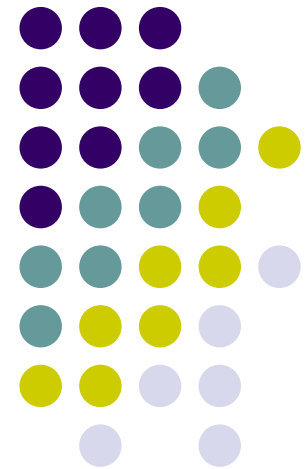


# **GNSS Status and Developments in China**

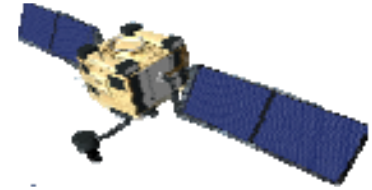
**Chuang Shi  
Jiming Guo**

**Wuhan University**



# Contents

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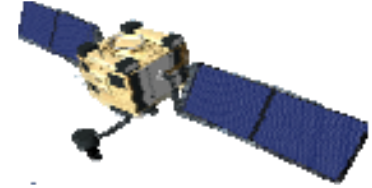


- **Overview of GNSS**
- **The market investigations of Satellite Navigation in China**
- **Current status GNSS System in China**
- **Future Projects**



# GPS Modernization Program

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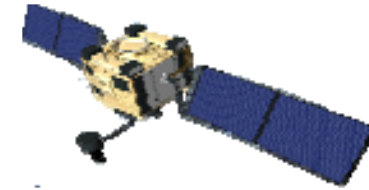


- **Military**
  - **Protection** of service for US/Allied forces
    - Add new signals and increased signal power to improve Navwar capability
    - Modify select platforms to detect and locate GPS jamming
    - Develop and field improved anti-jam and security technologies
  - **Prevention** of adversary exploitation
    - Spectrally separate new military signals from civil signals
    - Modify select platforms to accomplish mission
- **Civil**
  - **Preservation** of civil use while providing enhancements
    - Add new signals to improve accuracy and signal redundancy

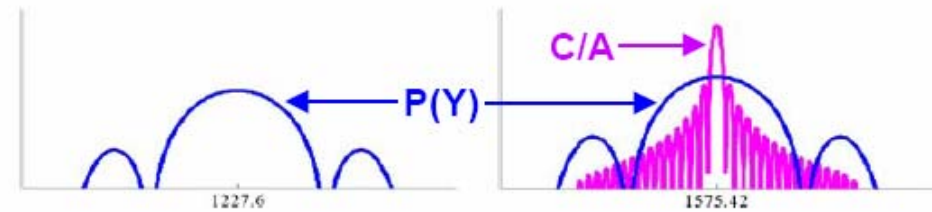
**The Termination of Selective Availability is the first step in the GPS Modernization Process**



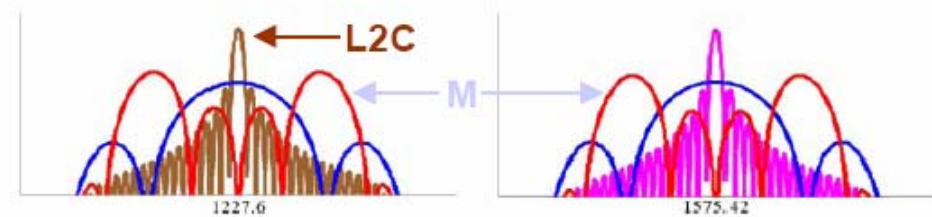
# Modernized GPS Signal Spectra



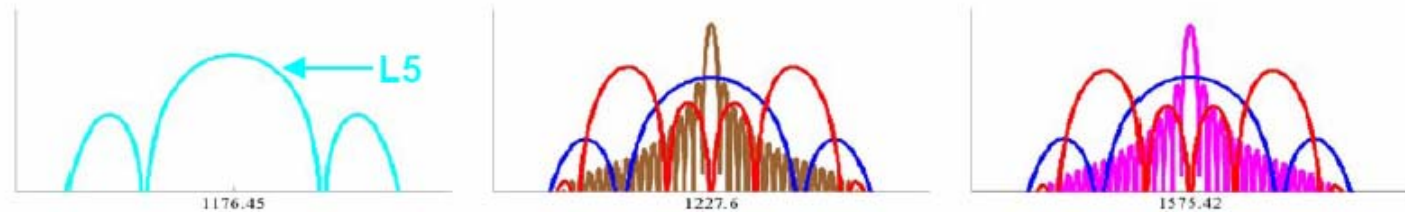
Block II/IIA/IIR  
Dual Frequency w/  
Semi-codeless P(Y)



