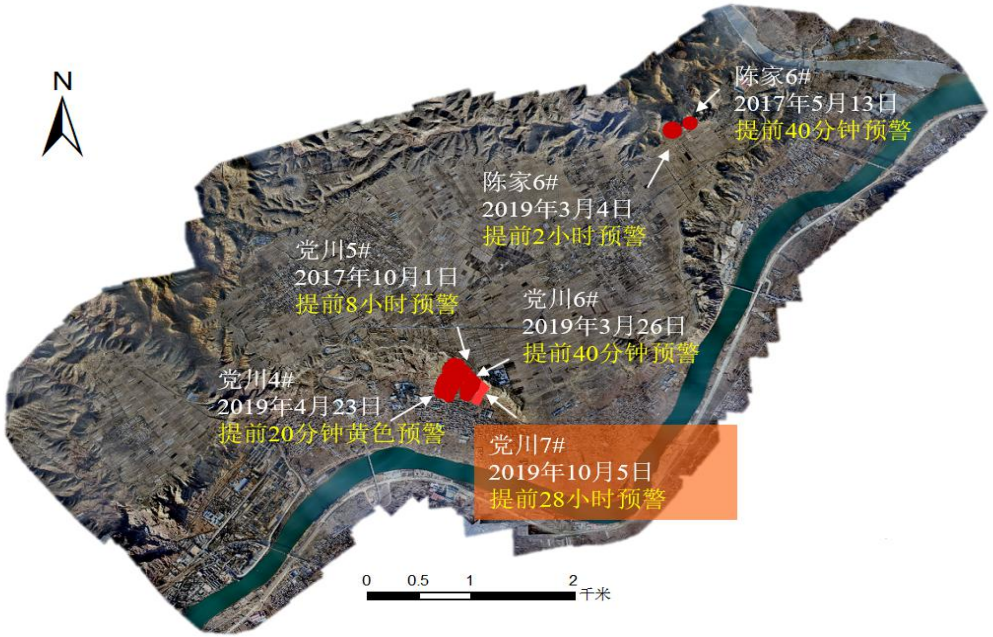
Operation of High Precision Deformation Monitoring System

2. Application Promotion

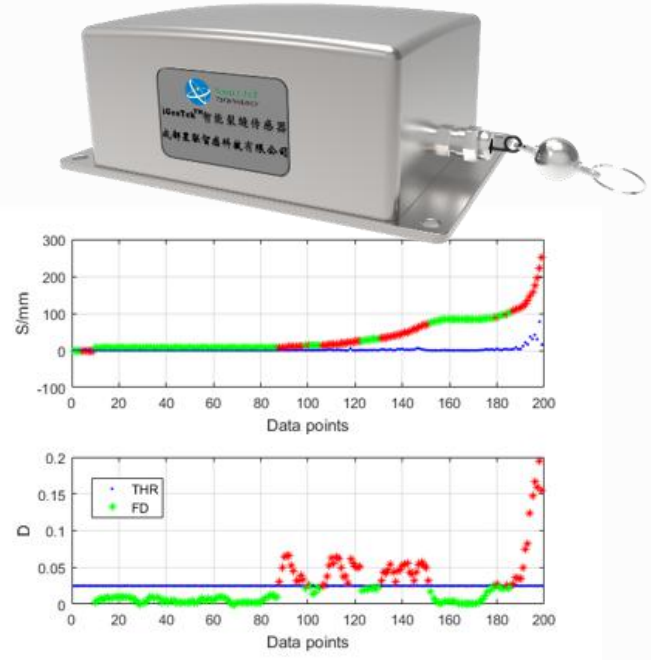
——BDS High Precision Deformation Monitoring

BDS high precision monitoring equipment is sensitive to any slight change on slope

Due to agricultural irrigation and other reasons, landslide disasters frequently occur in Heifangtai, Gansu Province. In October 2018, BeiDou high precision monitoring equipment was installed at the hidden geological hazard points in Heifangtai, which can capture millimeter-level landslide displacement changes in real time.



Location Map of the Successful Warning in Heifangtai



Adaptive frequency conversion landslide crack monitor

Red lines represent the adaptive frequency conversion data collection process, green lines represent the regular low frequency data collection process.

2. Application Promotion

BDS high precision monitoring equipment is sensitive to any slight change on slope

The technology team of the project has successfully warned landslide for many times, avoiding casualties and property losses, and has received extensive media reports and drawn great attention from many sectors of society.

