Update on BeiDou Navigation Satellite System (BDS)

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Development Plan

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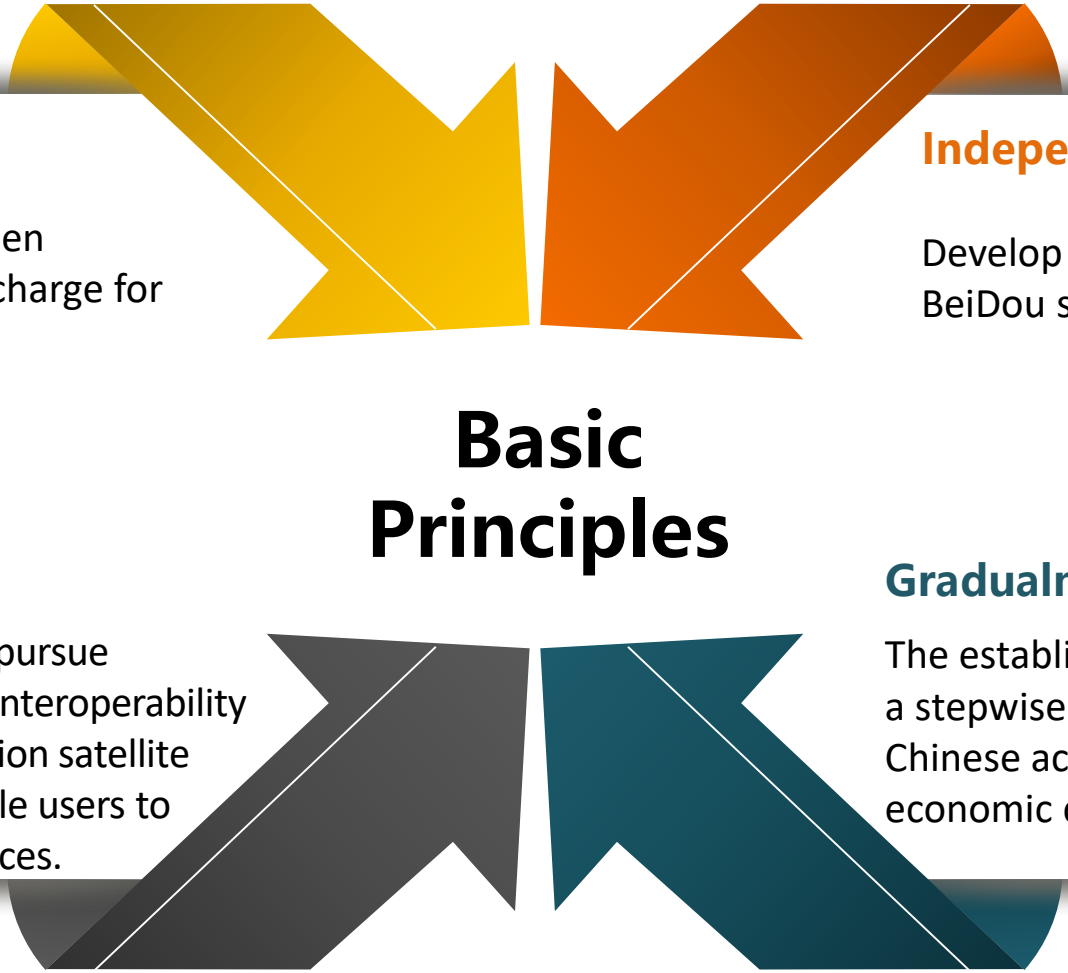
Development Objectives

BDS is committed:

- To provide continuous, stable and reliable positioning, navigation and timing services to global users;
- To meet the requirements derived from national security, economic and social development sectors, to accelerate IT applications and the transformation of economic development methods, and to improve both economic and social benefits;
- To serve the world and benefit the mankind through joint efforts with other navigation satellite systems across the globe.

Basic Principles



Openness

BDS will offer open services free of charge for global users.

Independency

Develop and operate the BeiDou system independently.

Compatibility

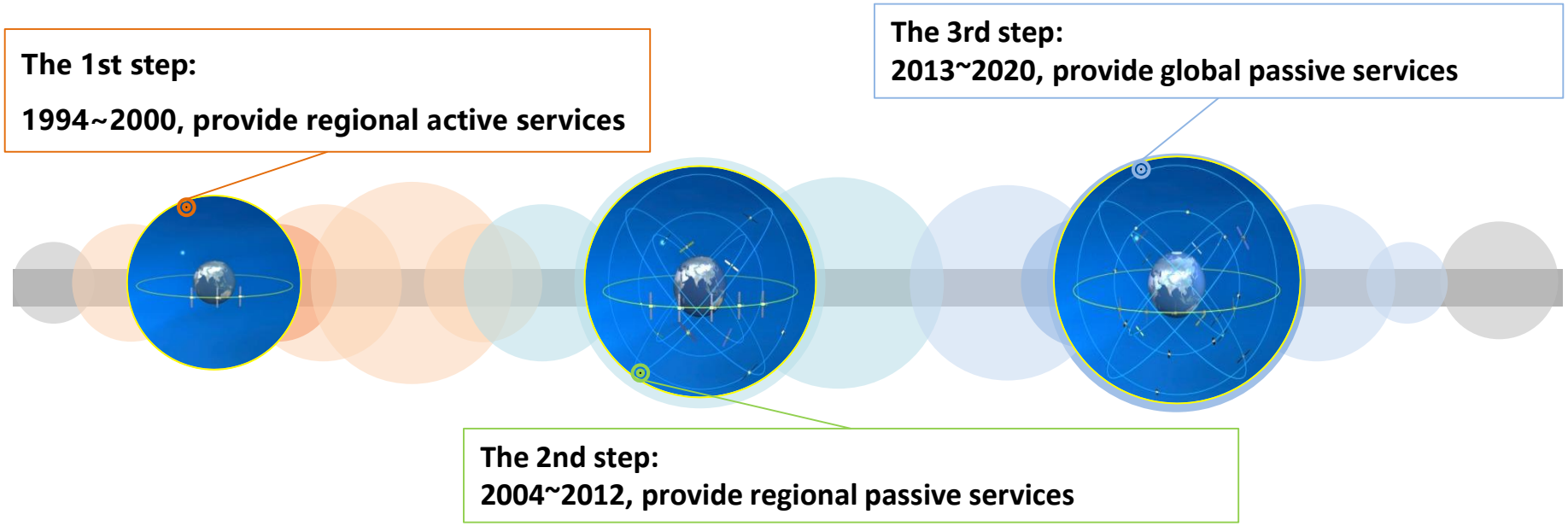
BDS is devoted to pursue compatibility and interoperability with other navigation satellite systems, and enable users to obtain better services.

Gradualness

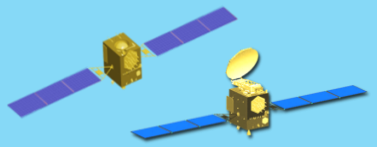
The establishment of BDS follows a stepwise manner in the light of Chinese actual technical and economic conditions.

Development Steps

- BDS has been developing
  - in line with the *three-step* roadmap
  - the thinking of *from regional to global, and from active to passive*
  - forms a development path as *world-oriented, region-highlighted, with its unique features*.



BDS - System Components

space segment		• 5 GEO satellites • 3 IGSO satellites • 27 MEO satellites
ground segment		• Master Control Stations (MCS) • Uplink Stations (US) • Monitoring Stations (MS)
user segment		• BDS terminals • Terminals compatible with other GNSS

- ✓ BDS is comprised of three major components: space segment, ground control segment and user segment.
- ✓ BDS is able to provide four types of services, namely, open, authorized, wide area differential and short message services.
- ✓ The positioning accuracy is better than 10 meters, the timing accuracy is better than 20 nanoseconds, and the velocity accuracy is better than 0.2 meters per second.

Fundamental Policies

- Provide open services free of charge for users.
- Maintain and enhance the system, and improve service performance continuously, and offer services with higher quality.
- Release open service performance specifications and related system documents on schedule, bring the function of government and market to full play, promote innovation, popularization and internationalization of BDS/GNSS applications, and lay foundation for the national strategic emerging industries.
- Adhere to the concept of development and win-win cooperation, realize compatibility and interoperability between BDS and other GNSS, give the system efficiency into full play and increase users' benefits.