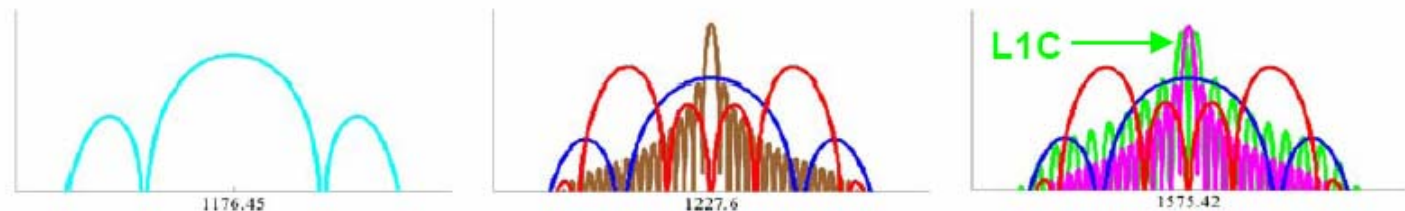
(Block IIR-M)  
Dual Frequency  
L1 C/A&L2C



Block IIF  
Three Frequency  
L1 C/A, L2C, & L5



Block III  
L1C, L2C, L5,  
& L1 C/A Code



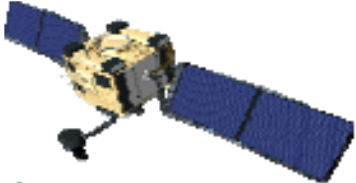
**L5**  
**ARNS/RNSS Band**

**L2**  
**RNSS Band**

**L1**  
**ARNS/RNSS Band**



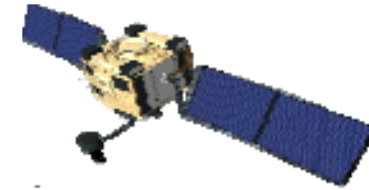
# Signals in Different GPS Satellite



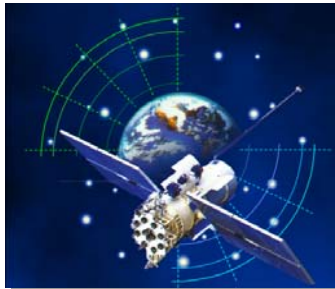
Signal\SV	IIR	IIR-M	IIF
L1 C/A	✓	✓	✓
L1 P/Y	✓	✓	✓
L1 M		✓	✓
L2 Civil		✓	✓
L2 P/Y	✓	✓	✓
L2 M		✓	✓
L5 Civil			✓



# GLONASS Satellite Modernization



## GLONASS 1982-2007



Developer NPO PM  
 Producer PO "Polyot"  
 Total launched 79 SV  
 Ordered 3 SV  
 In orbit 10 SV  
 Clock  $3-5 \cdot 10^{-13}$   
 Life-time 4.5 yrs

## GLONASS-M 2003-2013



Developer NPO PM  
 Flight Test phase  
 Ordered 3 SV  
 In orbit 1 SV  
 To be ordered 9  
 Clock  $1 \cdot 10^{-13}$   
 Life-time 7 years  
 2<sup>nd</sup> civil signal

## GLONASS-K 2007-2022



Developer NPO PM  
 D&D phase  
 To be ordered up to 27 SV  
 Life-time more 10 ys  
 3<sup>rd</sup> civil signal