2019-03-26

2019-10-05

2. Application Promotion

BDS high precision monitoring equipment is sensitive to any slight change on slope

2021-01-27 Successful early warning of landslide disasters

2. Application Promotion

——BDS High Precision Agriculture

High-precision positioning of intelligent agricultural machinery in black soil area

Broadcasting system

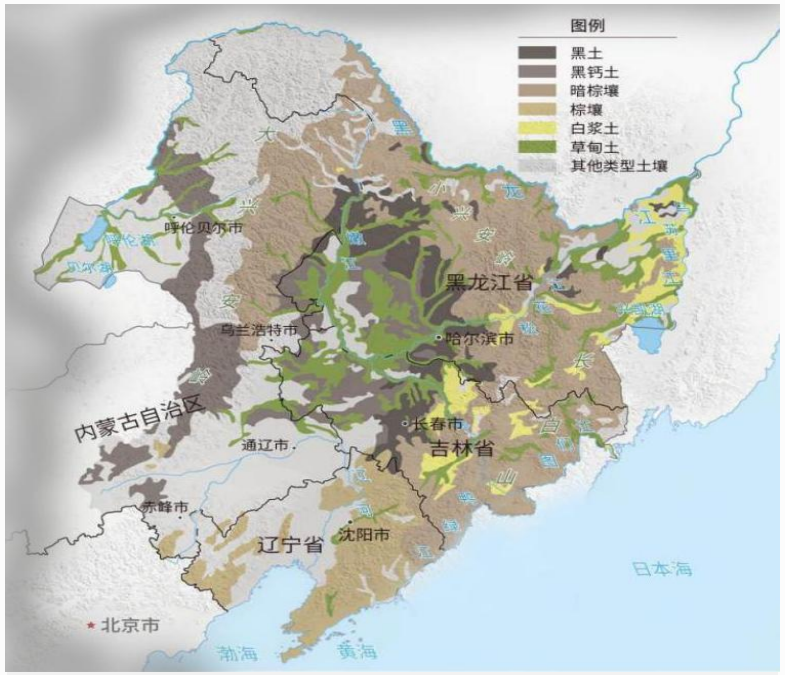
To build a space-based augmentation information broadcasting system for high-precision agricultural applications on black soil

Processing System

Research on high-level augmented information generation algorithms for wide-area areas to form a comprehensive information fusion processing system

Intelligent Terminals

To realize high-precision positioning is an effective measure in agricultural applications such as intelligent agricultural machinery, precision seeding, variable fertilization, etc.



