Update on BeiDou Navigation Satellite System and PNT System

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National Time Service Center Chinese Academy of Sciences

CONTENT

From Compass to Global Satellite Navigation Systems （GNSS）, Positioning, Navigation and Timing Technology (PNT) has made brilliant achievements. It has promoted the progress and development of human society as well the explorations of the world.

01 BDS System Construction

1. GNSS System Construction

Global Navigation Satellite Systems

Global Systems

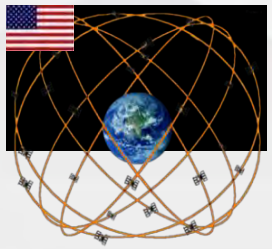
Regional Systems

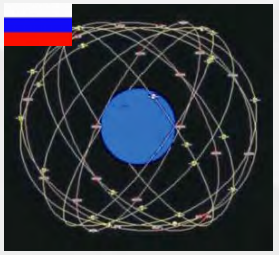
USA: GPS

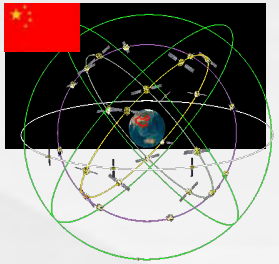
Russia: GLONASS

China: BDS

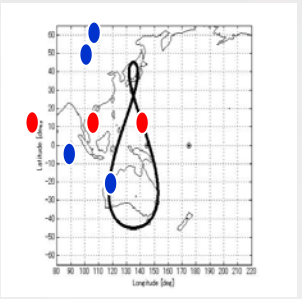
EU: Galileo







Japan: QZSS



India: NavIC

1. GNSS System Construction

There are **nearly 100 satellites in orbit** of other major systems in the world

The current quantity of satellites in orbit of each system	
GPS	31
GLONASS	24
Galileo	22
QZSS	4
NavIC	7
Total	88

PS. Beidou Satellites and in-orbit test and maintenance satellites are not included.

2. BDS Strategy and Principle

Three-step strategy of development:

Regional to Global, Active to Passive

Principle: **Independence, Openness**

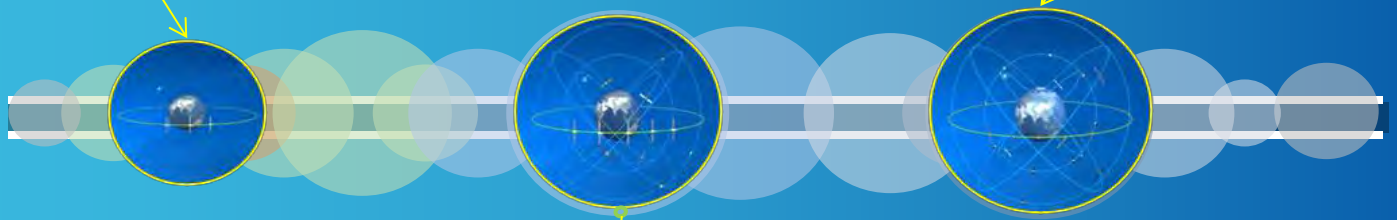
Compatibility, Gradualness

1st step: BDS-1, 1994~2000, Regional active

- Limited capacity
- Timing, Positioning, Short message communication

3rd step: BDS-3, 2013~2020, Global passive

- Precision Improved availability and reliability enhancement
- RNSS, SMS, SBAS, SAR, PPP



2nd step: BDS-2, 2004~2012, Regional passive

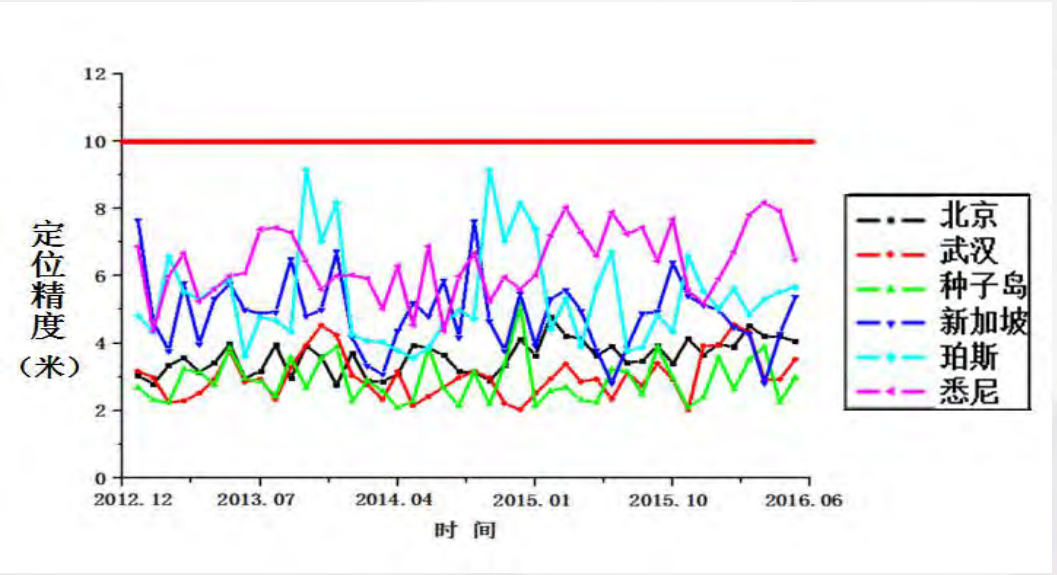
- Unlimited capacity
- RNSS, SMS, Wide Area Differential Service

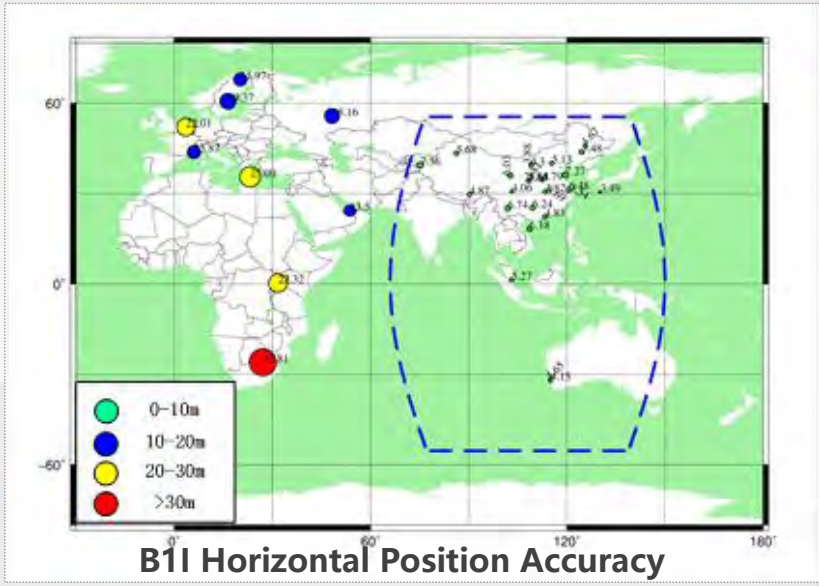
2. BDS-2 System Consruction

(1) The system runs continuously and stably

Operational without service interruption

meet service requirements for public and international users





B1I Horizontal Position Accuracy

Service interruption time (hours)	Continuous service rate
0	100%

3. BDS-3 System Construction




23 BDS-3 satellites have been successfully launched

In-orbit testing, system integration and performance evaluation of the satellites are underway, preliminary results show that the satellites are in good condition and the performance meets the promise.