## GLONASS-KM 2015-...



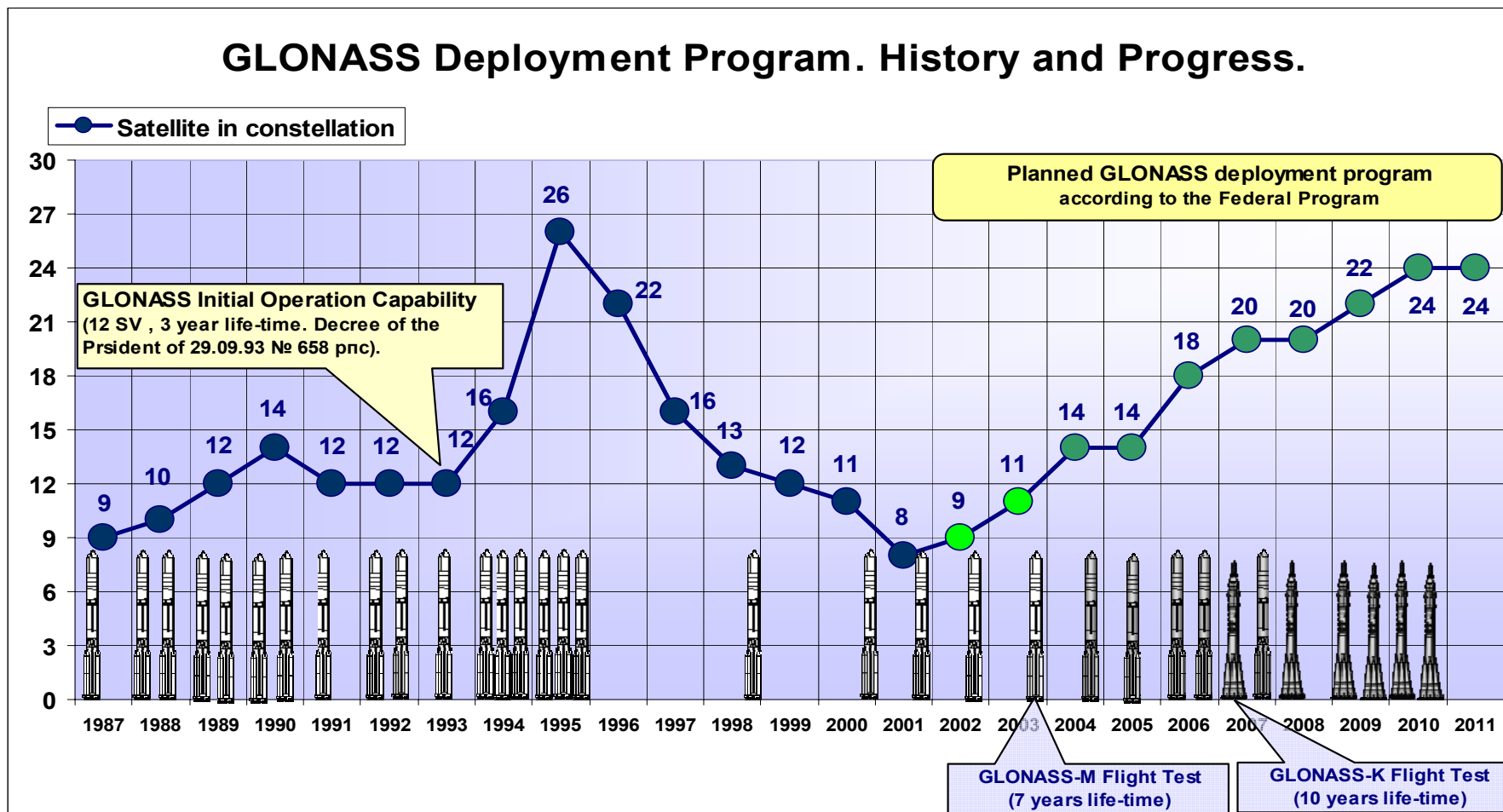
Requirement definition  
 since 2002 г.

Ground control segment modernization  
 Navigation (OD\$TS) system modernization  
 Integrity monitoring segment implementation  
 System certification for safety of life applications

Nuclear tests agreements monitoring  
 Search and Rescue service implementation  
 Supplementary functions (TBD)



# GLONASS Launch Program

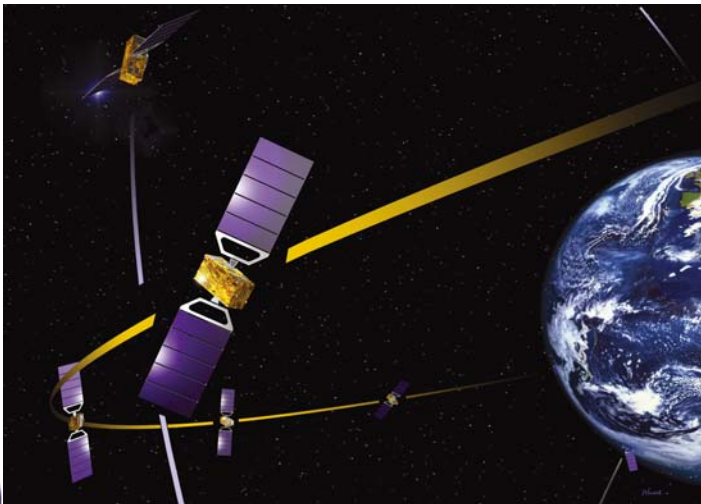
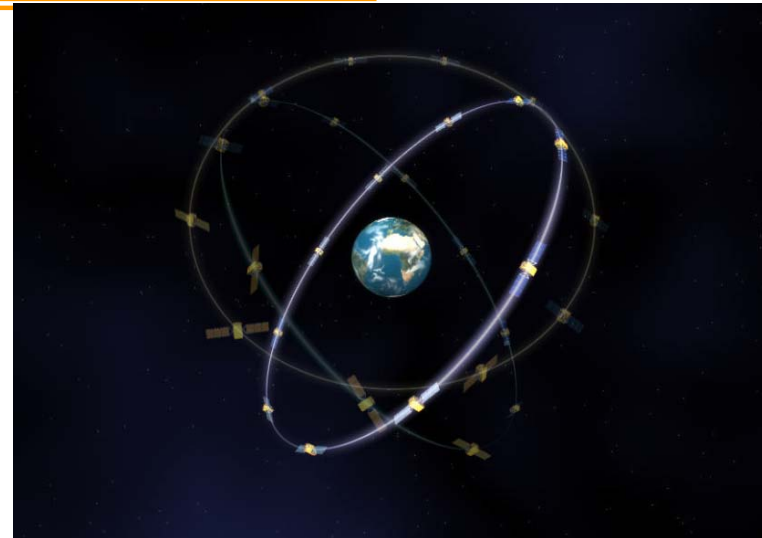
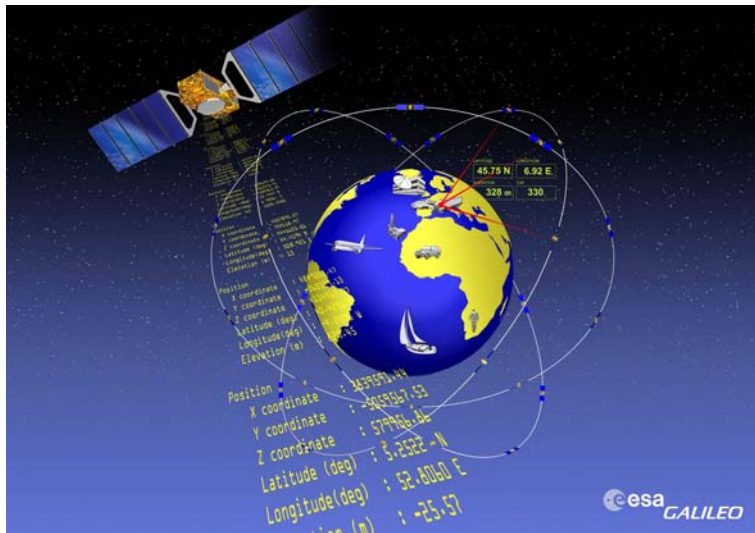