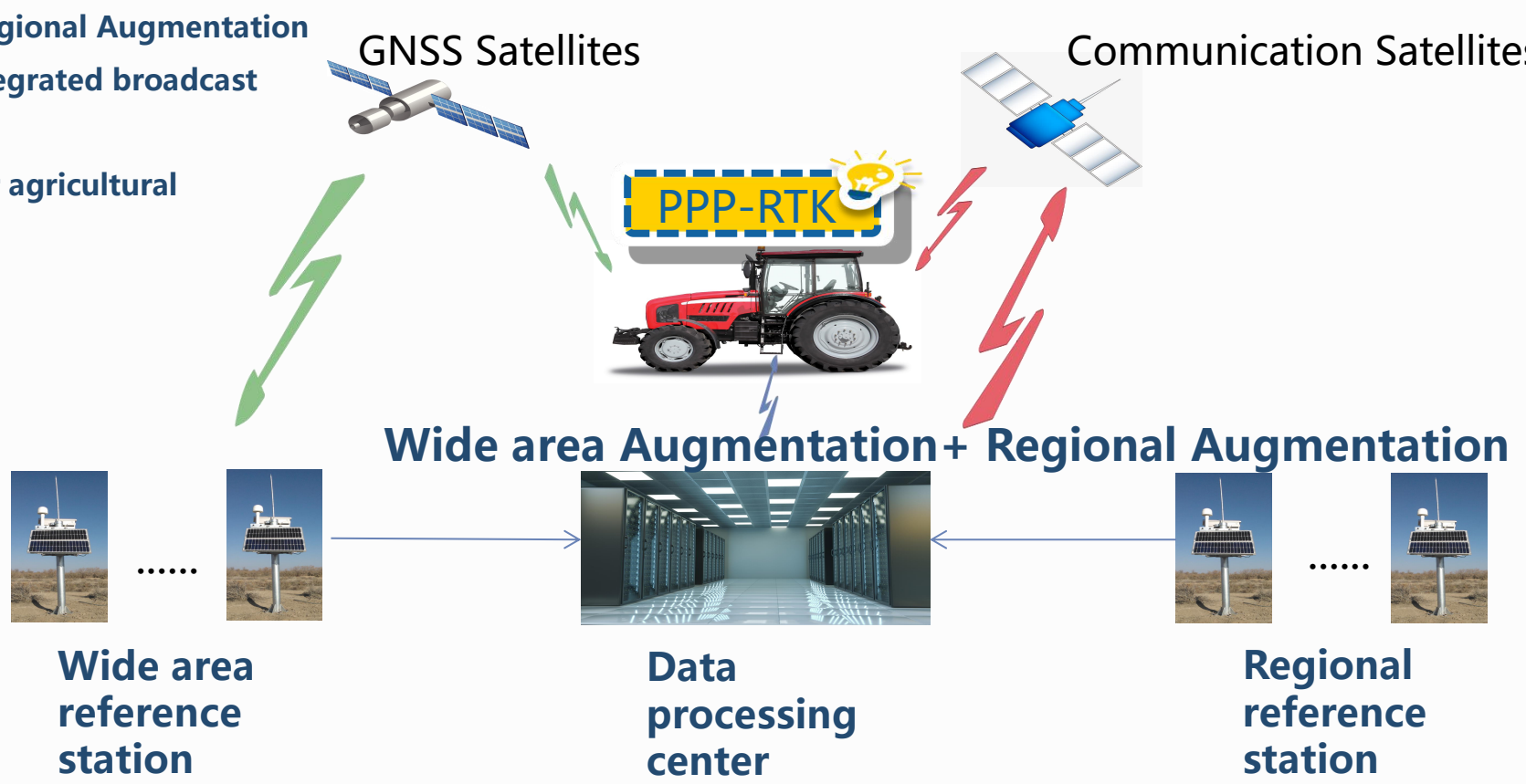
Black Soil Application Promotion Areas

2. Application Promotion

——BDS High Precision Agriculture

High-precision positioning of intelligent agricultural machinery in black soil area

- **Wide area Augmentation+ Regional Augmentation**
- **Space- and Ground-based Integrated broadcast**
- **Unlimited number of users**
- **High precision positioning for agricultural machinery**



2. Application Promotion

——BDS High Precision Agriculture

High-precision positioning of intelligent agricultural machinery in black soil area

Multiple operation modes

Straight line, circle, curve and diagonal operation without human intervention in the whole process




Application Scenarios


Precision farming


Auto fertilization and pesticide application


Precision harvesting


Precision plowing

2. Application Promotion

——Smart Transportation

With the development of urbanization, the pressure of urban traffic management is increasingly heavy, and traffic jam and congestion are becoming more and more prominent. It is particularly important for BDS to help intelligent implementation of urban transportation.

Waiting with anxiety

With the accelerating pace of life, public transport has become the preferred means of transportation for green travel, but waiting for cars has created anxiety。

Disordered parking

The number of shared bikes has soared, and parking in mess and disorder has not stopped, seriously affecting normal traffic and the appearance of the city.

Blind spots in school bus management

There are blind spots in school bus management. Chaos such as school bus not driving according to the specified route, overcrowding, and supervisor managing children to get on and off by "yelling" occurs from time to time.