3. BDS-3 System Construction

(1) Summary of Assessment Results

Index	Assessment Results	Requirements
UTCOE /ns	13.5	≤20.0
Power/dBw	B1C:-155.04 B1I:-156.02 B2a:-153.14 B2b:-153.83 B3I:-155.49	——
SCB/ns	0.3	——
SISRE/m	0.48	≤0.6
Orbit Accuracy of Broadcast /m	radial 0.06	——
Clock Bias Accuracy of Broadcast /ns	mean 1.57	——
Intersatellite Ranging Accuracy/ns	mean 0.1	——
Satellite Clock Performance	Rubidium Clock 1.62×10^{-14} Hydrogen Clock 5.21×10^{-15}	——
SISRRE/(m/s)	0.0009	≤0.006
SISRAE/(m/s^2)	0.0003	≤0.002
Spatial Signal Availability	99.78%	≥98.0%

3. BDS-3 System Construction

(1) Summary of Assessment Results

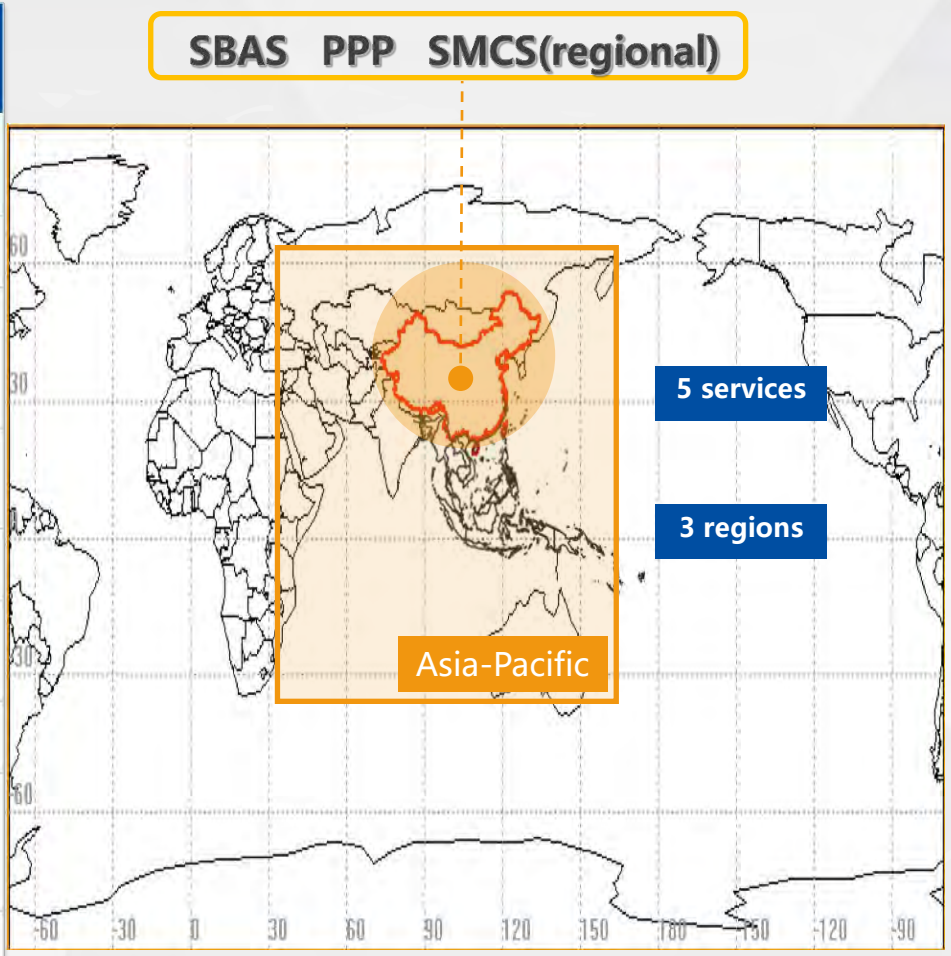
Index	Assessment Results	Requirements
Spatial Signal Continuity	99.99%/h	99.8%/h
PDOP Availability	85%	≥85.0%
Positioning Accuracy	Horizonal better than 6.0m Vertical better than 10.0m	≤10.0（PDOP≤6）
UERE/m	Better than 1.8	——
Ionospheric Model Accuracy	Scale-correction ≥ 65%	——
Velocity Accuracy/(m/s)	Horizonal better than 0.07 Vertical better than 0.10	——
Timing Accuracy/ns	19.1	≤20
Positioning Availability	Better than 91%	≥85.0%

Summary of Assessment Results

3. BDS-3 System Construction

(2) BDS-3 Five Major Services

Service Type		Signal Frequency	Satellite
RNSS		B1I, B3I, B1C, B2a	3IGSO+24MEO
		B1I、B3I	3GEO
SBAS		BDSBAS-B1C、BDSBAS-B2a	3GEO
Short Message Communication Service	Reginal	L (Uplink) S (Downlink)	3GEO
	Global	L (Uplink)	14MEO
		B2b (Downlink)	3IGSO+24MEO
International Search and Rescue Service (SAR)		UHF (Uplink)	6MEO
		B2b (Downlink)	3IGSO+24MEO
Precisise Point Positioning(PPP)		B2b	3GEO



Key area: 30°E~180°E, 70°N~70°S

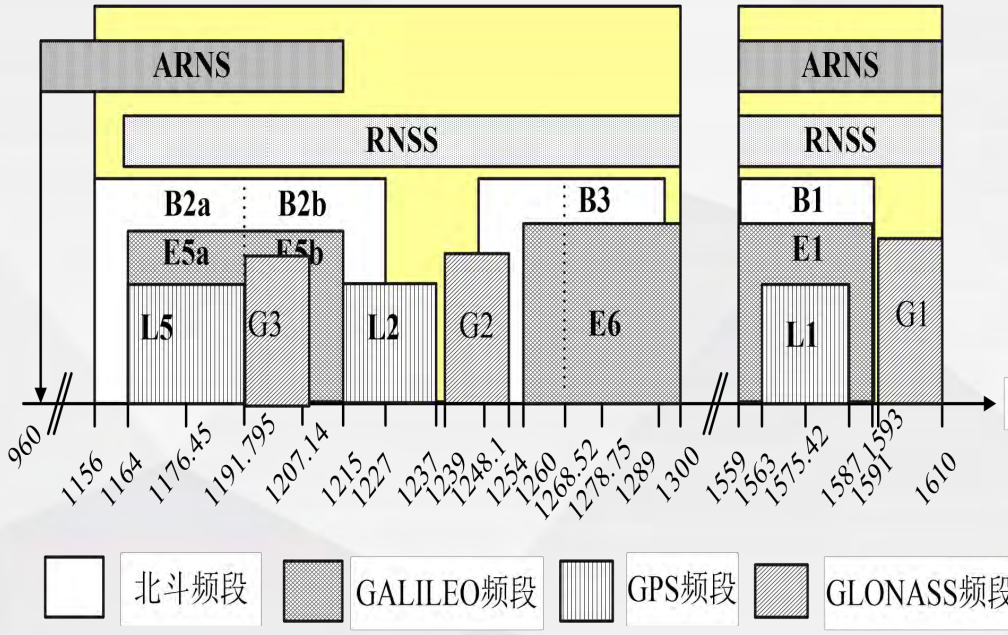
China and surrounding areas: 75°E~135°E, 10°N~55°N

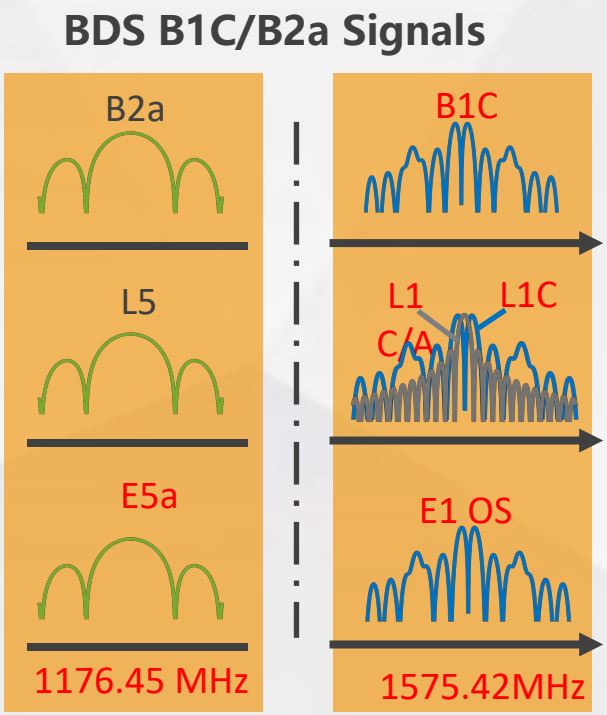
PNT SMCS(Global) SAR

3. BDS-3 System Construction

(2) BDS-3 Five Major Services-RNSS Service (Global)