由于克服了卫星的寿命短的难题，可在2010年以前实现24颗星座的部署



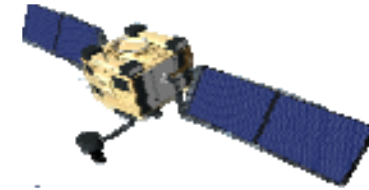







# Galileo Navigation Satellite System





# Galileo Service

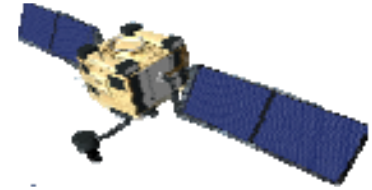


Navigation	Open Access	Free to air; Mass market; Simple positioning and timing	
	Commercial	Encrypted; High accuracy; Guaranteed service	
	Safety of Life	Open Service + Integrity and Authentication of signal	
	Public Regulated	Encrypted; Integrity; Continuous availability	
SAR	Search and Rescue	Near real-time; Precise; Return link feasible	



# GNSS Application Market analysis in China

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- **Railway:** about 11,000 train
- **Fishery:** about 200,000 ship
- **Shipping:** about 185,000 ship
- **Highway:** about 6,000,000 freight vehicles, over 2,000,000 passenger car
- **Data Service:** 100,000 monitoring station, such as environment, weather, atmosphere, forest, river, ect.