01

Development Plan

02

System Construction

Application Promotion

International Cooperation

Latest Progress

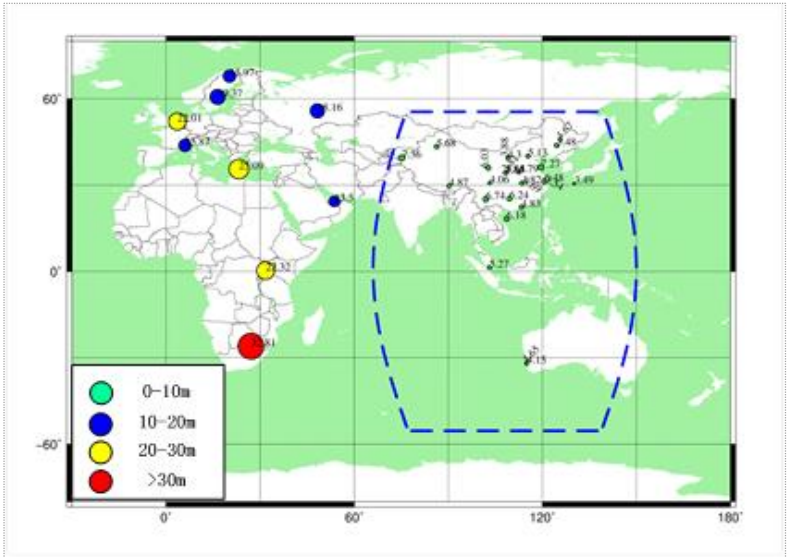
03

Near-term Plan

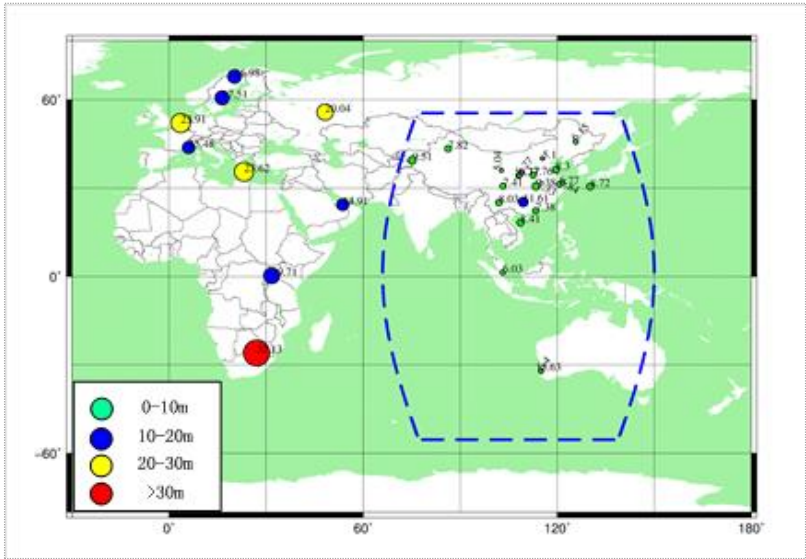
System Construction

Steady Improvement of the BDS Performance

- Since its formal regional services provision on December 27 2012, BDS has been maintaining continuous and stable operation, and the performance has been steadily improved.
- The performance meets the specification, while the positioning accuracy is much better than 10m in some of the coverage area.



B1I Horizontal Positioning Accuracy

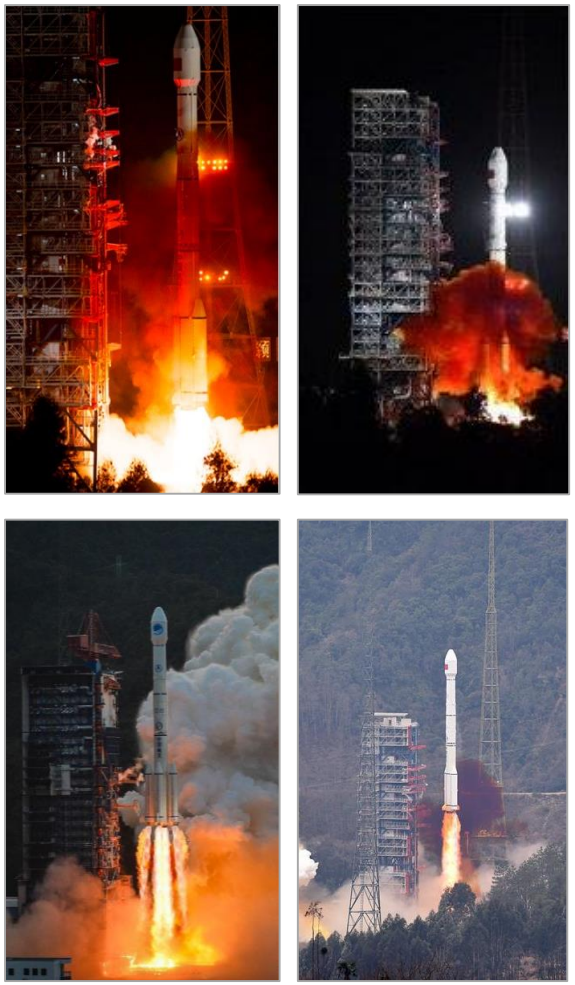


B1I Vertical Accuracy

System Construction

Five New Generation BDS Satellites – An Important Step for the BDS Global Constellation Deployment

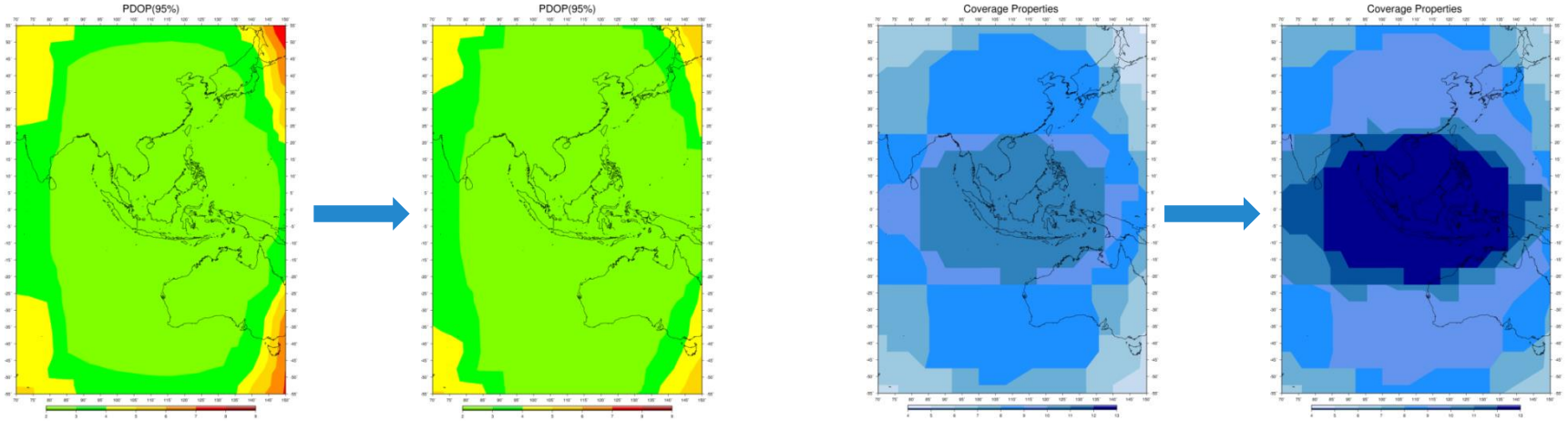
- Since 2015, five new-generation BDS satellites and two in-orbit spare satellites have been successfully launched.
- The advanced signal structure, inter-satellite link, on-board clocks with higher accuracy and other key system components and technical issues have been verified.
- After the intra-system technical state is coordinated, five new-generation BDS satellites will provide services in a timely manner.
- The new satellites will also further enhance the solidity of the BDS constellation, improve the ability of system services, and establish a solid foundation for the future global services.