- Excellent performance
- Compatible and Interoperable



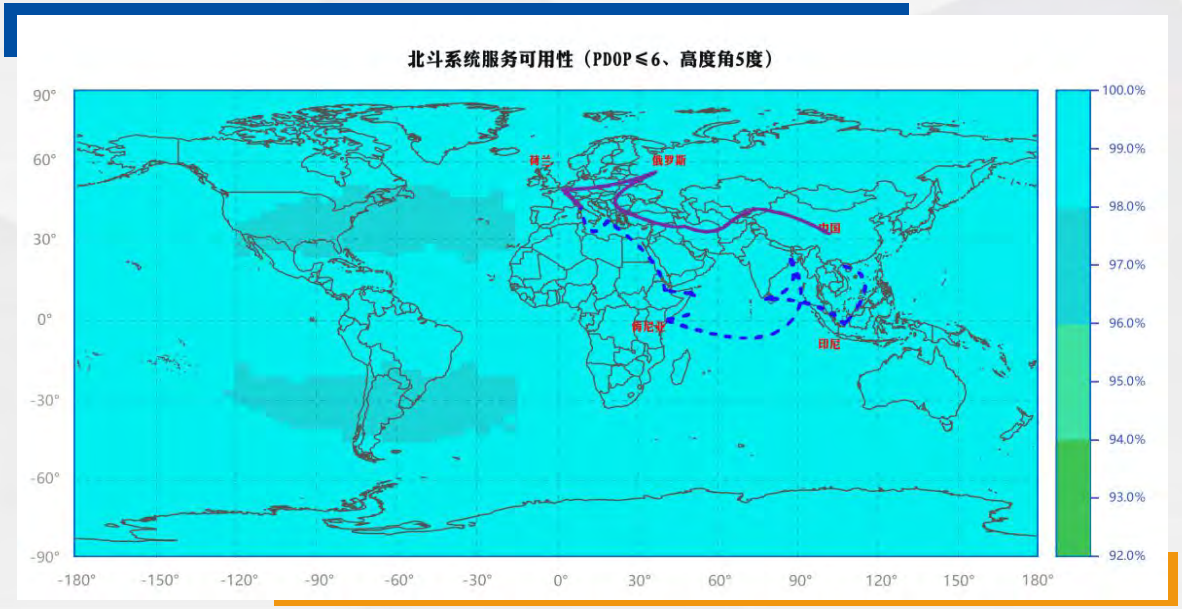


3. BDS-3 System Construction

(2) BDS-3 Five Major Services-RNSS Service (Global)

➢ B1I, B3I :

- System Service Availability : > 99%
- Positioning Accuracy: 3.6 meters horizontally, 6.6 meters vertically (95%)
- Velocity Measurement Accuracy: 0.05m/s,
- Timing Accuracy: 9.8ns (95%)
- In the Asia-Pacific region, the positioning accuracy and availability increased about 30% and 5% respectively.

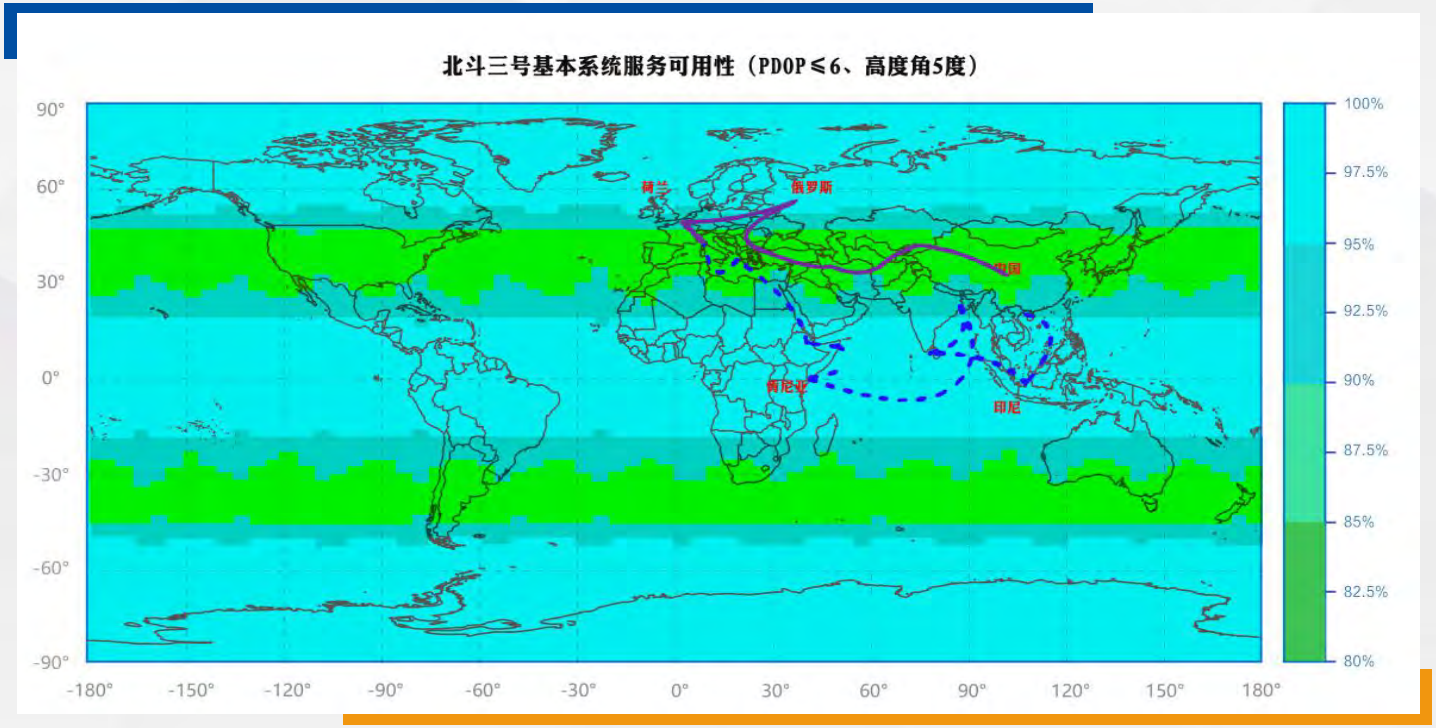


3. BDS-3 System Construction

(2) BDS-3 Five Major Services-RNSS Service (Global)

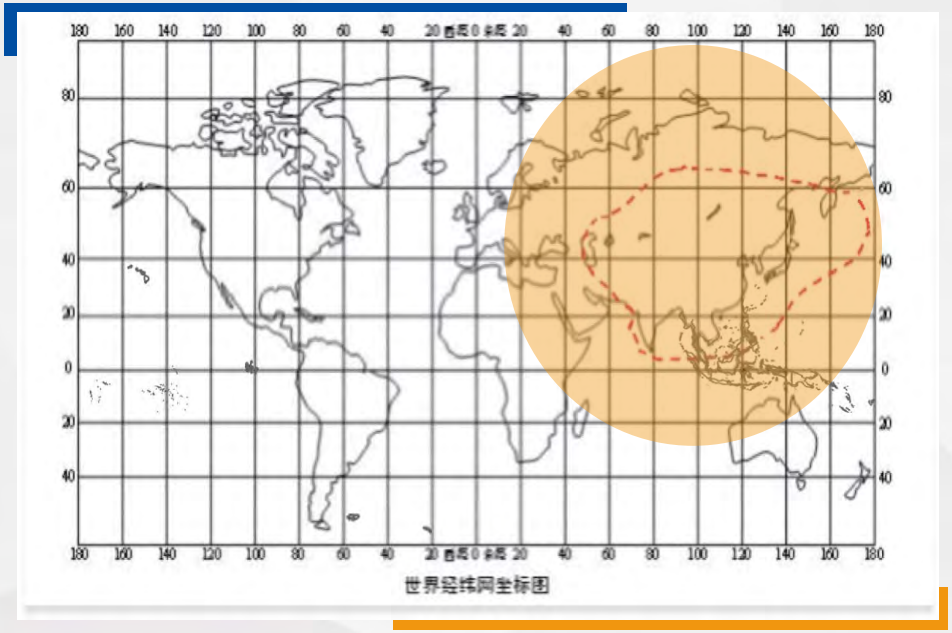
➢ **B1C, B2a :**

- Global Coverage, Availability>87%;
- Positioning Accuracy: 2.4 meters horizontally, 4.3 meters vertically
- Velocity Measurement Accuracy: 0.06m/s
- Timing Accuracy: 19.1ns (95%)