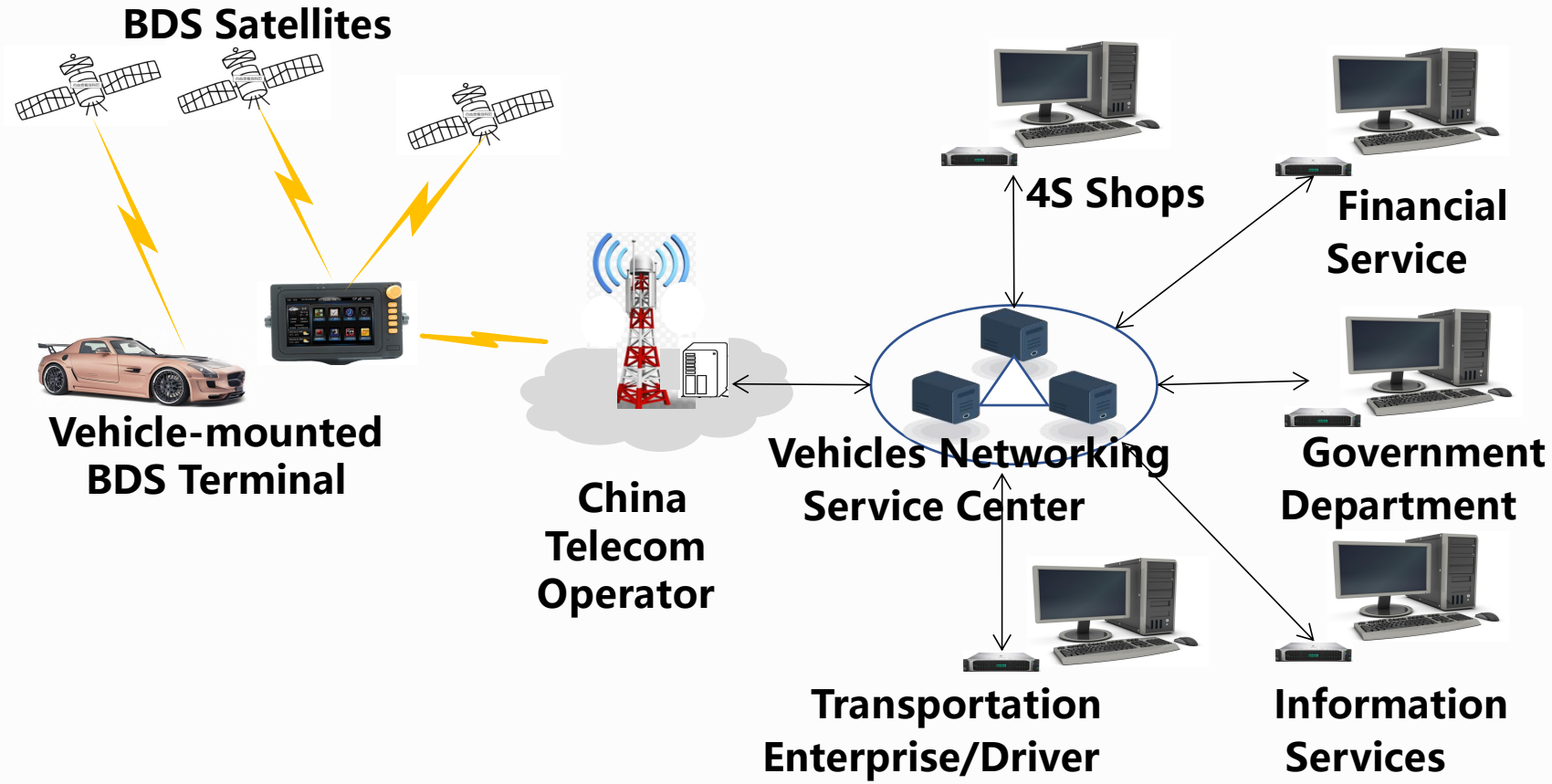
Container Supervision

It is difficult to supervise the container. Capturing the location of the container is not available in real time, and the goods cannot be tracked in the whole process. Regulatory problems such as scheduling problems and information delay need to be solved urgently.

2. Application Promotion

——Smart Transportation

The Vehicle networking platform based on BDS is a real-time, accurate, and efficient vehicle management and control platform. It is an integrated network platform that realizes intelligent traffic management, intelligent dynamic information services, and intelligent vehicle control.



2. Application Promotion

——Application of BDS in Land Surveying

High-precision and Rapid Measurement of Hospital Construction in Burkina Faso

GNSS Based Technology in the Civil Construction in Saudi Arabia

Application of Harbors Reconstruction in Lebanon

With the high-precision positioning technology provided by BDS/GNSS ground-based augmentation system (also known as Continuously Operating Reference Stations, CORS) and in combination of communication technology, the requirements of different users on the positioning accuracy, real-time and anti-jamming performance across different applications can be satisfied, such as city planning, land surveying and mapping, cadastral management, urban and rural construction, environmental monitoring, disaster prevention, traffic monitoring, mine surveying and others.

2. Application Promotion

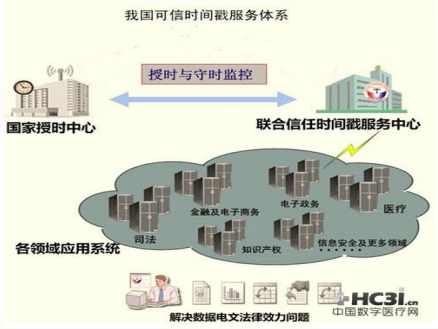
——BDS Standard Time Applications

1s

Smart grid
seismic observation

1 milisecond

E-government
fire prevention and
disaster relief



1 microsecond

Financial
Securities

Power grid connection:

Power grid connection: 1us
Internal control: 1ms-10ms
Fault detection: 1s

1 nanosecond

Navigation
and
positioning

1 picosecond

Precise measurement,
networked radar,
deep space exploration

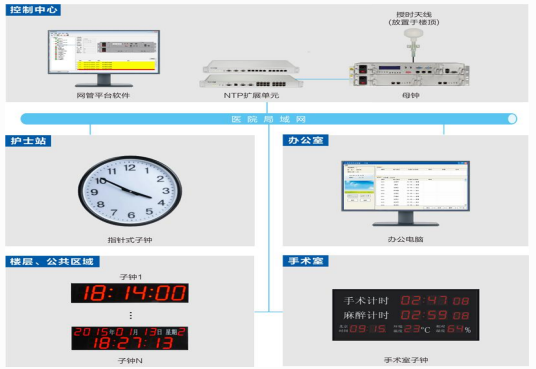
Smart transportation system:

Intelligent signal light management and control 1s
Intelligent road monitoring 1s
Rapid deployment of emergency roads 1s
Sky-eye tracking camera 1s
Sky-eye data transmission 1s

2. Industrial Application

——BDS Standard Time Applications

- Platform deposit certificate business
- Illegal broadcast video forensics
- Application of product traceability
- Time synchronization systems
- Smart transportation control system

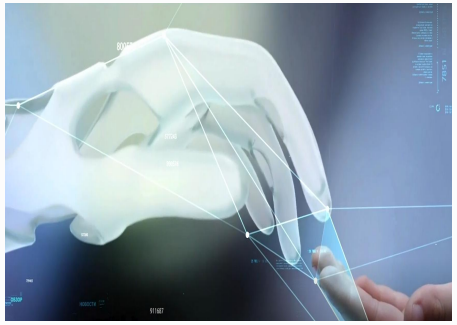


Meeting the needs for different accuracies in different standard time application scenarios