System Construction

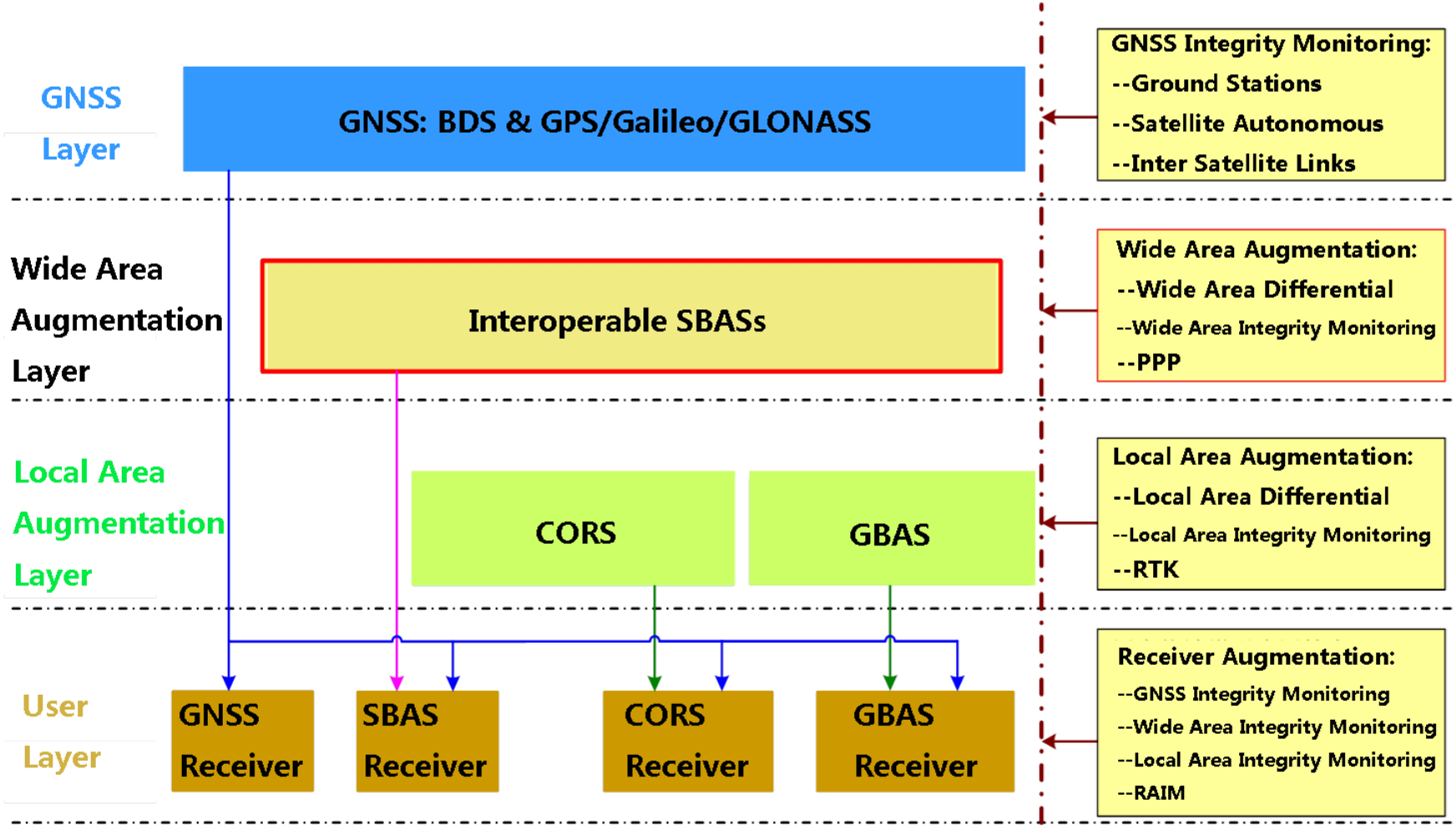
Steady Improvement of BDS Performance

- After two IGSO satellites were successfully launched recently, in the BDS coverage area,
  - the average PDOP（95 percent）decreases from 3.07 to 2.84
  - the average minimum number of visible satellites increases from 7.0 to 8.3



BDS - Design & Development Plan

BDS Augmentation System Architecture



System Construction

Accelerate Construction of BDS Augmentation Systems

BDS Ground-Based Augmentation System

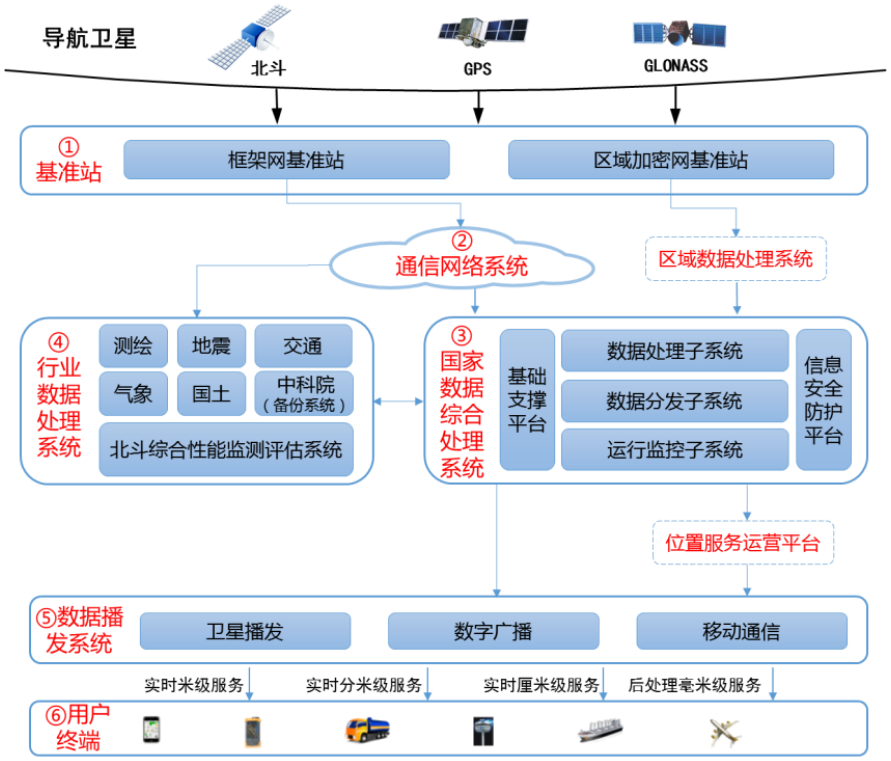
- Accelerate the construction of the National BeiDou Ground-Based Augmentation System （BDGBAS）, and create a high-accuracy location platform with special application services.
- A nation-wide reference station network has been built, and the construction of the basic system has been preliminarily completed.
- The system performance is being tested, including meter and decimeter level for wide-area real-time services, centimeter level for the areas within Beijing, millimeter level for post-processing services.

System Construction

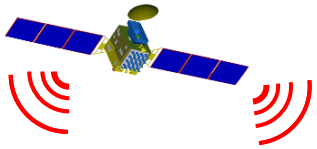
Steady Construction of BDS Augmentation Systems

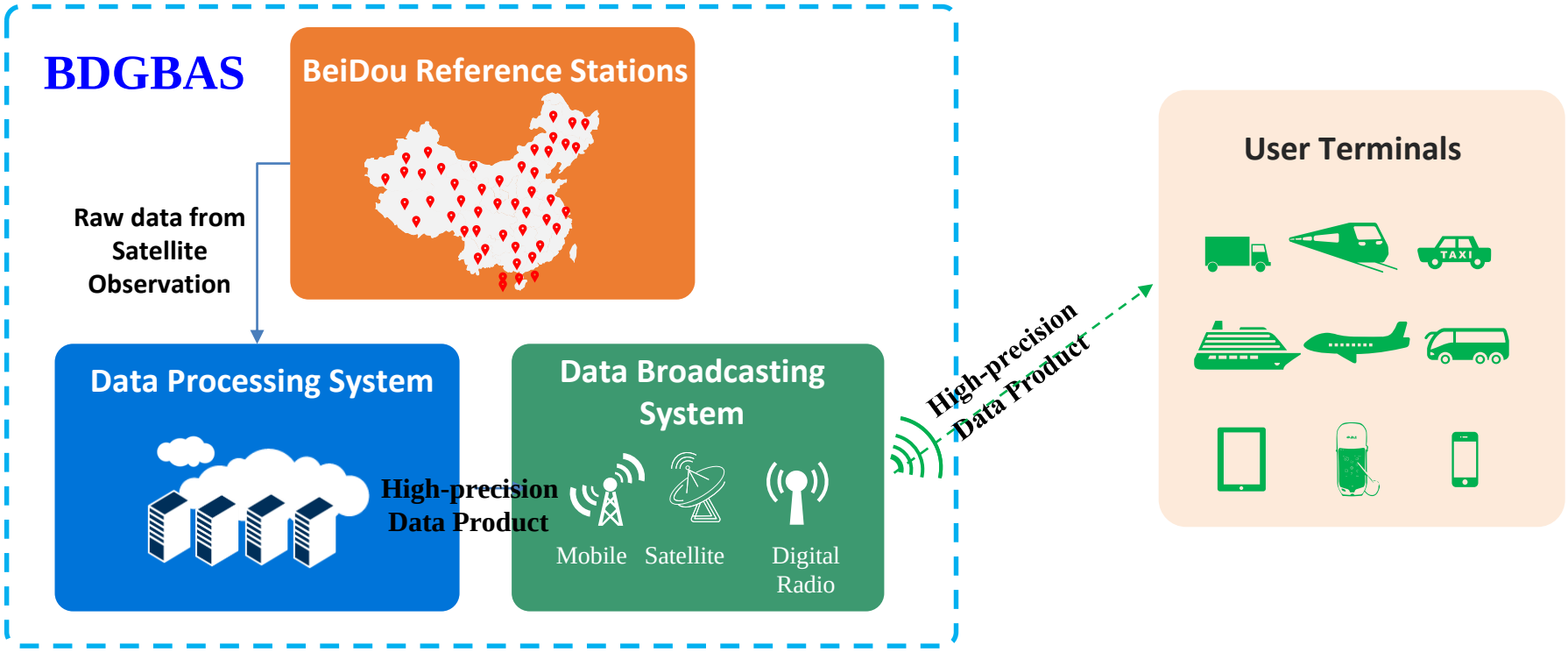
National Ground-Based Augmentation System

- When the system is operational, it will provide meter and decimeter level real-time location services for users in China, even centimeter level service in some areas.
- BDS-based high-precision applications, such as the lane-level vehicle navigation service, could be realized.