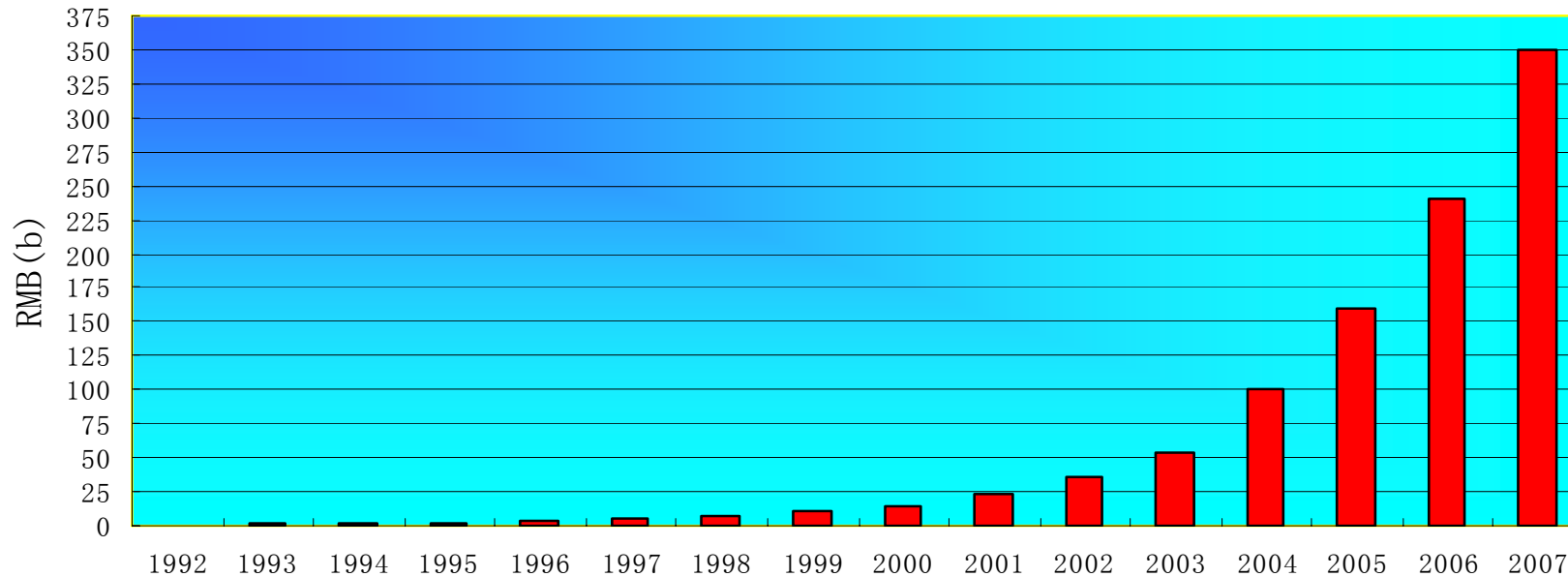
*(Ruxin Zhou, 2005)*



# Course of navigation industry in China



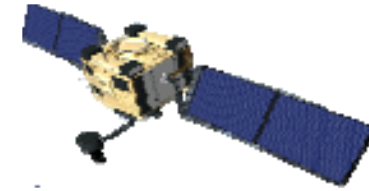
- The market was less than 1b RMB in 1992 to 100b RMB in 2004



- The app. fields are the most interested by the industry:
  - Vehicle tracking and navigation
  - Surveying and Mapping/GIS
  - DGPS network system integration
  - The terminal information equipment



# Applications of Real-time GNSS



## Surveying and Mapping

Vehicle tracking

and Precision Agriculture

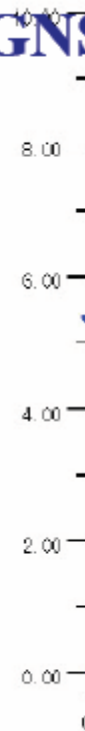
Harbor operation and

GNSS Meteorology

Space weather Research

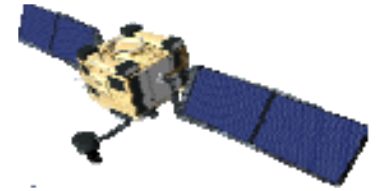
And so on ...

precipitable water and Rain Fall (mm)