2. Industrial Application

——More Diversified Application Modes

BDS & Technologies



BDS & Terminals

BDS & Platforms

BDS & Data

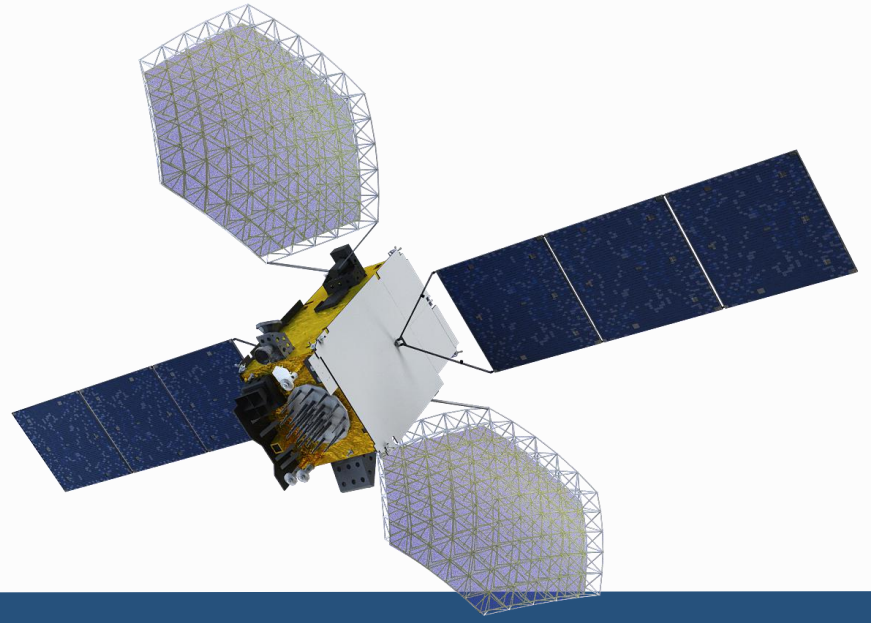
BDS & Services

BDS+5G→More Mature Fusion of Communication & Navigation

2. Industrial Application

——BDS Provides Good Services for Global Users

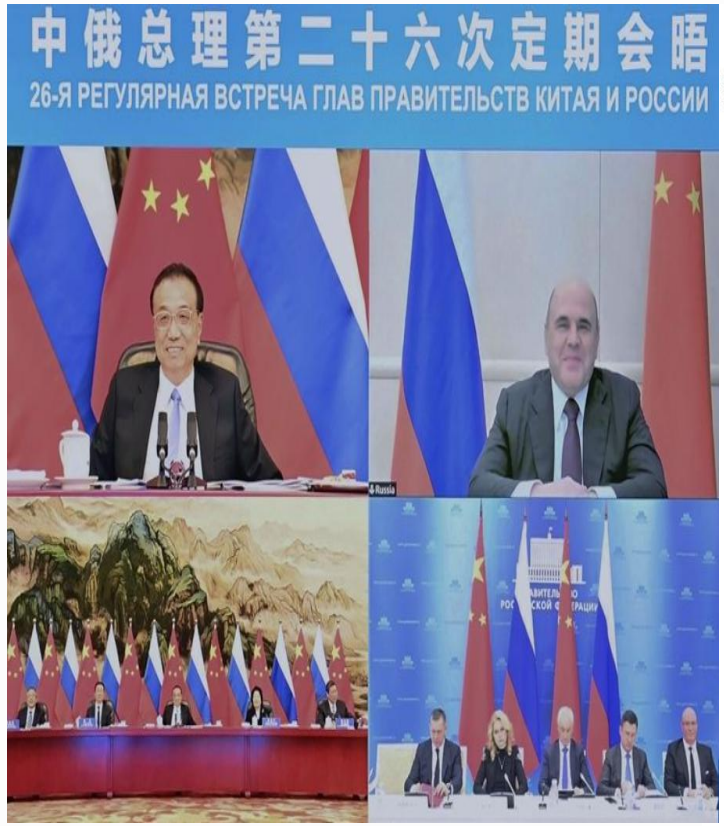
BDS-based products have been exported to and used in more than half countries and regions in the world. BDS has been widely used in ASEAN, Southern Asia, Eastern Europe, Western Asia, Africa in land ownership confirmation, precision agriculture, intelligent port management, etc., promoting local economic and social development.