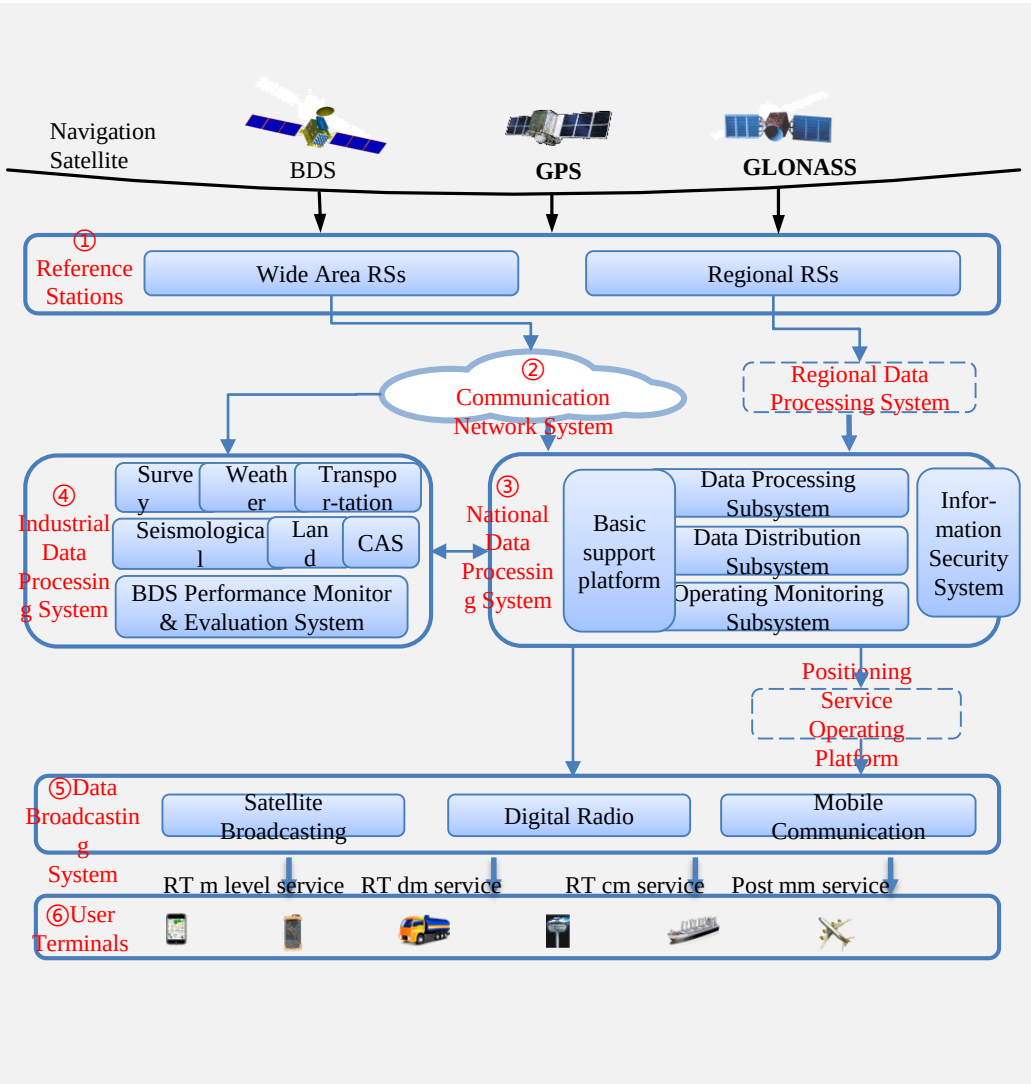
National Ground-Based Augmentation System – System Architecture





BDGBAS – System Components

- 150 national wide-area reference stations (RSs), 1200 regional RSs
- National BeiDou Data Integrated Processing System, Data Backup System, 6 kinds of Industrial Data Processing Systems
- 3 broadcasting paths: Mobile Communication, Satellite Broadcasting, Digital Radio
- 4 kinds of high-precision positioning services: wide-area real-time meter level and decimeter level, regional real-time centimeter level, post-processing millimeter level



Main Specifications of BDGBAS

Satellite System	BDS	BDS	BDS	BDS/GP/GLONASS	BDS/GPS
Augmentation Mode	Wide-area real-time single-frequency pseudo range mode	Wide-area real-time single-frequency carrier phase mode	Wide-area real-time dual-frequency carrier phase mode	Local-area real-time RTK	Post-processing millimeter mode
Horizontal Position Accuracy	Meter level (95%)	Meter level (95%)	Decimeter lever (95%)	Centimeter level (RMS)	Millimeter level (RMS)
Vertical Position Accuracy	Meter level (95%)	Meter level (95%)	Decimeter lever (95%)	Centimeter level (RMS)	Millimeter level (RMS)
Broadcasting Data	Data of Precise orbit, Clock bias, Ionosphere			Synthetic correction data	Post processing
Broadcasting Mode	Satellite ， Digital Radio, Mobile Communication			Mobile Communication	Internet

Main Services of BDGBAS

Satellite System	BDS	BDS	BDS	BDS/GP/GLONASS	BDS/GPS
User Number	Unlimited			10^6	Unlimited
Service Area	Depending on the coverage area of the chosen broadcasting mode				
Service Target	People，Vehicles，Objects			Applications of Centimeter level	Deformation monitoring
Application Terminal	Smart phone, wearable Devices, navigation instruments, tablet computers, and so on			Hand-held terminals, and so on	Static or fixed sensors, and so on

- Implement one system to realize 4 categories and 5 kinds of high-precision positioning services for the first time.

BDGBAS Application Model

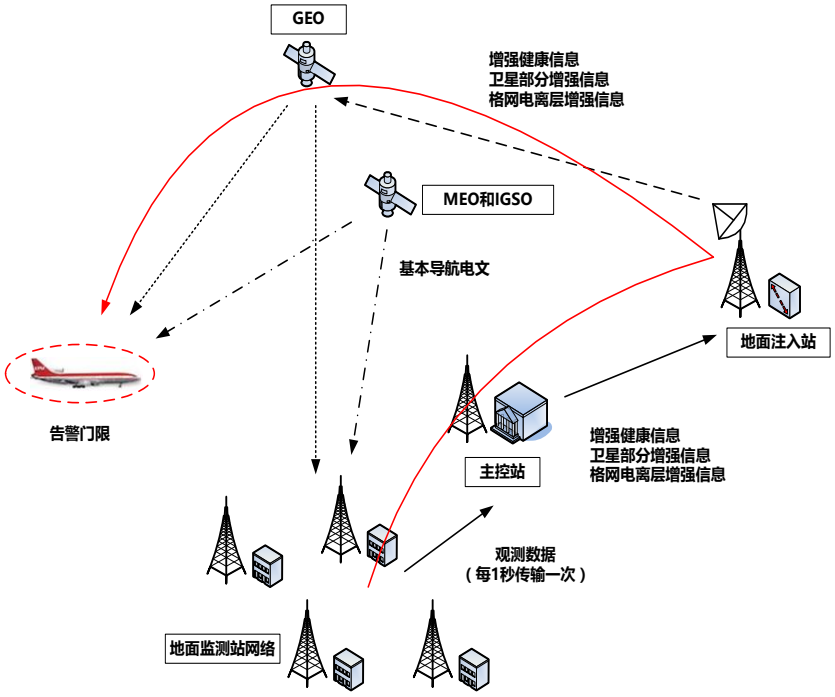
- Support the development of BeiDou high-precision chips, smartphones, navigators, smartphone + BeiDou mate/“Magic Box”, and other user terminals.
- Relative tests have been conducted and application demonstrations are verified.

System Construction

Steady Progress on Construction of BDS Augmentation Systems

Satellite-Based Augmentation System

- BDS will comply with the international civil aviation standards, carry out the design, validation and construction of BeiDou Satellite-Based Augmentation System (BDSBAS), and provide CAT-I services to civil aviation users in China and surrounding areas.
- At present, BDS is actively participating in the design and international coordination activities for the next-generation Double Frequency Multiple Constellation (DFMC) SBAS Standards.



BDSBAS - Design & Development Plan

★ Objectives

- ✓ Support single frequency and dual frequency multi-constellation augmentation
- ✓ Provide CAT-I service for China and surrounding areas

Typical operation	Accuracy horizontal 95%	Accuracy vertical 95%	Horizontal alert limit	Vertical alert limit	Integrity	Time-to-alert	Continuity	Availability
En-route (oceanic/continental, low density)	3.7 km	N/A	7.4 km	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route (continental)	3.7 km	N/A	3.7 km	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km	N/A	1.85 km	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{8}$/h	0.99 to 0.99999
NPA	220 m	N/A	556 m	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
APV-I	16.0 m	20 m	40 m	50 m	$1 - 2 \times 10^{-7}$ per approach	10 s	$1 - 8 \times 10^{-6}$ in any 15 s	0.99 to 0.99999
APV-II	16.0 m	8.0 m	40 m	20 m	$1 - 2 \times 10^{-7}$ per approach	6 s	$1 - 8 \times 10^{-6}$ in any 15 s	0.99 to 0.99999
CAT-I	16.0 m	6.0 m to 4.0 m	40 m	15.0 m to 10.0 m	1 – 2 × 10–7 per approach	6 s	1 – 8 × 10–6 in any 15 s	0.99 to 0.99999

BDSBAS - Design & Development Plan

- **System Components**
  - ✓ Constellation/Space Segment: 3 GEO Satellites (80°E, 110°E, 140°E).
  - ✓ Augmentation signals: BDS B1C and B2a, interoperable with international SBAS standards.
  - ✓ Augmentation messages: ephemeris correction, ionospheric delay correction, and corresponding UDRE and GIVE, compatible with international SBAS standards.
  - ✓ Monitoring Station Network: 30 stations in China, 20 stations in surrounding areas.
  - ✓ Master Control Station: processing dual frequency signals from BDS, GPS, GLONASS and GALILEO; generate augmentation messages.