# IGS core station from 1991



# GPS OEM board, Navigation rover and single frequency receiver



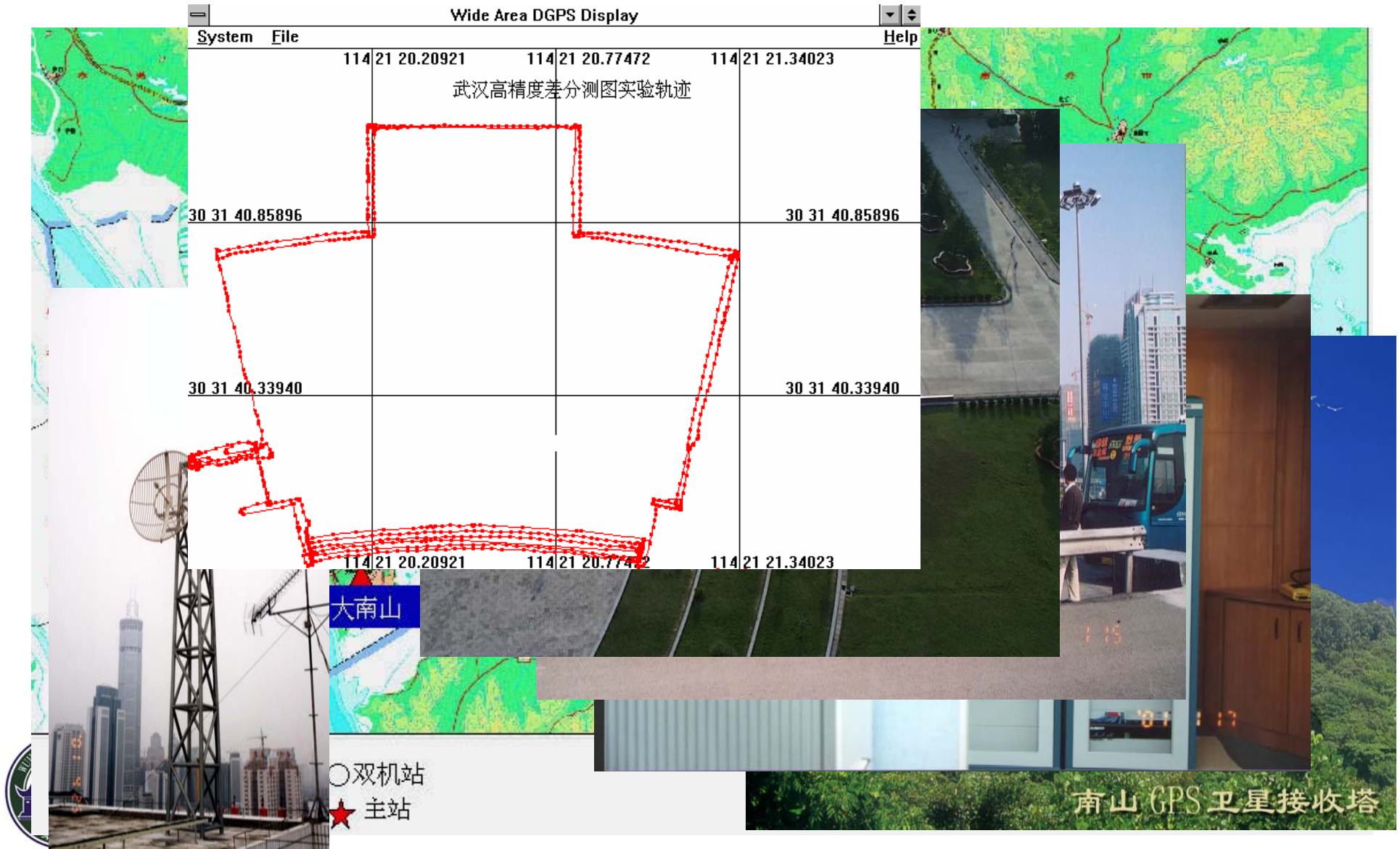
12/18/2006



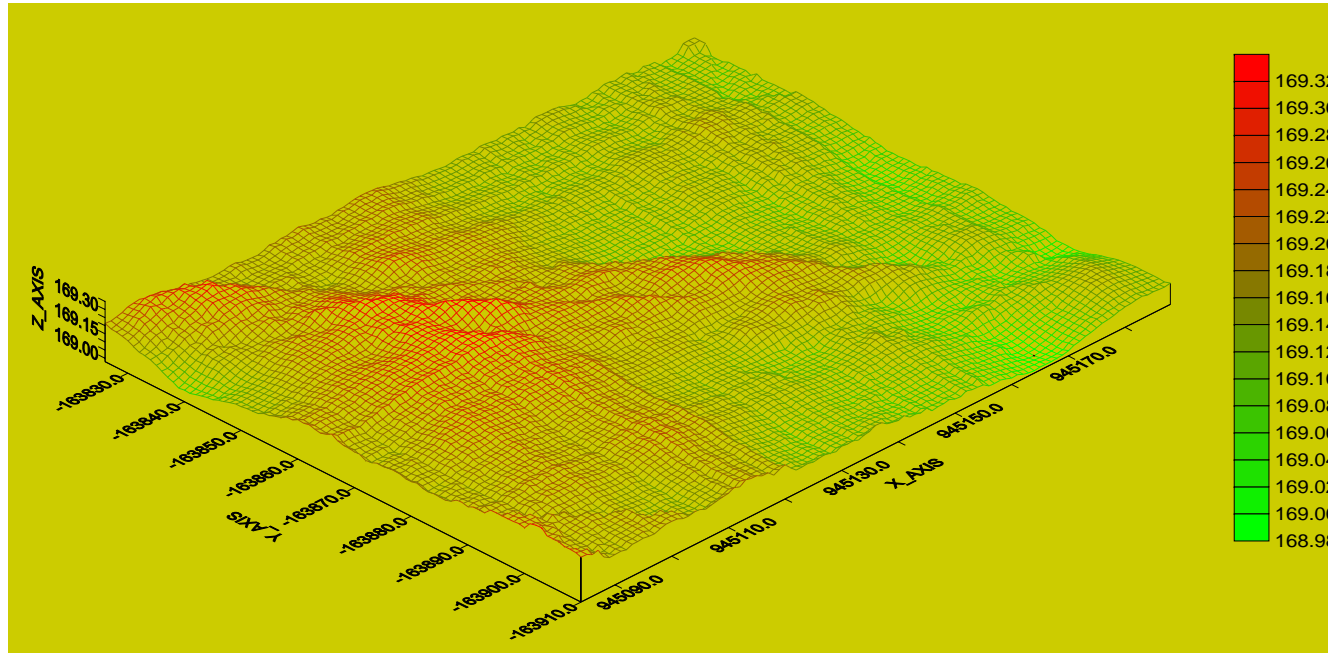
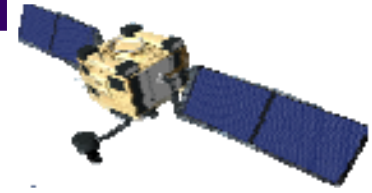
# Dam Deformation Monitoring System