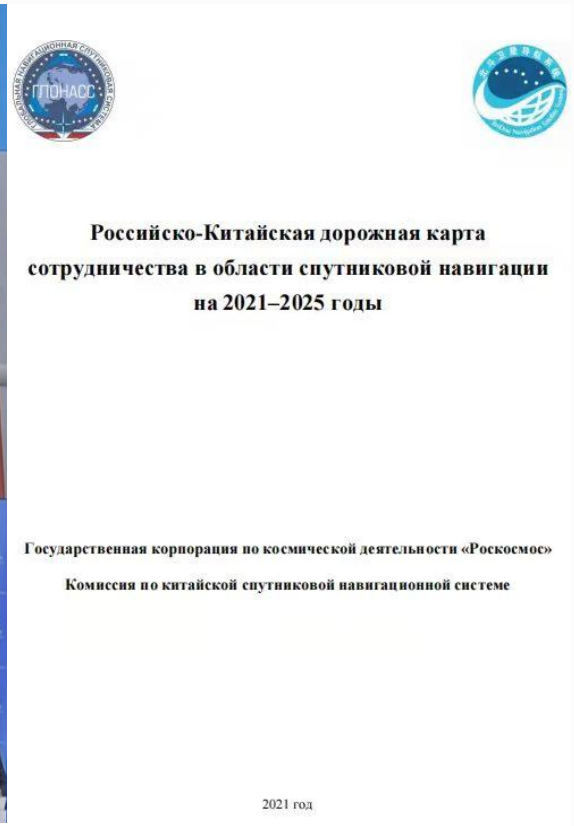
03 International Cooperation

3. International Cooperation

3.1 Compatibility and Openness to Provide Better Service (Bilateral Cooperation)

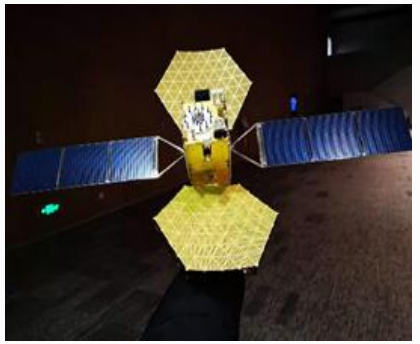


The 26th China-Russia Prime Minister Regular Meeting



BeiDou - GLONASS Compatibility and Interoperability 2021-2025 Cooperation Roadmap

Cooperation in joint test, station construction, and precision agriculture under the China-Russia Satellite Navigation Key Strategic Cooperation Project Committee framework



China and U.S. fostered the cooperation in compatibility and interoperability, SBAS, and civil use industries

L1 C/A PRN Code Number	C/A			System (Satellite)	Orbital Slot	Effective Through	Assignment Type
	G2 Delay (chips)	Initial G2 Setting (Octal)	First 10 Chips (Octal)				
130	355	0341	1436	BDSBAS (GEO-1)	140E	Aug 2030	Final
143	307	1312	0465	BDSBAS (GEO-3)	110.5E	Aug 2030	Final
144	127	1060	0717	BDSBAS (GEO-2)	80E	Aug 2030	Final

L5 PRN Code Number	XB Code Advance (Chips)		Initial XB Code State (Octal)		System (Satellite)	Orbital Slot	Effective Through	Assignment Type
	I5	Q5	I5	Q5				
130	1224	1092	17754	12737	BDSBAS (GEO-1)	140E	Aug 2030	Final
143	3745	8126	05474	15167	BDSBAS (GEO-3)	110.5E	Aug 2030	Final
144	4723	7017	02275	16761	BDSBAS (GEO-2)	80E	Aug 2030	Final

3. International Cooperation

3.1 Compatibility and Openness to Provide Better Service (Bilateral Cooperation)

Virtual Signing Ceremony of MoU between CSNO and CONAE

CSNO and CONAE has built a kind of normal cooperation mechanism in satellite and navigation, and will carry out cooperation in joint applications, test and assessment, education and training, etc., to accelerate economic and social development in Argentina.

Workshop on BDS/GNSS Applications in China and South Africa

In order to promote national construction and social and economic development for both countries and enhance cooperation and communication in the satellite navigation field, CSNO and SANSA signed the MOU at the workshop on BDS/GNSS Applications in China and South Africa.

3. International Cooperation

3.2 Joint Discussion, Construction and Sharing with The Belt and Road countries

3rd China-Arab States BDS Cooperation Forum
Dec. 8, 2021

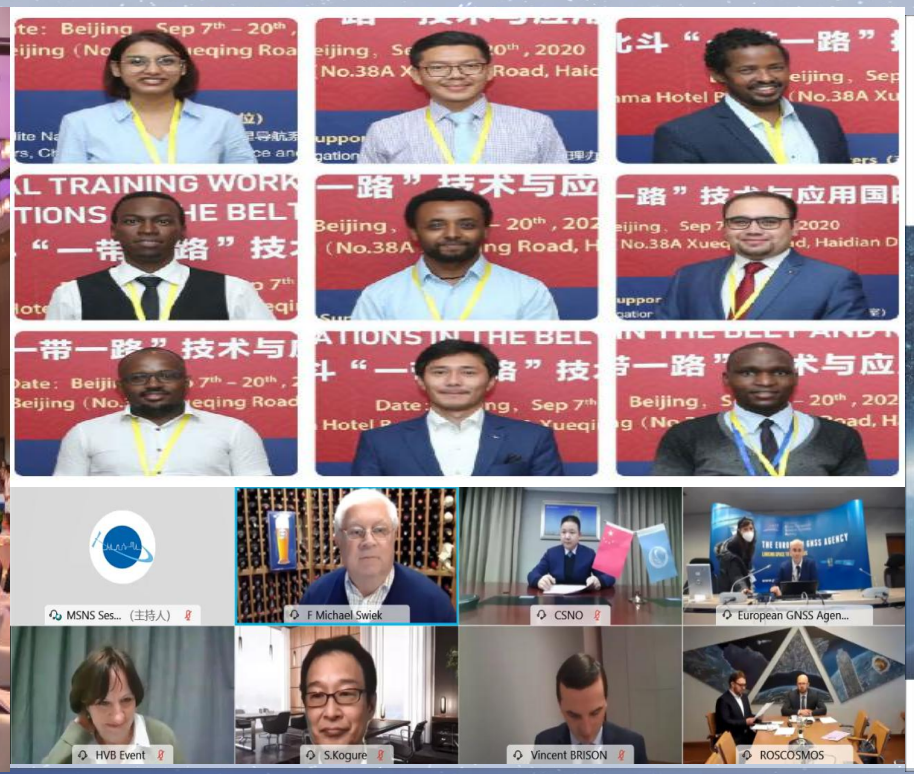
2nd China-Central Asia BDS Cooperation Forum
Oct. 13, 2021