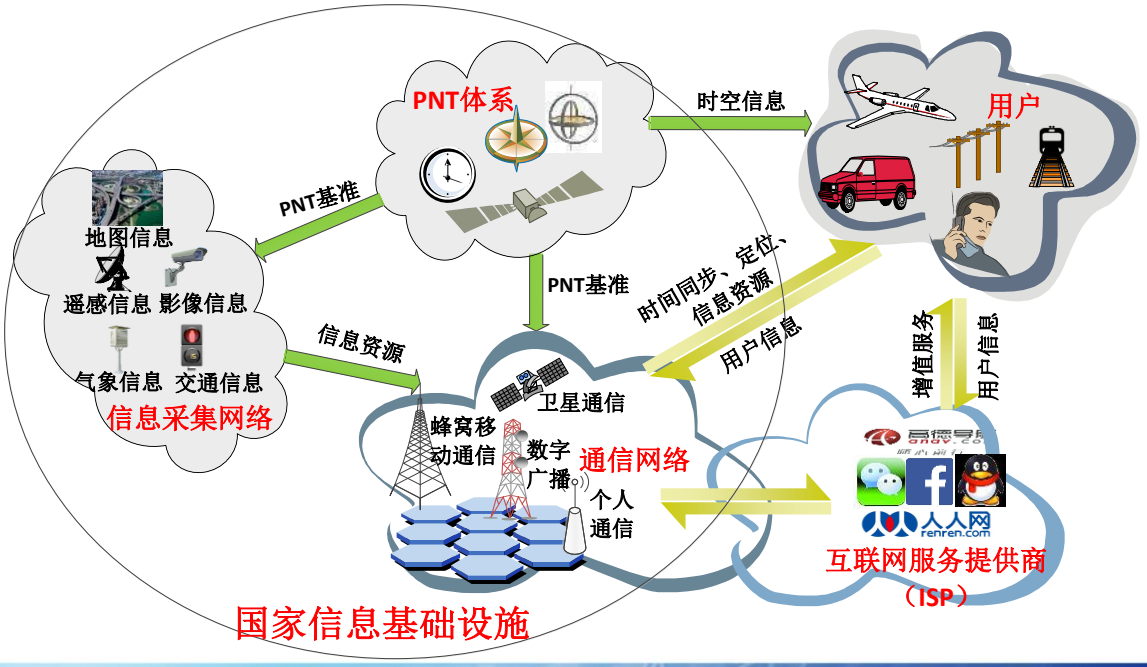
BDSBAS - Design & Development Plan

- **Development Plan**
  - ✓ 2014: Evaluation of BDS augmentation performance.
  - ✓ 2014-2015: Participate in dual frequency multi-constellation SBAS standard establishment through ICAO, IWG etc.
  - ✓ 2018: Launch the first BDSBAS GEO satellite.
  - ✓ 2020: Finish the launch of 3 GEOs. Start to provide dual frequency multi-constellation SBAS service for China and surrounding areas users.
  - ✓ 2025: Provide augmentation services for users in larger areas through international cooperation.

SYSTEM CONSTRUCTION

Beginning of National Integrated PNT System Construction

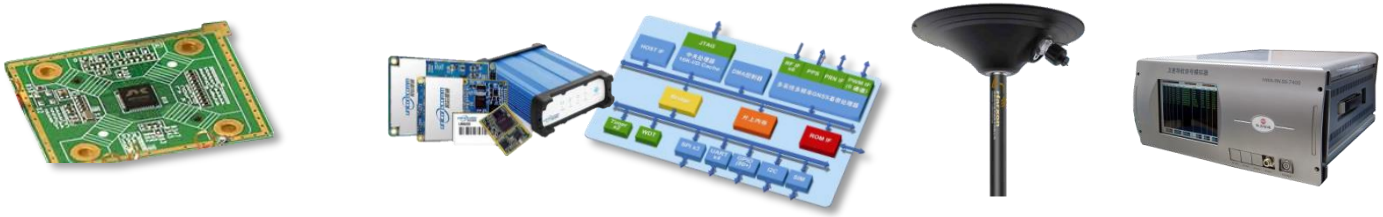
- Satellite navigation system has some blind areas in deep spaces, indoor spaces and underwater spaces. In order to compensate it and to meet the needs of economic and social development, the cornerstone of the BeiDou system is being reinforced.
- At the same time, national PNT system is being demonstrated, and some related technical research is being carried out.



Application Promotion

Upgrade of Fundamental Products

- In 2015, BDS fundamental products have been upgraded in terms of self-controlled intellectual properties, quality and quantity.
- BDS chips have entered a new era of 40-nanometer, and achieved a jumped upgrade from basic products to high-end industry.



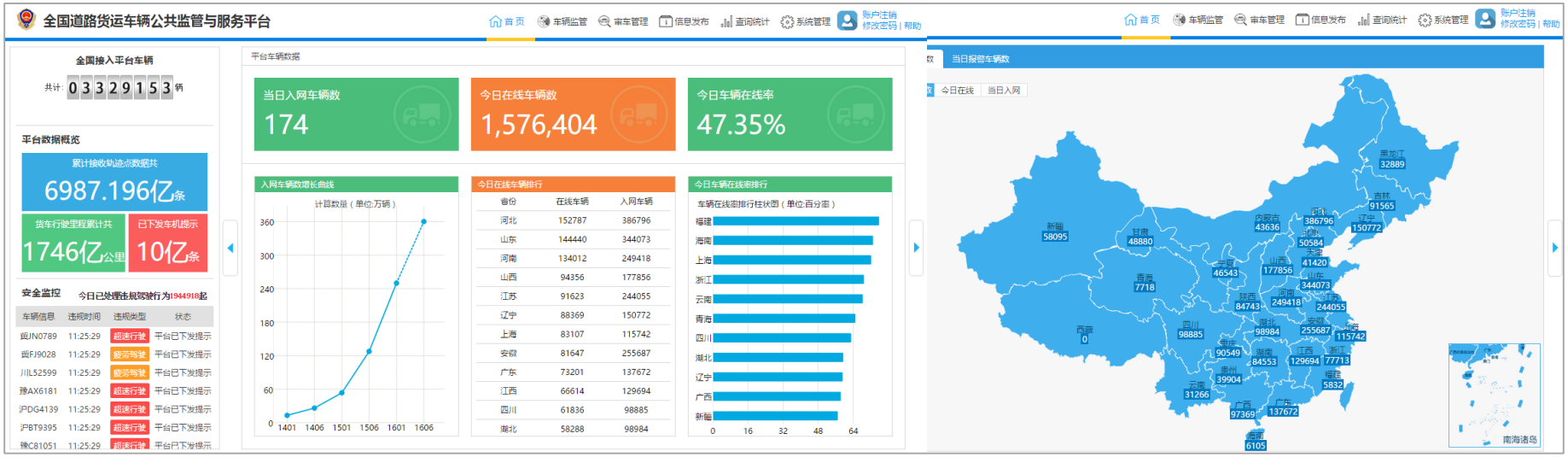
- BDS/GNSS navigation chip/module, surpass 24 million pieces
- high-precision surveying boards, approximately 120, 000 sets
- navigation antenna, 4 million pieces
- high-precision antenna, surpass 500,000 pieces
- satellite navigation IP core used in mobile communication, approximately 18 million

Application Promotion

Industrial/Regional Demonstration Applications

Demonstrations in the Transportation Industry

- A total of 3 million sets of BDS/GNSS compatible terminals have been installed in the coach, tourism charter, dangerous goods vehicles and other key fields.

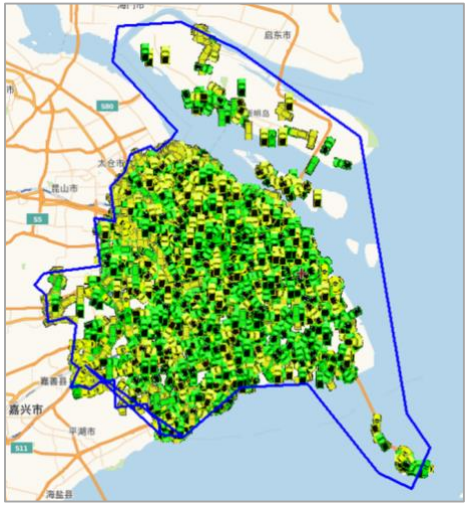


Application Promotion

Industrial/Regional Application Demonstrations

Demonstrations in the Yangtze River Delta Region

- Some BDS application demonstrations related to the Smart City, such as vehicle monitoring services, public location services and high accuracy positioning service etc., have been conducted, and 80,000 sets of BDS terminals have been deployed.