3. BDS-3 System Construction

(3) BDS-3 Five Major Services-Short Message Communication Service (Regional)



Service Planning:

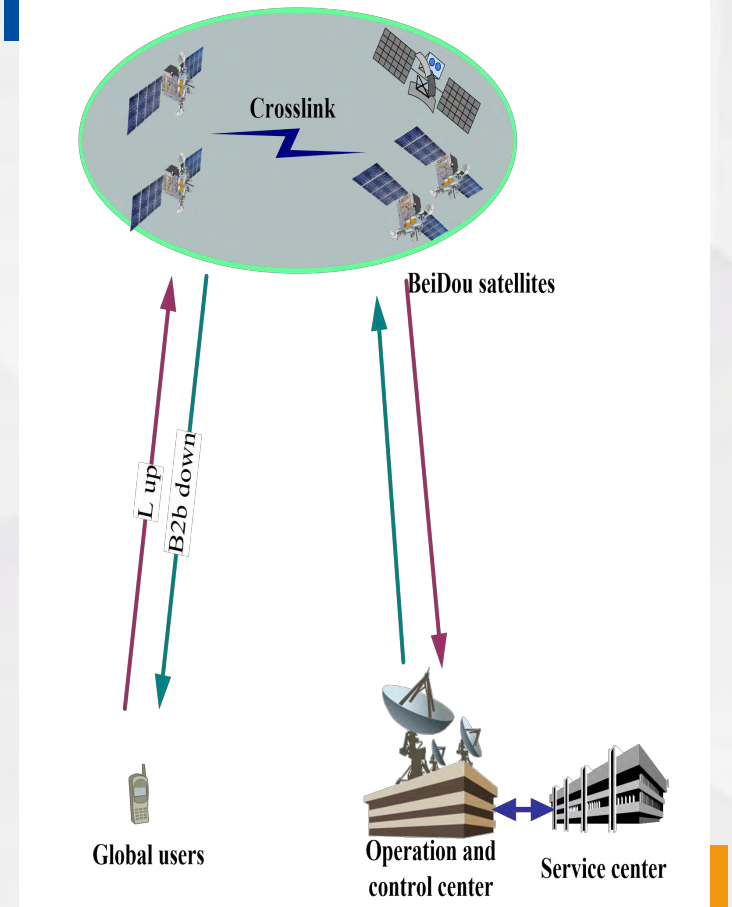
- 3GEO
- Two-way links
- Serve China and surrounding areas
- Service volume: increases by 10 times
- User's transmit power is 1-3w
- 1000 Chinese characters per message

Construction Progress:

- Launched: 1 GEO
- Underway: in-orbit technical tests

3. BDS-3 System Construction

(3) BDS-3 Five Major Services-Short Message Communication Service (Global)



Service Planning:

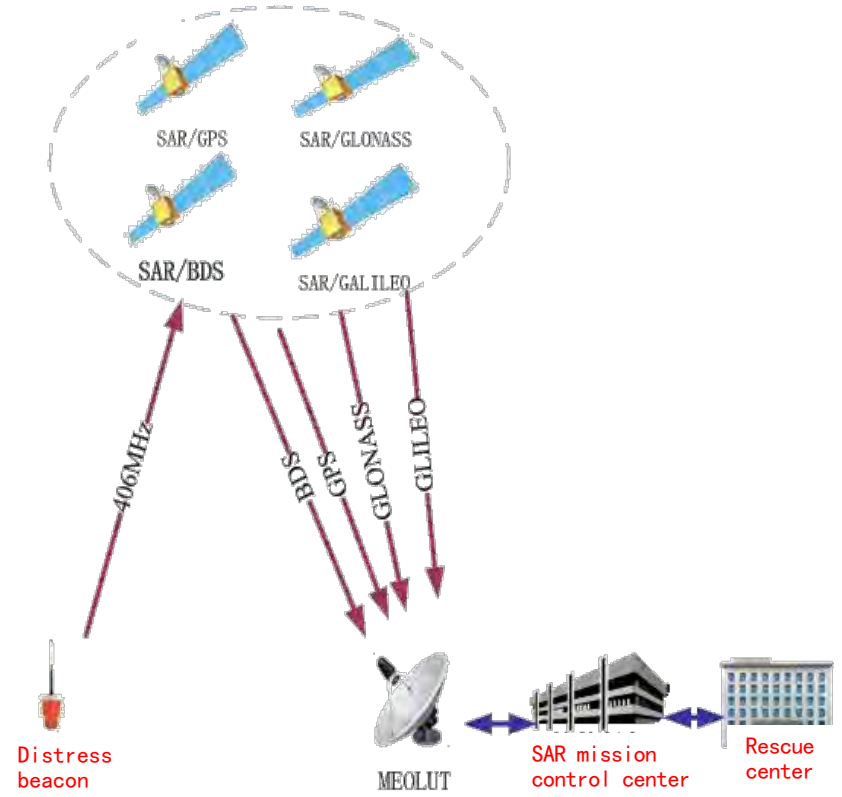
- 14 MEO
- Global casual access
- Service capability is 40 Chinese characters per message (560 Bytes)

Construction Progress:

- Launched: 10 short-message-communications-loaded MEO satellites
- Underway: in-orbit technical tests

3. BDS-3 System Construction

(4)BDS-3 Five Major Services-International SAR Service （Global)



Service Planning:

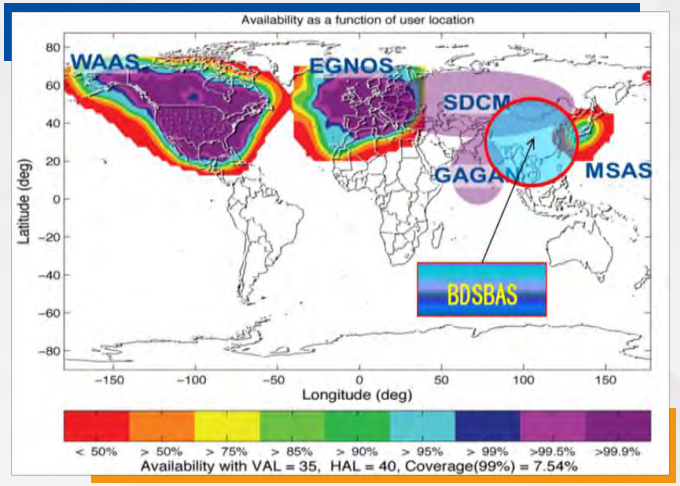
- 6 MEO
- Global Services
- Compliance with standards of the International Maritime Organization (IMO) and COSPAS/SARSAT
- Return-links, improve the efficiency

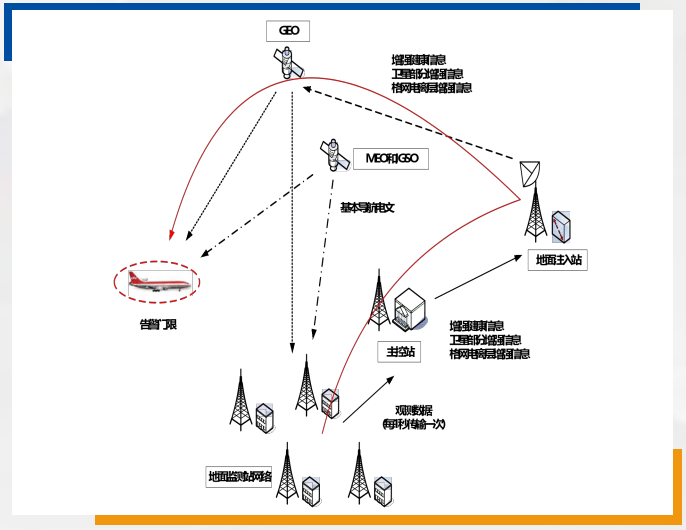
Construction Progress:

- Launched:4 SAR-loaded MEO satellites
- Underway: in-orbit technical tests

3. BDS-3 System Construction

(5) BDS-3 Five Major Services-Satellite-Based Augmentation Services (SBAS)





Service Planning:

- 3 GEO（80°E（Nov. 2018），110.5°E, 140°E (2020)）
- Following the ICAO standards and realizing precision service according to CAT-I
- China and surrounding areas

Construction Progress:

- **Launched:** 1 GEO
- **Underway:** in-orbit technical tests

  Information dissemination test

3. BDS-3 System Construction

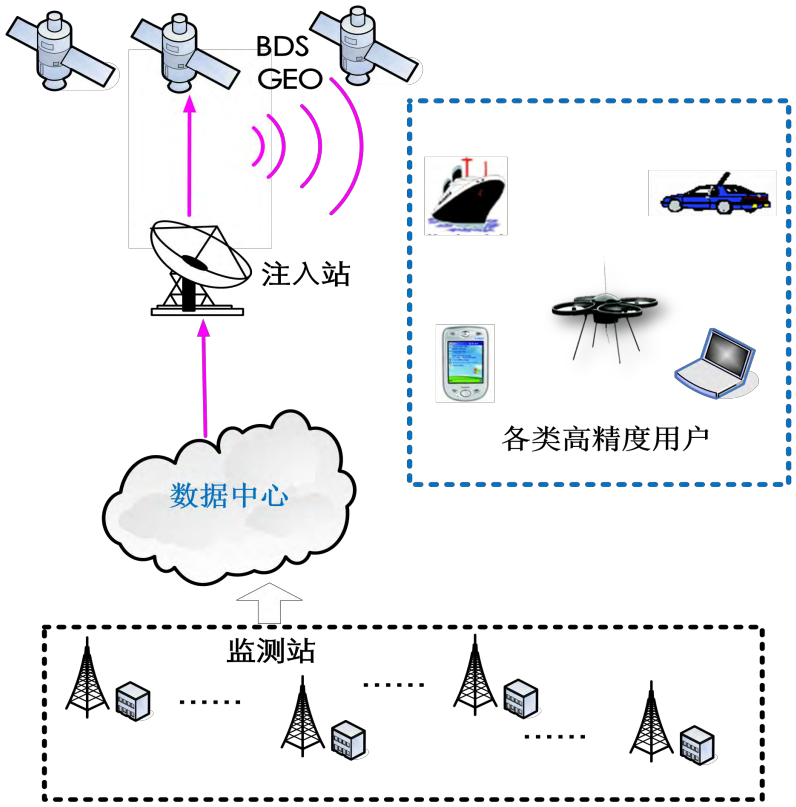
(5) BDS-3 Five Major Services-Satellite-Based Augmentation Services (SBAS)

Performance		BDSBAS	
		SF(Single Frequency)	DFMC(Dual Frequency Multi-Constellation)
Service Coverage		10°N~55°N；75°E~135°E	10°N~55°N；75°E~135°E
Augmentation Constellation		BDS B1C GPS L1C/A	BDS B1C/B2a GPS L1C/A/L5 GALILEO E5a/E1 GLONASS L1/L2/L3
Signal	Frequency	1575.42MHz	1176.45MHz
	Signal Structure	SBAS L1 C/A	DFMC SBAS L5
Accuracy (95%)		H：2.5m V：4m	H：1.5m V：2m
Integrity	Time To Alarm	10s	6s
	Integrity Risk	2×10^{-7}/150s	2×10^{-7}/150s
	Alarm Threshold	HAL：40m VAL：50m	HAL：40m VAL：10m
Continuity		$1-8\times10^{-6}$/15s	$1-8\times10^{-6}$/15s
Availability		Better than 99%	Better than 99.9%
Compatibility		SF SBAS ICD	DFMC SBAS ICD
User capacity		Unlimited	

The Performance of BDSBAS

3. BDS-3 System Construction

(6) BDS-3 Five Major Services-Precise Point Positioning service (PPP)



Service Planning:

- 3 GEO
- Serve China and surrounding areas
- Dynamic precise position service accuracy at decimeter level and static precise position service accuracy at centimeter level

Construction Progress:

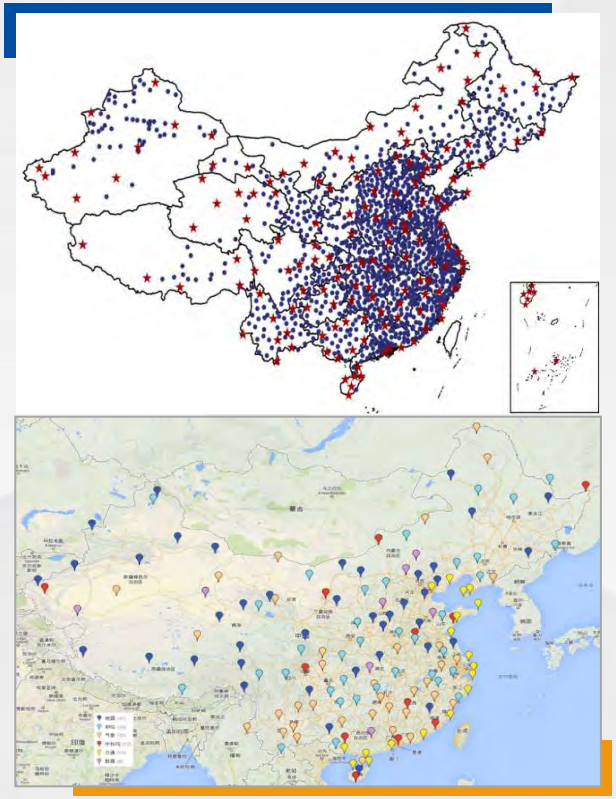
- Launched: 1 GEO
- Underway: in-orbit technical tests and Information dissemination test

3. BDS-3 System Construction

(7) Construction of Ground Facilities-National Differential System

Service Perencialng:

- 175 framework constellation reference stations, 1200 regional network reference stations
- China and most maritime area
- Satellite broadcasting, digital broadcasting and mobile communication broadcasting
- wide-area at meter level and decimeter level, area at centimeter level and post-processing at millimeter level



Construction Progress:

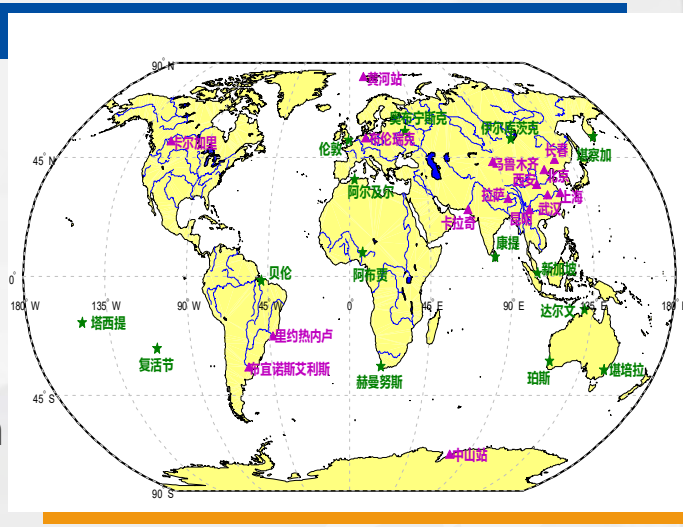
- More than 2,200 reference stations
- Three broadcasting means
- Services at the wide-area meter in the whole country and sub-meter levels

3. BDS-3 System Construction

(8) Construction of Ground Facilities-International GNSS Monitoring and Assessment System

Service Planning:

- 30 Global Reference Station
- 3 data centers
- 10 analysis centers
- Raw observation data, basic high-precision products (precision orbit, clock difference, ionosphere, earth rotation parameters, etc.), monitoring and evaluation information (constellation status, space signal, navigation information, service performance)



Construction Progress:

- An international Monitoring and Assessment System
- Related data and products are available at www.csno-tarc.cn

3. BDS-3 System Construction

(9) Smooth Transition from BDS-2 to BDS-3

System Evolvement

	BDS-2	BDS-3
Area	Regional	Global
Type	RNSS, RDSS, Wide Area Differential	RNSS、SMS(including RDSS)、SBAS、SAR、PPP
Constellation	5G+5I+4M	3G+3I+24M
RNSS Signal	6	8
RDSS Signal	Old system	Old system + New system
Performance	Positioning accuracy 10m URE 2.5m	Positioning accuracy 10m URE 0.5m .....