# Continuous Operational Satellite Positioning System with PPP and Network RTK technique



# Machinery vehicle monitor and control



远端  
GPS  
基站



控中心

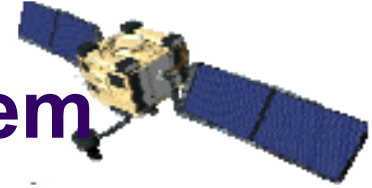




# Current status of China GNSS System

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- **Infrastructure**

- **GPS permanent stations**

- **CORS**

- **China Satellite Navigation System**

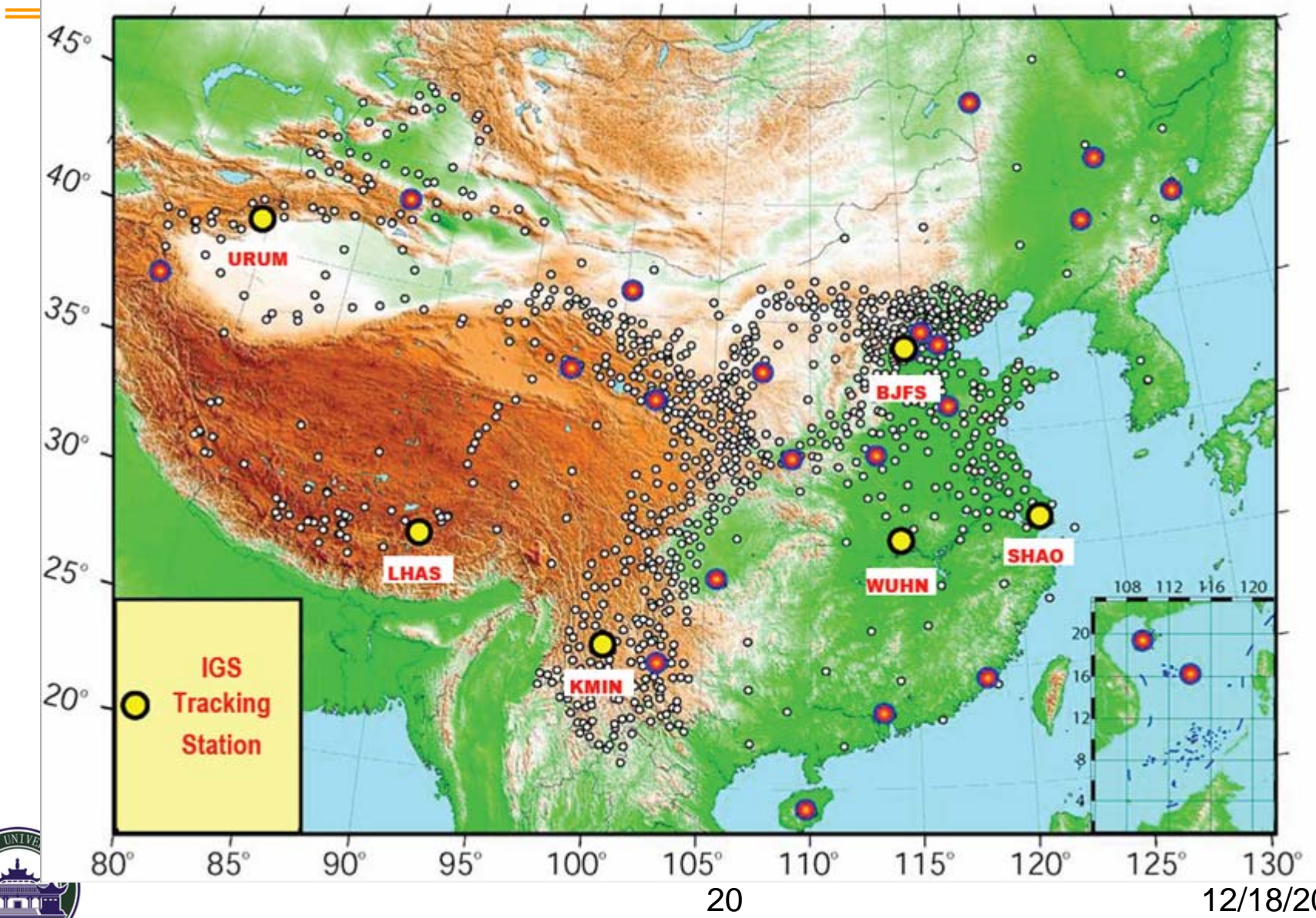


# 2000' National GPS Network (2609 stations)





# IGS Tracking Stations in China





# CORS in China

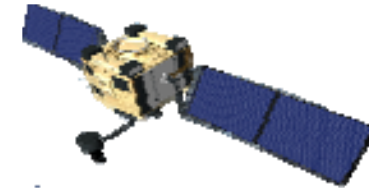
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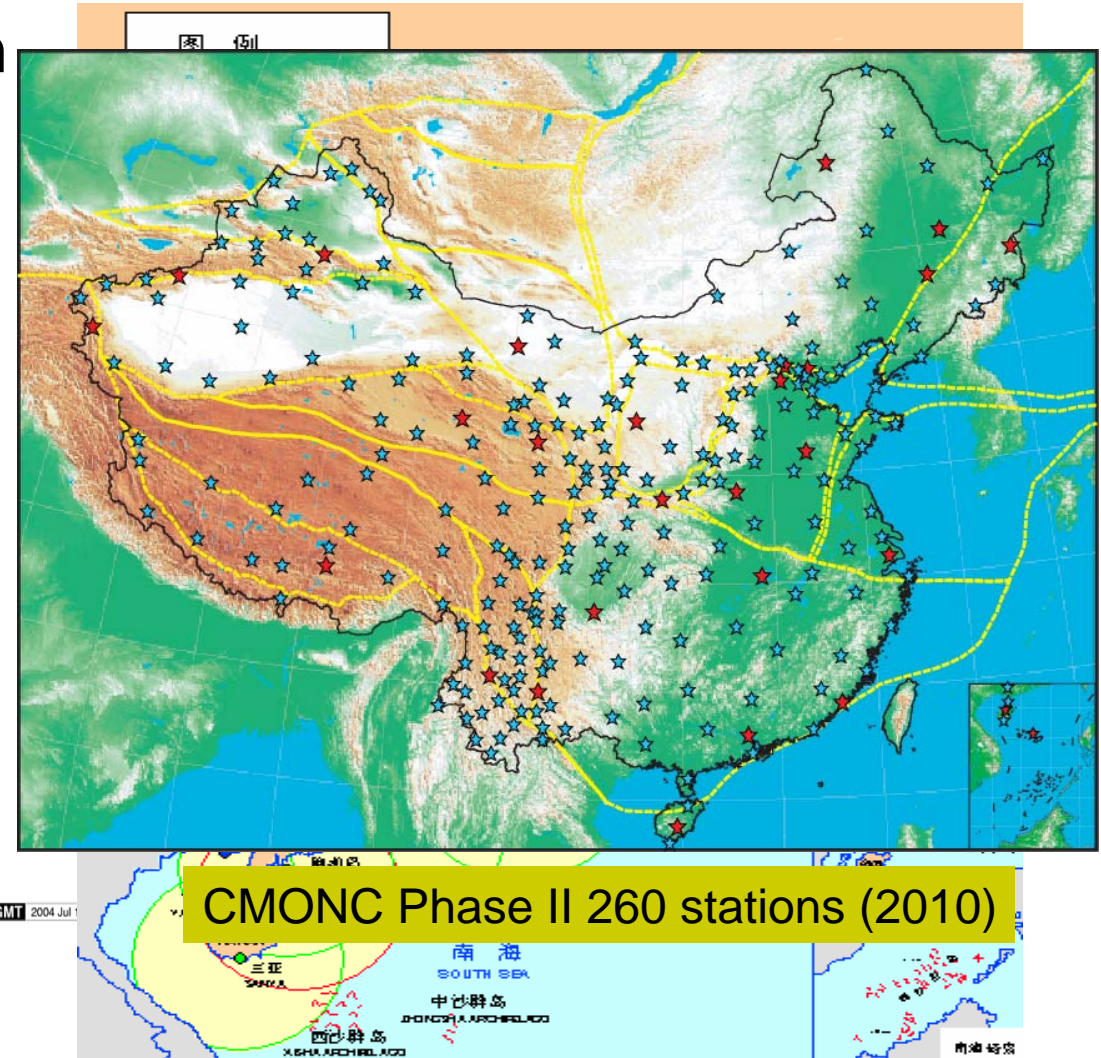
- **Chinese CORS Plan**
  - More than 100 permanent reference stations up to now
  - More than 1000 permanent reference stations to be established
- **Professional CORS Project**
  - Crustal Movement Observation Network of China (CMONOC)
  - Geodetic reference stations
  - Ionosphere monitoring stations
  - Transportation Navigation Stations: RBN-DGPS
- **Regional CORS and urban CORS**
  - Network RTK system