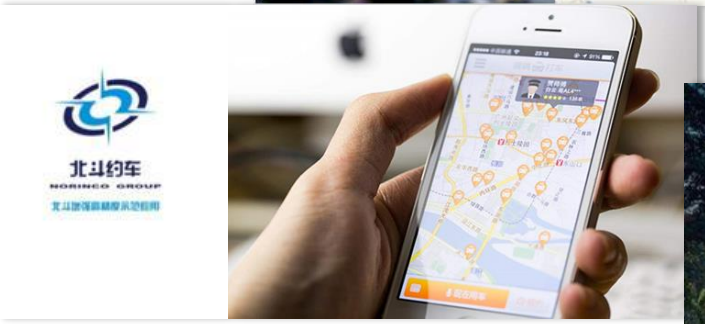
Application Promotion

Industrial/Regional Demonstration Applications

- 11 industrial demonstrations, such as maritime transportation, meteorology, fisheries, public safety, disaster relief and civil affairs , as well as 17 regional demonstration projects, including those in Pearl River Delta, Beijing, Shaanxi, Hunan, Guizhou, Hubei and Jiangsu, are being carried out .

Application Promotion

Mass Market Applications Flourished

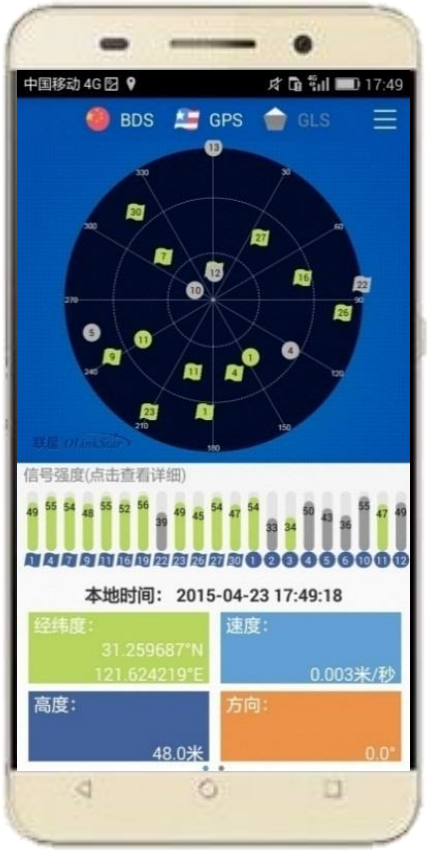


Application Promotion

Mass Market Applications Flourished

- With the development of some key technologies, such as chip miniaturization, low power, low cost, and RF baseband integration etc., as well as extensive integration of satellite navigation IP core and mobile communications, BeiDou will be fully applied to the mass market and serve the public.

BDS High-precision Smartphones



LX1101multi-function chip

- Receive BDS B1, GPS L1and GLONASS L1 data
- BDS and GPS single-mode positioning, BDS+GPS dual-mode joint positioning
- Integrated Bluetooth, WiFi, RF (Radio Frequency) and BB (baseband) frequency modulation
- Enable high-precision positioning, A-GNSS, anti-narrowband interference
- Low cost, low SWaP (Size, Weight and Power). the chip size is only 4.8mm×4.8mm
- Allow ease of use for smartphones, tablet computers, wearable devices, hand-held terminals, and on-board vehicle terminals
- Shipments in 2015 are over 18 million pieces

BeiDou “Magic Box”

- Allow BeiDou high-precision positioning service embedded in the existing smartphones.
- Receive BeiDou high-precision data through 3G/4G mobile communication channels and derive BeiDou high-precision positioning information.
- Communicate with Smartphone via Bluetooth.

MG20 by UniStrong

- A compact，high-precision GNSS data collection device.
- It integrates multi-GNSS high-precision card, 3.75G mobile communication module, WIFI, Bluetooth, etc.
- Coupled with an Android phone or a Windows tablet, it can work with a GNSS argumentation system to provide CM-level high-precision services.

A High-precision, GNSS Smart Phone by UniStrong

- Built-in GNSS positioning module, supporting BDS/GPS/ GLONASS systems (including BDS-only mode).
- Uses quad-core 1.2GHz snapdragon chip, with a Cortex-A53 architecture.
- Supports all mobile communication standards, including FDD-LTE/TDD-LTE/TD-SCDMA/WCDMA/ CDMA2000/ GSM.
- Rugged structure.
- Android 5.1 operating system.
- 5.3” ultra-sensitive screen.
- Supports RTCM-IN, can be connected using NTRIP to work with a GNSS argumentation system to provide high-precision services.

Application Promotion

Thrived Development of Industrialization

- The government attaches great importance to and promote the development of satellite navigation industry actively.
  - “National medium and long term development program on satellite navigation industry” and “National medium and long term development program on civil space fundamental facility” have been released, which makes the general dispositions in the long term development of satellite navigation industry at the national level.


中华人民共和国中央人民政府
The Central People's Government of the People's Republic of China
www.GOV.cn

国务院办公厅关于印发国家卫星导航产业中长期发展规划的通知

国办发〔2013〕97号

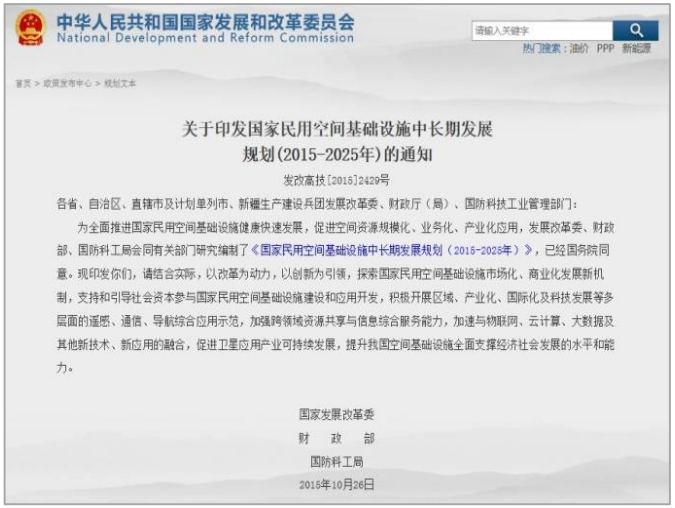
各省、自治区、直辖市人民政府，国务院各部委、各直属机构：

《国家卫星导航产业中长期发展规划》已经国务院同意，现印发给你们，请结合实际认真贯彻执行。

国务院办公厅

2013年9月26日

（此件公开发布）


中华人民共和国国家发展和改革委员会
National Development and Reform Commission

关于印发国家民用空间基础设施中长期发展规划（2015-2025年）的通知

发改高技〔2015〕2429号

各省、自治区、直辖市及计划单列市、新疆生产建设兵团发展改革委、财政厅（局）、国防科技工业管理部门：

为全面推进国家民用空间基础设施健康快速发展，促进空间资源规模化、业务化、产业化应用，发展改革委、财政部、国防科工局会同有关部门研究编制了《国家民用空间基础设施中长期发展规划（2015-2025年）》，已经国务院同意。现印发你们，请结合实际，以改革为动力，以创新为引领，探索国家民用空间基础设施市场化、商业化发展新机制，支持和引导社会资本参与国家民用空间基础设施建设和应用开发，积极开展区域、产业化、国际化及科技发展等多层面的遥感、通信、导航综合应用示范，加强跨领域资源共享与信息综合服务能力，加速与物联网、云计算、大数据及其他新技术、新应用的融合，促进卫星应用产业可持续发展，提升我国空间基础设施全面支撑经济社会发展的水平和能力。

国家发展改革委

财政部

国防科工局

2016年10月26日

The BDS White Paper

- A government white paper, entitled as "China's BeiDou Navigation Satellite System", was released on June 16, 2016.
- The white paper describes the Chinese government's policy, roadmap, major achievements, etc. on the development process of BeiDou Navigation Satellite System.
- The white paper contains five major parts:
  - Goals and Principles of Development
  - BDS Development
  - Reliable and Safe Satellite Navigation Services
  - BDS Application and Industrial Development
  - International Cooperation and Exchanges

Application Promotion

Thrived Development of Industrialization

- “BeiDou Navigation Satellite Standard System (version 1.0)” and 17 BeiDou standards have been released, which promote the construction of BeiDou navigation satellite standard system.