3. BDS-3 System Construction

(9) Smooth Transition from BDS-2 to BDS-3

AIMS

- **Guarantee interests of existing users**
  Existing user service of BDS-2 will not be interrupted
- **Provide quality service as soon as possible.**
  New users will give priority to use of BDS-3 service to shorten transition period

KEYS

- **The signal is the basis**
  Signal is upgraded in an incremental manner, and BDS-3 retains main signals of BDS-2
- **The constellation is a guarantee**
  On any time profile, DOP value will not decrease
- **Ground segment is the core**
  Ground system of BDS-2 and BDS-3 can work together and joint operate

3. BDS-3 System Construction

(10) Construction Process

2018-2019.10

launched:

- 20 MEO satellites
- 1 GEO satellite
- 2 IGSOsatellites

Dec. 2018

Completed the primary system of BDS-3 and provided operational service to the global users

From 2019.10 To 2020

- 4 MEO satellites
- 1 IGSOsatellite
- 2 GEO satellites

Dec. 2020

Complete full constellation and global coverage

02

Application and Cooperation

1. Applications Promotion

(1) Industrial and Regional Applications

BDS-enabled products have been widely used in traffic & transportation, public security, agriculture, forestry and fishing, hydrologic monitoring, weather forecast, communications system, generation dispatch and disaster response & relief, as well as national core infrastructure, which has greatly increased economic and social benefits.

1. Applications Promotion

(2) Applications in Traffic and Transportation

- The **world's largest** dynamic monitoring system for operational vehicles has been built
- **6.2 million** operational vehicles
- **30,000** postal and delivery vehicles
- **80,000** buses
- **Over 3200** inland waterway navigation facilities
- **Over 2900** marine navigation facilities

1. Applications Promotion

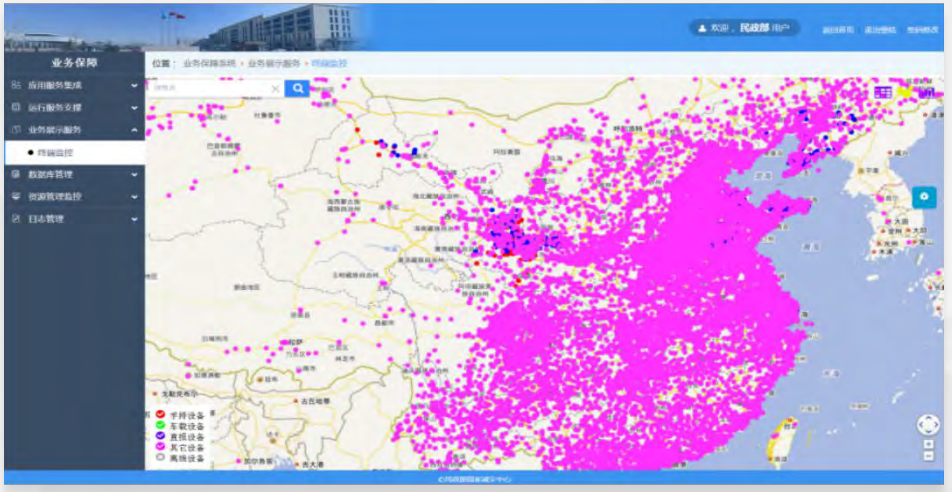
(3) Applications in Agriculture, Forestry and Fishing

- Serve over **50,000 a**gricultural equipment
- Precision farming output has increased by **5%**
- Income growth of RMB **60-90 p**er month per peasant household
- Positioning & short-message communication function help prevent forest fires
- Over **70,000 n**etworked boats
- Has rescued over **10,000 p**eople

1. Applications Promotion

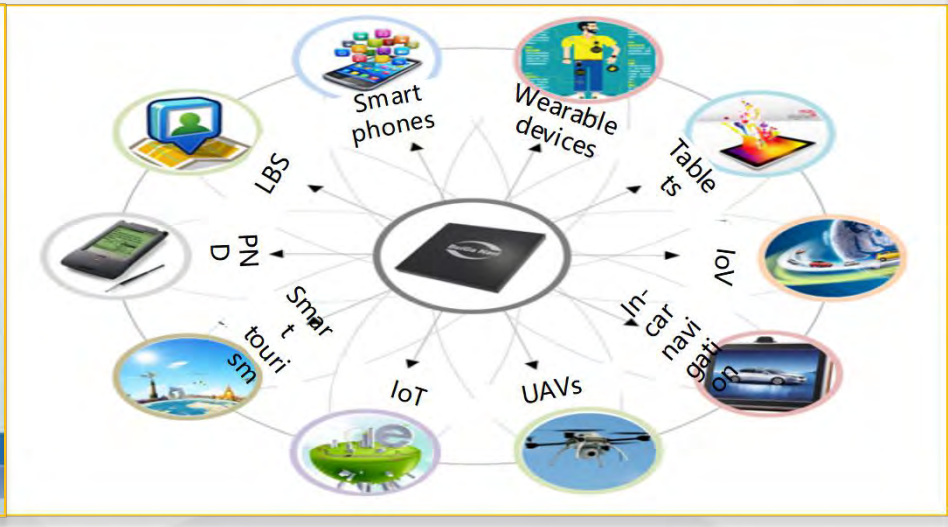
(4) Applications in Disaster Response and Relief

- **6 levels** of business applications
- Over **45,000** BDS terminals have been promoted
- Relevant disaster response information has been reported
- Disaster relief materials management has been improved



1. Applications Promotion

(5) Mass Market Applications



In terms of mass-market applications, the BDS-based navigation services have been adopted by e-commerce, mobile intelligent terminal manufacturing and location-based service manufacturers. In the meanwhile, it has entered into mass consumption, shared economy and people's livelihood, as well as affected peoples' lifestyles in a profound way.

1. Applications Promotion

(5) Mass Market applications

According to statistics, around 470 types of smartphones sold in the first three quarters in China have a positioning function, among them 298 support BDS positioning, which is accounting for 63% of the total. A wide range of BDS-based smart wearable devices such as watches, bracelets and care products such as student cards and senior citizen cards keep popping up and have been used widely.

1. Applications Promotion

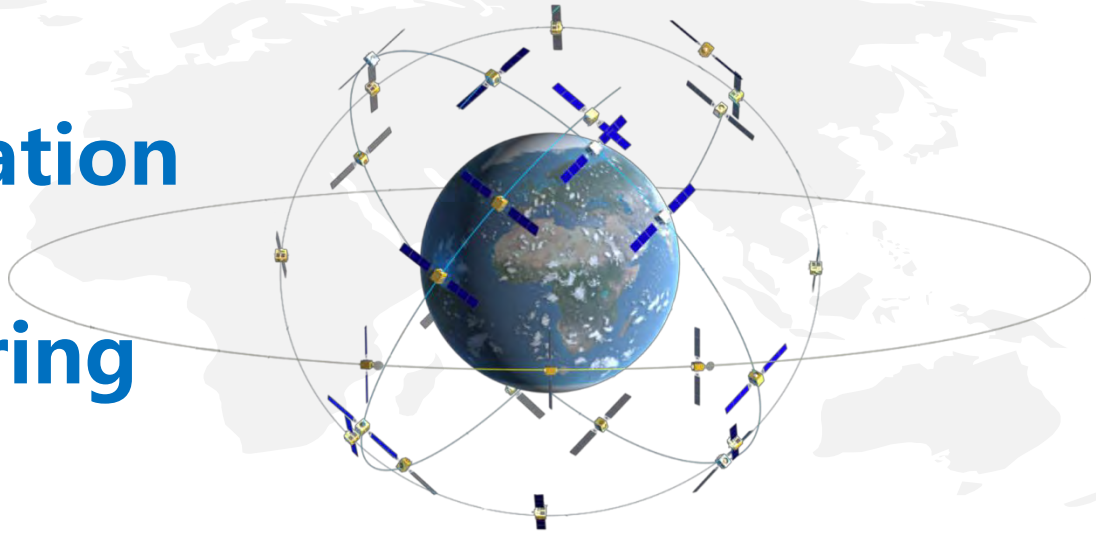
(6) Strategic Emerging Industries——” BeiDou +”

Next, we will focus on promoting the integrated development of BeiDou with the Internet, cloud computing, Internet of things,artificial intelligence, 5G mobile communications and other tehnologies.

International Cooperation

Open Cooperation

Resource Sharing



2. Internationa Cooperation

(1) Bilateral Cooperation——China-US Cooperation

On Nov. 29, 2017, China and the U.S. signed a Joint statement on Civil Signal Compatibility and Interoperability between GPS and BDS.