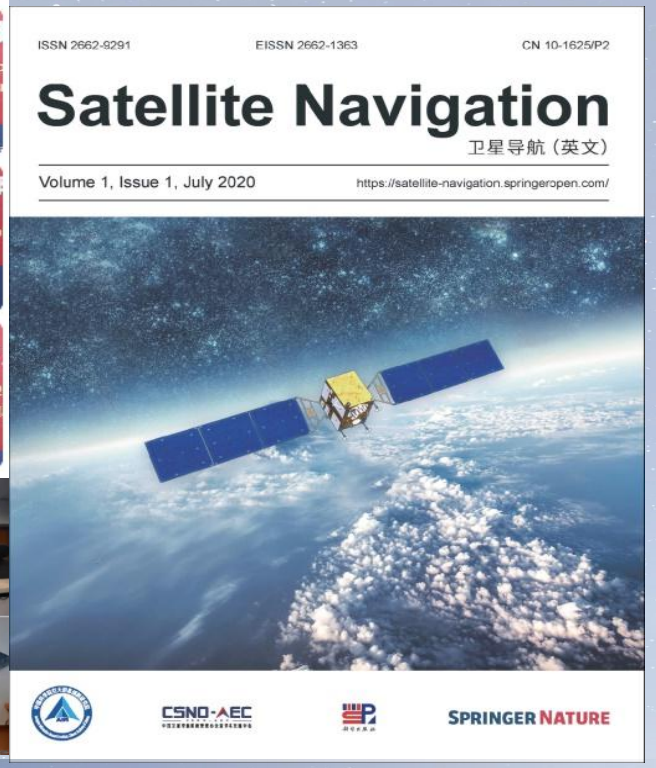
1st China-Africa BDS Cooperation Forum
Nov. 5, 2021

EXPO 2020 Dubai BeiDou Showcase
Oct. 2, 2021

3. International Cooperation

3.3 Chinese Wisdom and Contribution through Multi-lateral Exchanges





Communicated with other GNSS providers technically, and issued updates on BDS in multilateral academic platforms such as Munich Satellite Navigation Summit, Scientific and Technical Subcommittee, UNOOSA, China Satellite Navigation Conference, etc.

3. International Cooperation

3.4 Active participation in ICG Programs and Activities

3. International Cooperation

3.5 Ratification by International Standards

3GPP™ A GLOBAL INITIATIVE

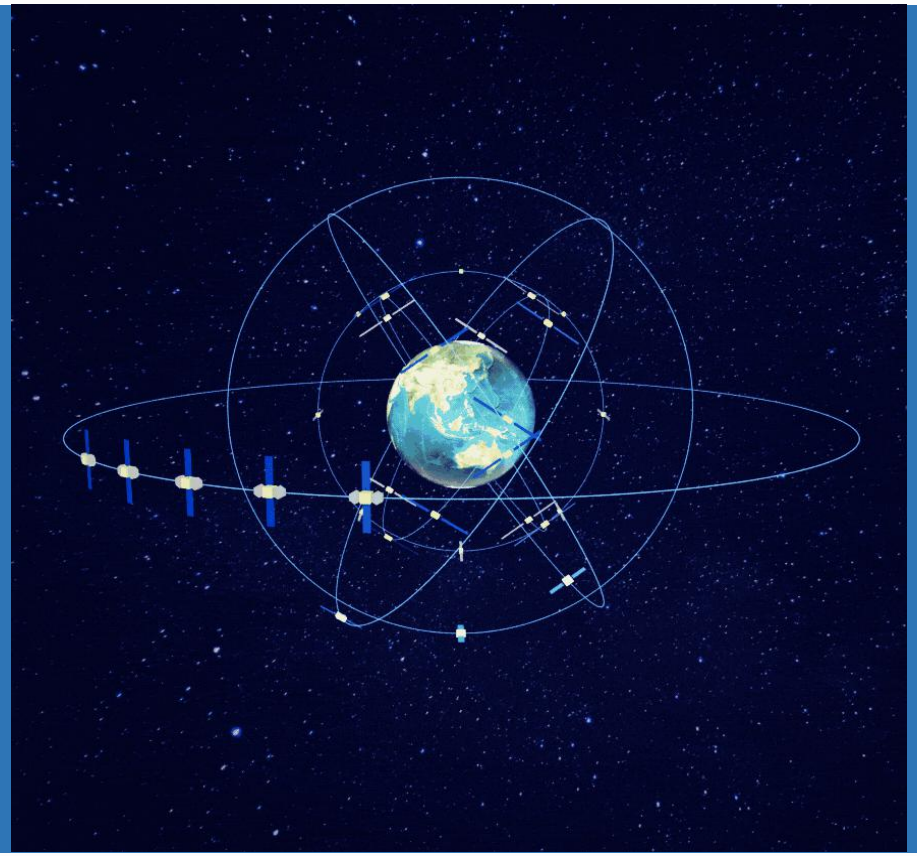
IEC International Electrotechnical Commission