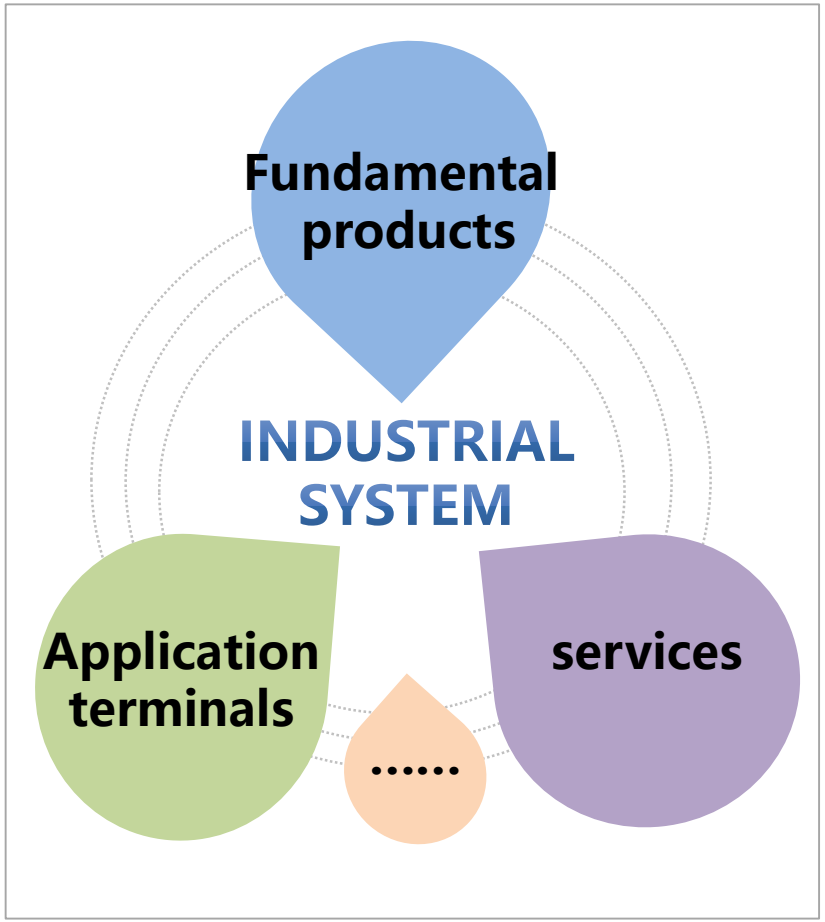
Application Promotion

Thrived Development of Industrialization

- “Legal Rules for BeiDou Navigation” have been listed in the legislation work plan of the state department in 2016, and it will be the first administrative law and regulation in the field of satellite navigation. It will protect reliable BDS services and improve the level of BDS management.

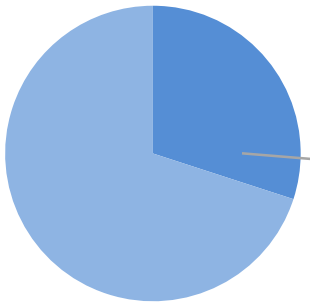
Application Promotion

Thrived Development of Industrialization



RMB 19 billion

In 2015
The output value of satellite navigation



BDS contribution counts

30%

International Cooperation

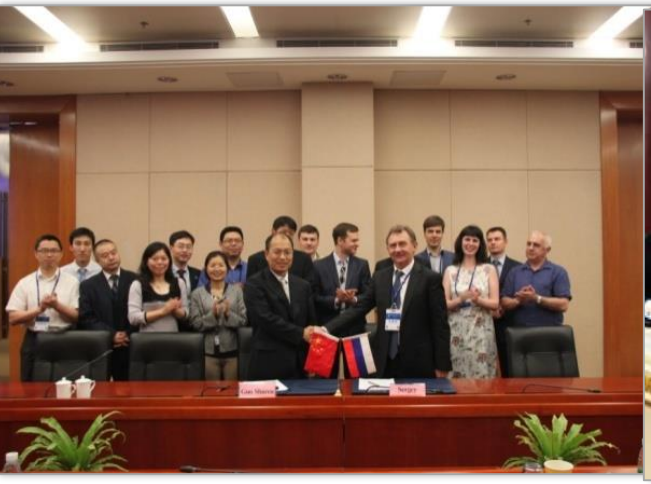
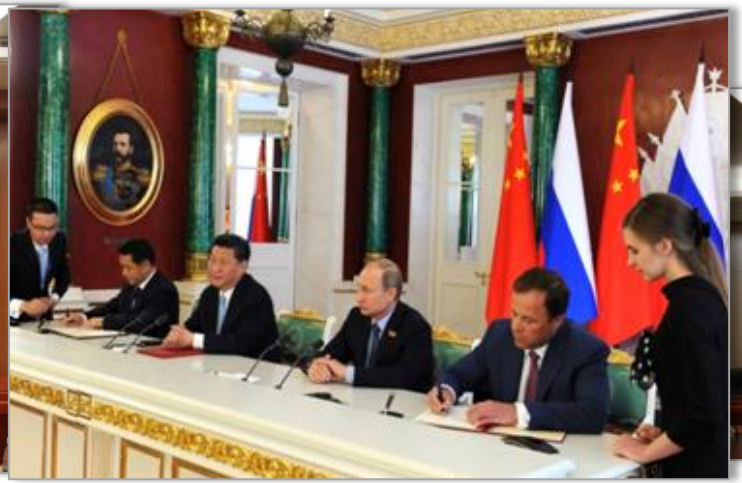
Bilateral Cooperation

- Coordinate with other navigation satellite system providers in the sector of compatibility and interoperability, and provide users with high quality services.

International Cooperation – China-U.S. Cooperation

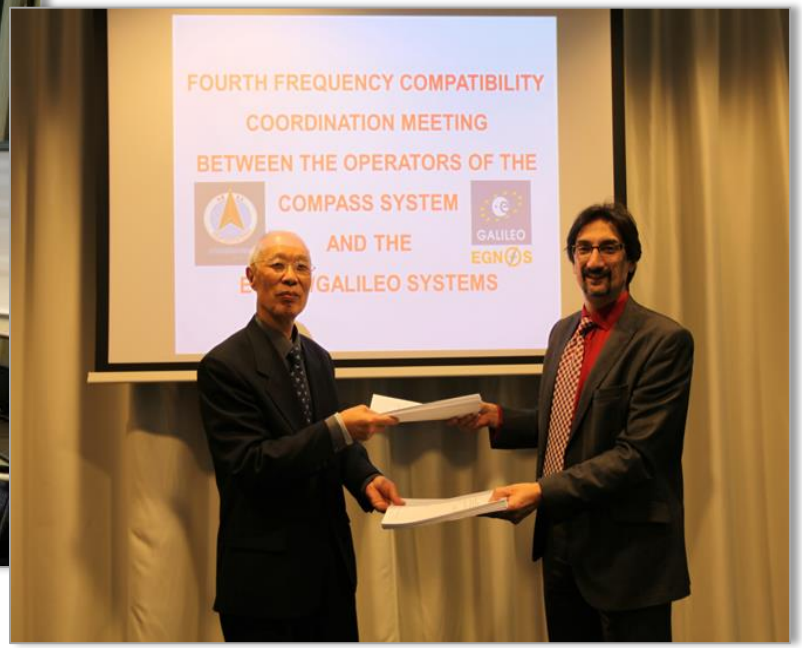
- The cooperation mechanism between BDS and GPS has been set up.
- Two bilateral meetings of China-U.S. civil GNSS cooperation were held, and the Joint Statement between these two systems was released.
- Cooperation has been carried out in the field of compatibility and interoperability, augmentation system and civil aviation application, civil service, monitoring and evaluation.

International Cooperation - China-Russia Cooperation


- The Chinese-Russian Committee on Important Projects of Strategic Cooperation in the field of Satellite Navigation has been founded within the China-Russia Prime Ministers' Regular Meeting Framework.
- The memorandum of understanding on satellite navigation cooperation has been signed.
- Working groups have been set up. Station building exploring has been finished.
- The Joint Statement on GLONASS/BeiDou systems Compatibility and Interoperability and Navigation Technology Application Cooperation has been released.
- The first seven cooperation projects have been brought out.

International Cooperation – China-EU Cooperation



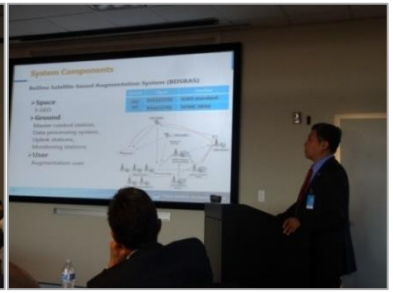
- The frequency coordination towards navigation frequency channels between BeiDou and Galileo has been completed,
- The cooperation mechanism between these systems are under discussion, especially in the field of compatibility and interoperability.

International Cooperation

Participate in International Satellite Navigation Organization Activities

- Participated in the meetings of the ICG, ITU and other GNSS activities organized by the United Nations, and hosted the 30th SBAS IWG meeting.
- Attended the United States Positioning, Navigation and Timing (PNT) Advisory Board Meeting and ICAO Advanced Meeting for the first time in 2015, to carry out technical exchanges and cooperation.