2. International Cooperation

(2) Multilateral Cooperation

The 13th ICG Conference was successfully held in November 2018 following the 7th ICG Conference in 2012. Manual on GNSS Space Service Interoperability was launched during the Conference and Xi'an Initiative was also agreed during the Conference.

03 Comprehensive PNT System

Humans Keep Looking for Better Navigation and Positioning Methodologies

Two Driving forces: Demand & Technology

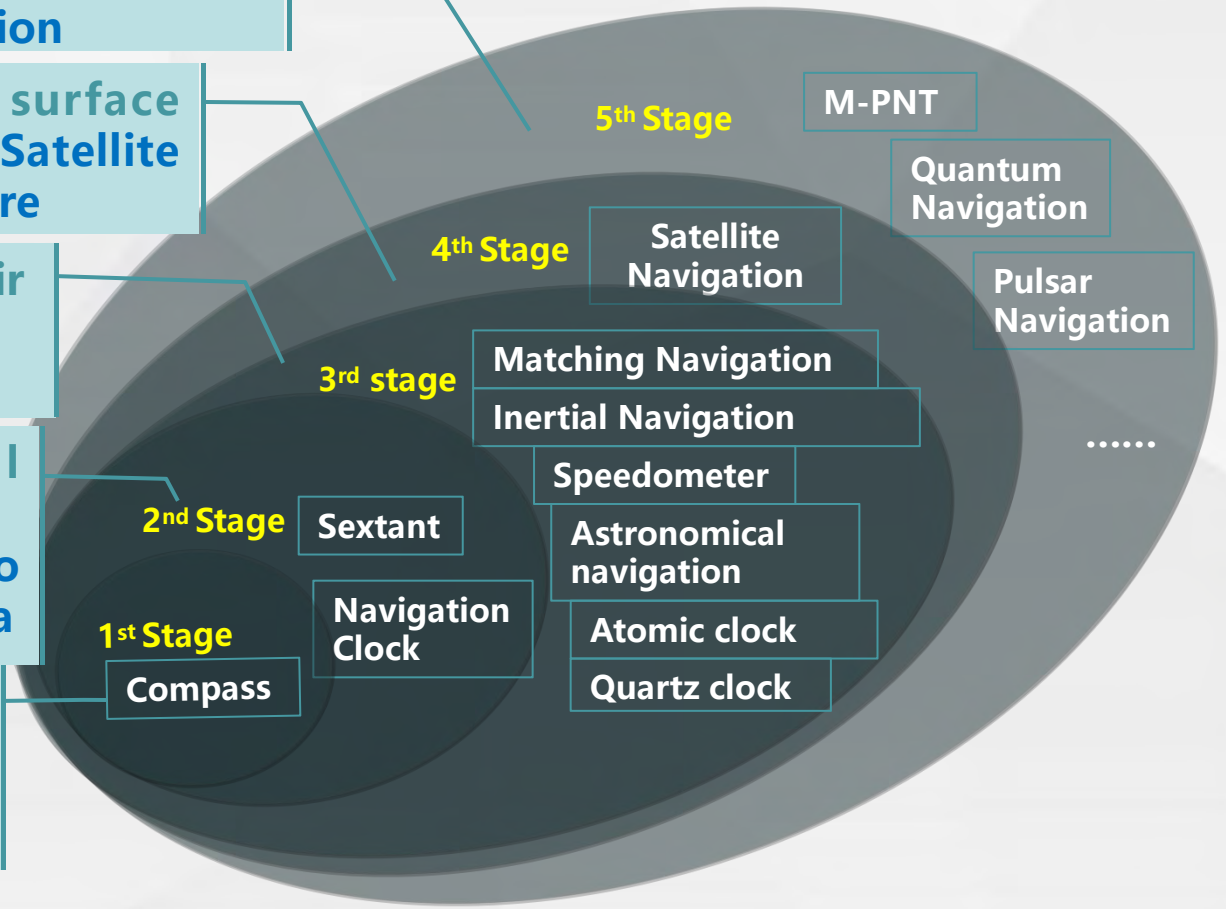
Full and high performance coverage of sea, land and air
Systematic Construction

Human activities in surface and near space with **Satellite Navigation As the Core**

Remote land, sea and air transport
Radio and Electronics

Ocean voyage, colonial development
Simple instrument to observe natural phenomena

Human migration , hunting and farming
Visual observation of natural phenomena



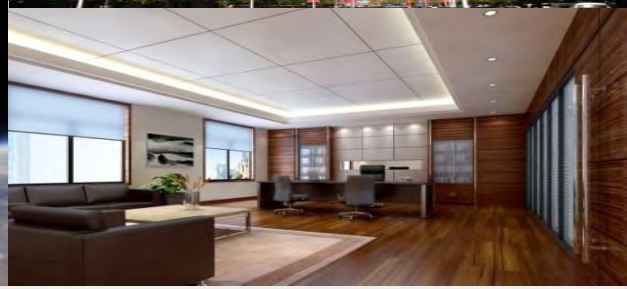
1. The Current Difficulties

(1) The weakness of Satellite Navigation

- Weak signal, Susceptible to interference, easy to be blocked by tall buildings and mountains
- Poor penetration: underwater, indoor and urban canyons cannot be covered
- Unable to provide interstellar navigation
- Depend on the ground facilities





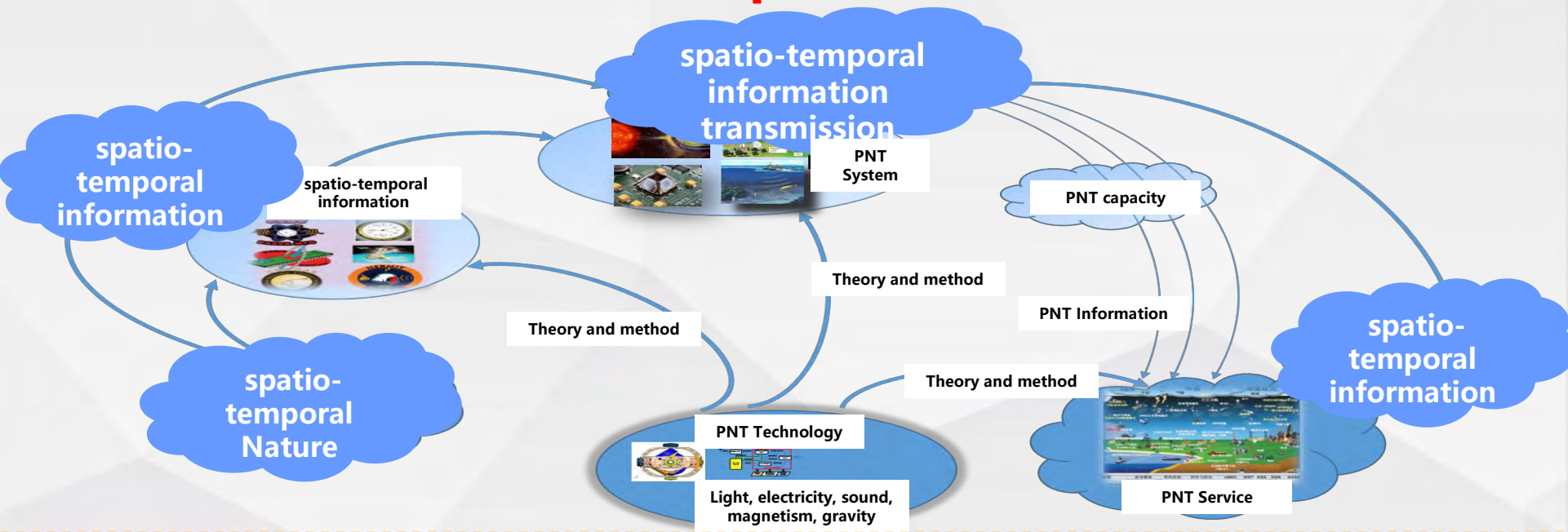



How can we solve this problem?

2. System Construction of PNT System

(1) Basic Definition

What is Comprehensive PNT?