COSPAS-SARSAT.INT
INTERNATIONAL SATELLITE SYSTEM FOR SEARCH AND RESCUE
406™ DISTRESS ALERTING SERVICE
COSPAS SARSAT

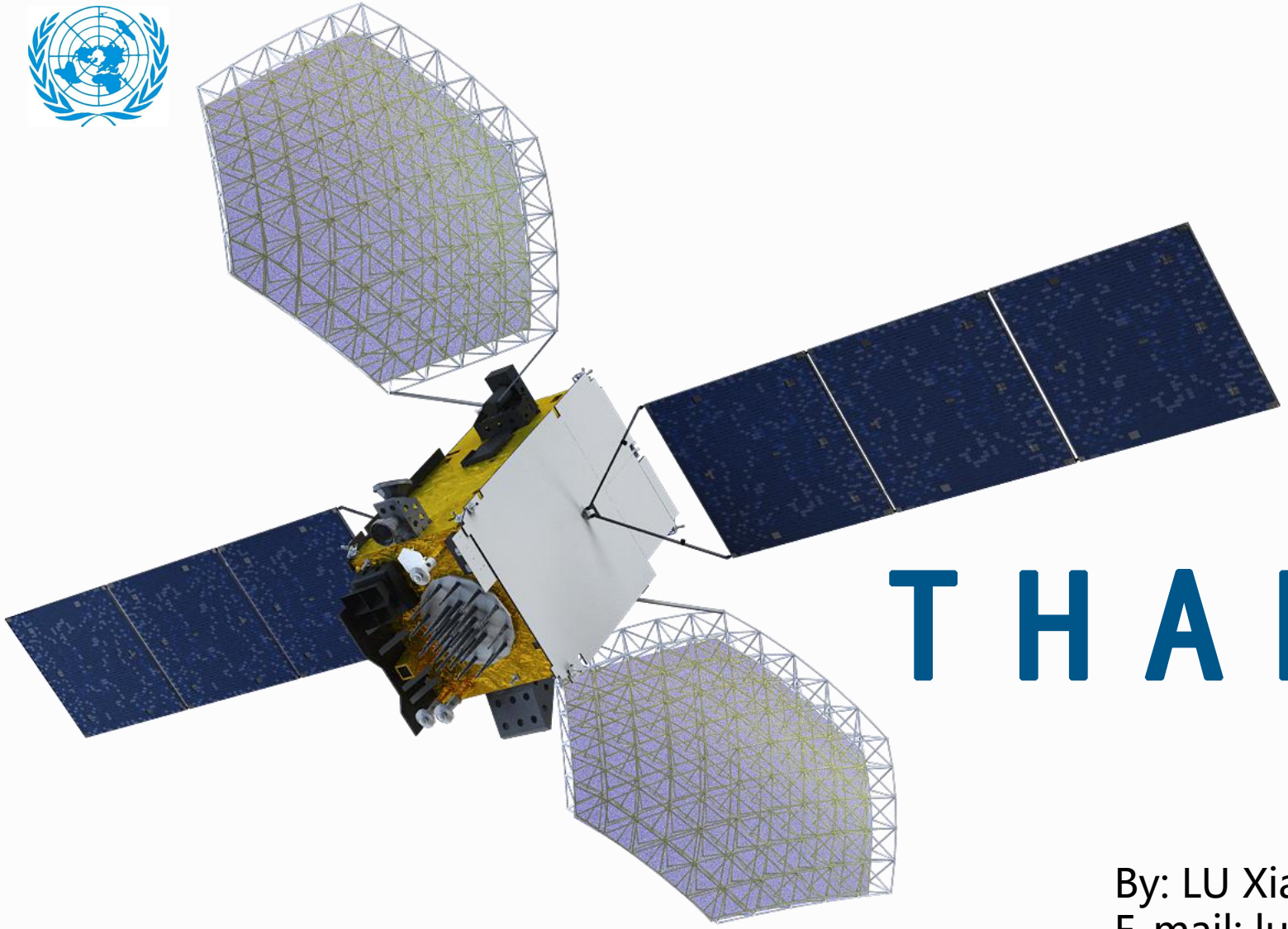
IMO

ICAO · OACI · ИКАО
国际民航组织 · ايكاو

RTCM RTCM



China's BDS
World's BDS
First-class BDS



THANK YOU

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