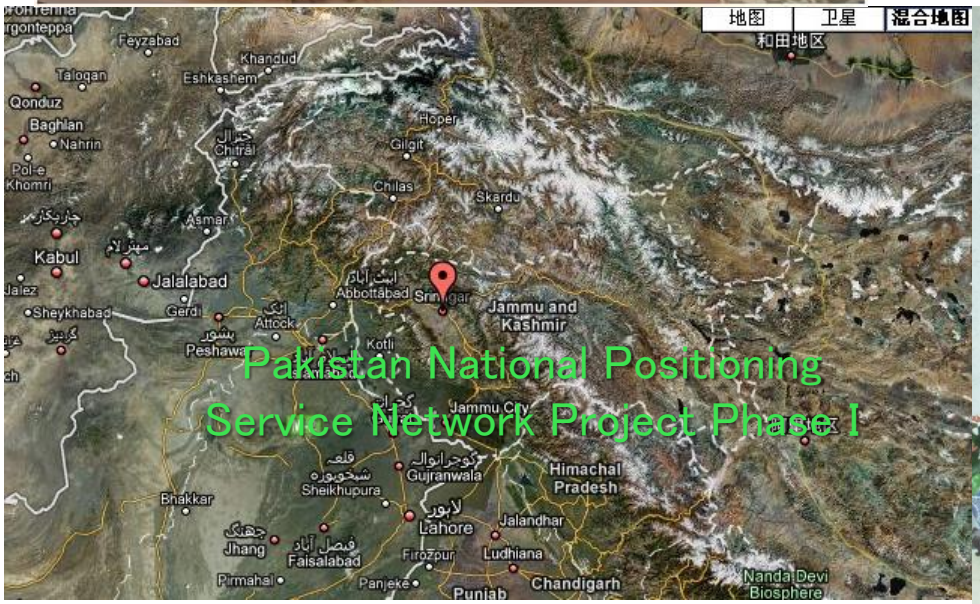



International Cooperation

Participate in International Satellite Navigation Organization Activities

- Encourage academic exchanges
  - Host the China Satellite Navigation Conference, the largest GNSS conference in the world
  - Attend other international academic conferences in the field of satellite navigation
  - Carry out the education and training on global satellite navigation, especially in the developing countries.

Pakistan National Positioning Service Network Project (Phase I)



International Cooperation

Integration with the International Standardization System

- Propel the recognition of the BeiDou System in international organizations such as IMO, ICAO and 3GPP.
- BDS has obtained the legal status in international maritime applications and become the global satellite navigation system supported by the international mobile telecommunications.
- The RINEX 3.03 standard which supports BeiDou was published in Jan 2016.

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3GPP™ A GLOBAL INITIATIVE

01

Development Plan

02

System Construction

Application Promotion

International Cooperation

Latest Progress

03

Near-term Plan

System Construction

1. Keep improving the continuous stability and service accuracy of the BeiDou System, and ensuring its regional service performance stable and enhancing.

2. The BDS performance in Asia-Pacific area will be continuously improved. In the future, the status of the new-generation satellites will be solidified which would promote the construction of the global constellation. BDS will provide services for Silk Road Economic Belt and 21st-Century Maritime Silk Road countries by 2018. And it will possess the global services capability and construct the high-class global navigation system by 2020.

System Construction

3

Complete the integration and the test of BeiDou Ground-Based Augmentation System by mid-2016, with meter/decimeter-level positioning accuracy available to major regions nationwide, centimeter level to densified regions, and millimeter level correction data for post-processing services. Complete the construction of dense reference stations for the nationwide frame network by 2018. Start launching GEO satellites of BDSBAS in 2018. Finish the construction of BDSBAS services covering China and surrounding regions in 2020.

4

Promote and complete the construction of the national comprehensive PNT system with a united benchmark, no-gap coverage, security and effectiveness by 2030. Remarkably advance the national time and space services, meet the requirements derived from national economic and security sectors, and provide high-quality services to global users.

Application Promotion

1. Carry out all-round R&D and industrialization of new generation BDS/GNSS fundamental products, improve the core strength (e.g. service performance, power consumption, physical dimensions, cost) so as to promote the mass market applications of hundred-million units.

2. Bring GNSS in the integration procedure between industrialization and IT applications, integrate GNSS with the national policies (the Silk Road Economic Belt and 21st-Century Maritime Silk Road, Beijing-Tianjin-Hebei Integration, Yangtze River Economic Belt), push forward applications.

3. Accelerate the legislation process of “Legal Rules of BeiDou Navigation”, bring BeiDou into the national information security system, establish a legal environment for BeiDou construction, circulation and application promotion.

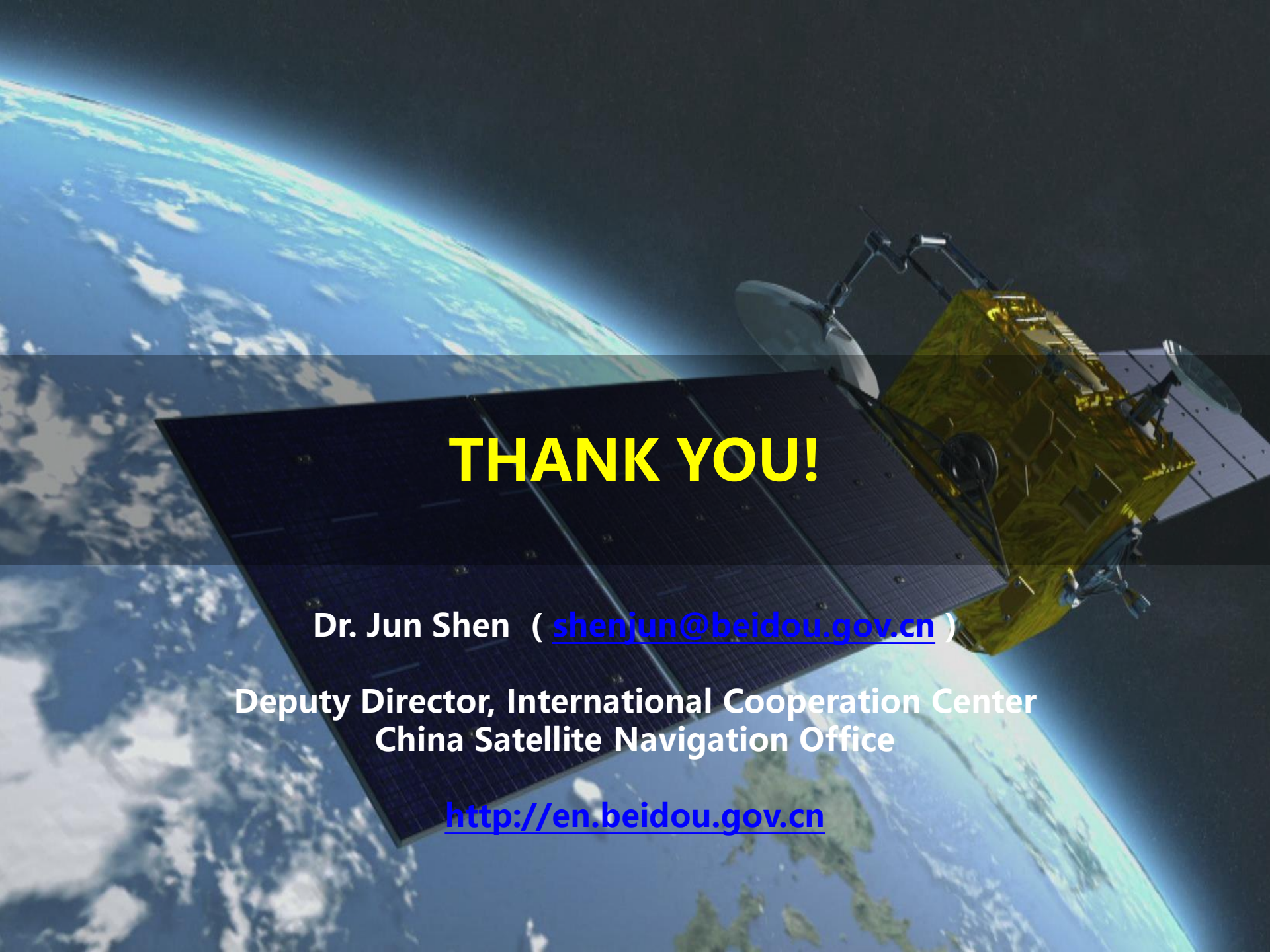
4. Construct ecologic system for BeiDou applications and services; promote the innovation of BeiDou applications according to “Four Combination” with the network, the data, the terminal and the capital.

International Cooperation

1. Continue to promote cooperation and exchanges between BeiDou and other GNSS providers, enhance the cooperation in compatibility and interoperability, monitoring and evaluation, SBAS and aviation applications, etc.
2. Continue to carry out international coordination in international organizations, such as ICG, ITU, ICAO, IMO, promote the BDS internationalization, and to undertake the international responsibility of BDS.
3. Use the Silk Road Economic Belt and 21st-Century Maritime Silk Road as a fulcrum, promote the BDS internationalization process, and serve the areas along it.

Conclusions

- Perception is the foundation of intelligence, and the intelligent demand leads the development of perception.
- Time and space information are the basic needs that people born with and lead our perception all the time and make our life more intelligent.
- Satellite navigation system enables a revolutionary change of the perception of time and space information, and accelerates the arrival of the intelligent era.
- BDS will play a major role in terms of promoting the development of the intelligent time.
- BeiDou appreciates your attention and support.



THANK YOU!

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