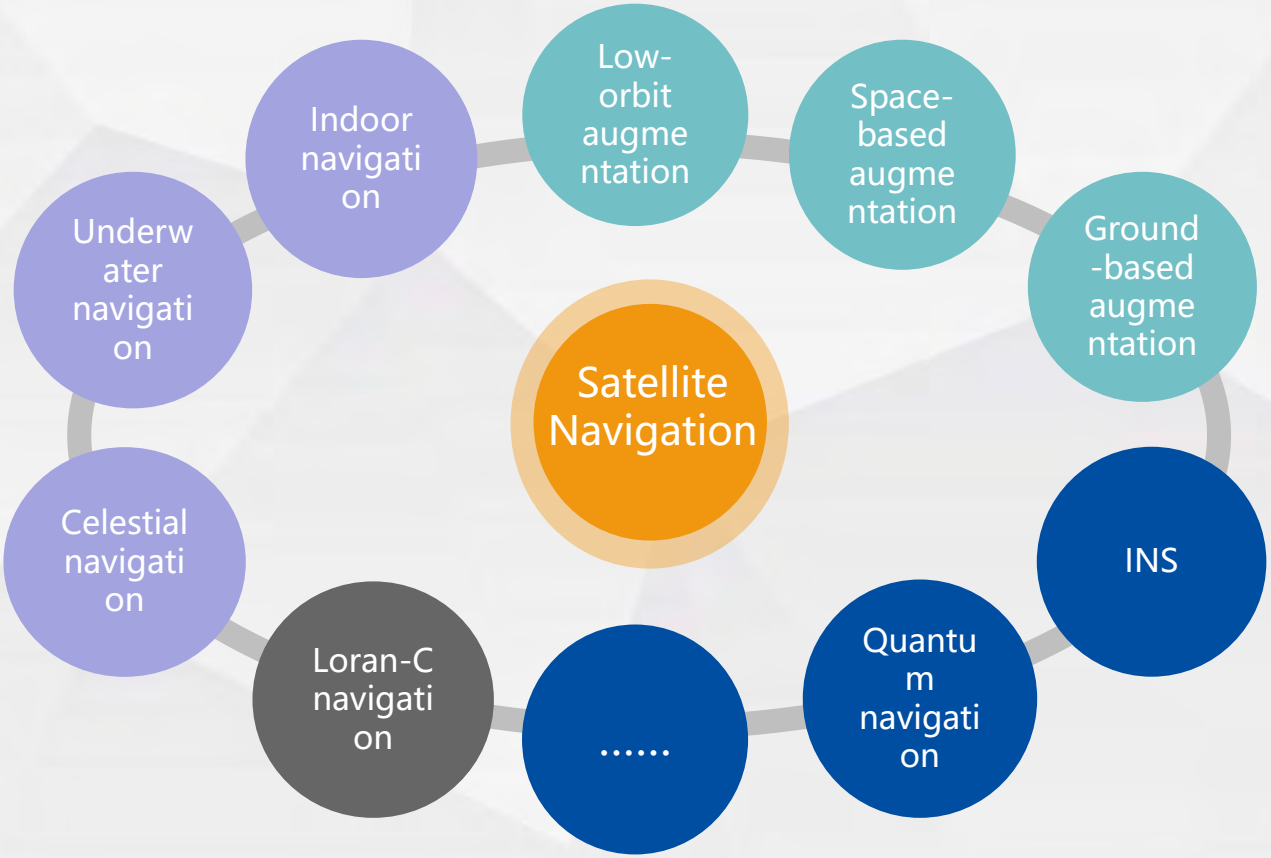


Comprehensive PNT technology is the generic name of various PNT technologies, systems and services, covering and penetrating the whole process of establishment, maintenance, transmission and application of spatio-temporal reference, providing unified, accurate and reliable spatio-temporal information service for human activity space.

2. System Construction of PNT System

(2) Prospect of the Development

It's expected to be built into a national comprehensive PNT system by 2035
more ubiquitous, more integrated ,more intelligent,



2. System Construction of PNT System

(6) Key Application Field

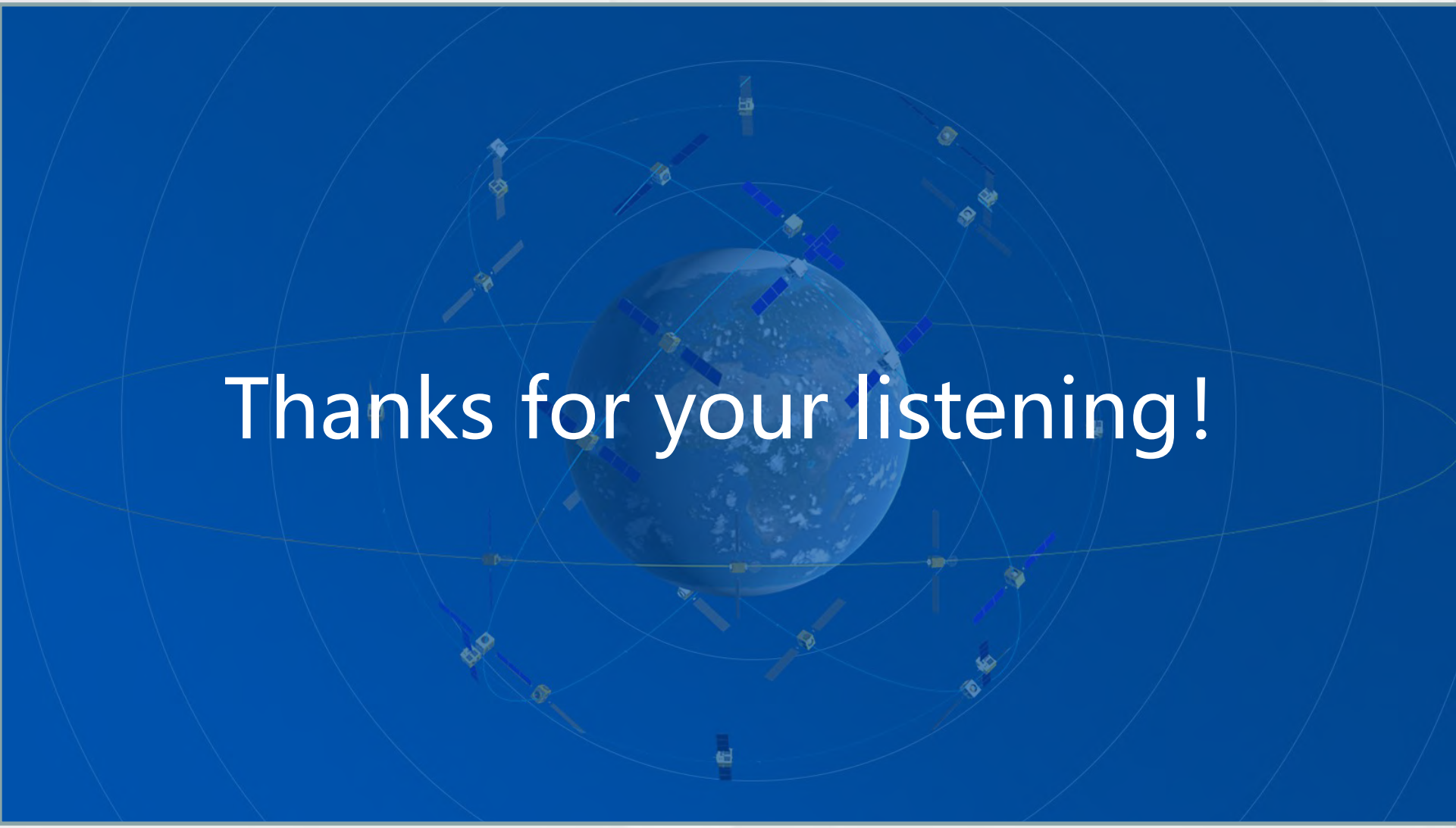
Unified, Real-time, Accurate PNT Information

National Security Governance	Economic and Social Development	Scientific and Technological Progress
• All things connected • Information sharing • Accurate perception • Accurate operation	• Transportation, communication • Finance, logistics • Infrastructure	• The Internet • The Internet of things • Big data • Cloud computing • Artificial intelligence (AI)

Conclusion

The global satellite navigation systems are changing rapidly. In particular, with the four global systems and two regional systems, the number of orbiting satellites has increased to more than 100. The service has improved dramatically and has provided more options for users.

BDS will play a more active role in serving mankind and the world and keep contributing wisdom and strength to the world with its stronger abilities and better-quality services.


Thanks for your listening!