  - More than 5 cities, more than 50 stations (total)



# National Area CORS

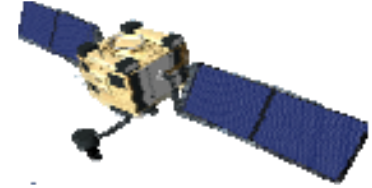


- There are 8 ref. Station for IGS in China
- CRBN-DGPS China Radio Beacon Navigation DGPS: 21 Ref.Stations
- CMONC—Crustal movement observation network of China:
  - 25 Re. Stations in phase I
  - 260 Station in phase II, 2006-2010



## FP6: Galileo Geodetic Service Provider Prototype (GGSP)

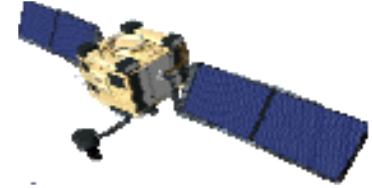
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- Technical Research and Data Analysis Centre for Galileo System in China
  - Positioning And Navigation Data Analysis (PANDA)
  - Multi-technical SINEX Data combination
- Study for the connection of the GTRF with the local reference frames in China, develop exemplary relevant optimisation methods to provide services for Chinese Galileo users.
- Contribute to the 'External Regional Integrity Systems (ERIS)' for the China region.
- Wuhan GSTB-V2 monitoring stations
- Promote the application of Galileo system in China.



# *PANDA software Introduction*



## ✓ Motivation

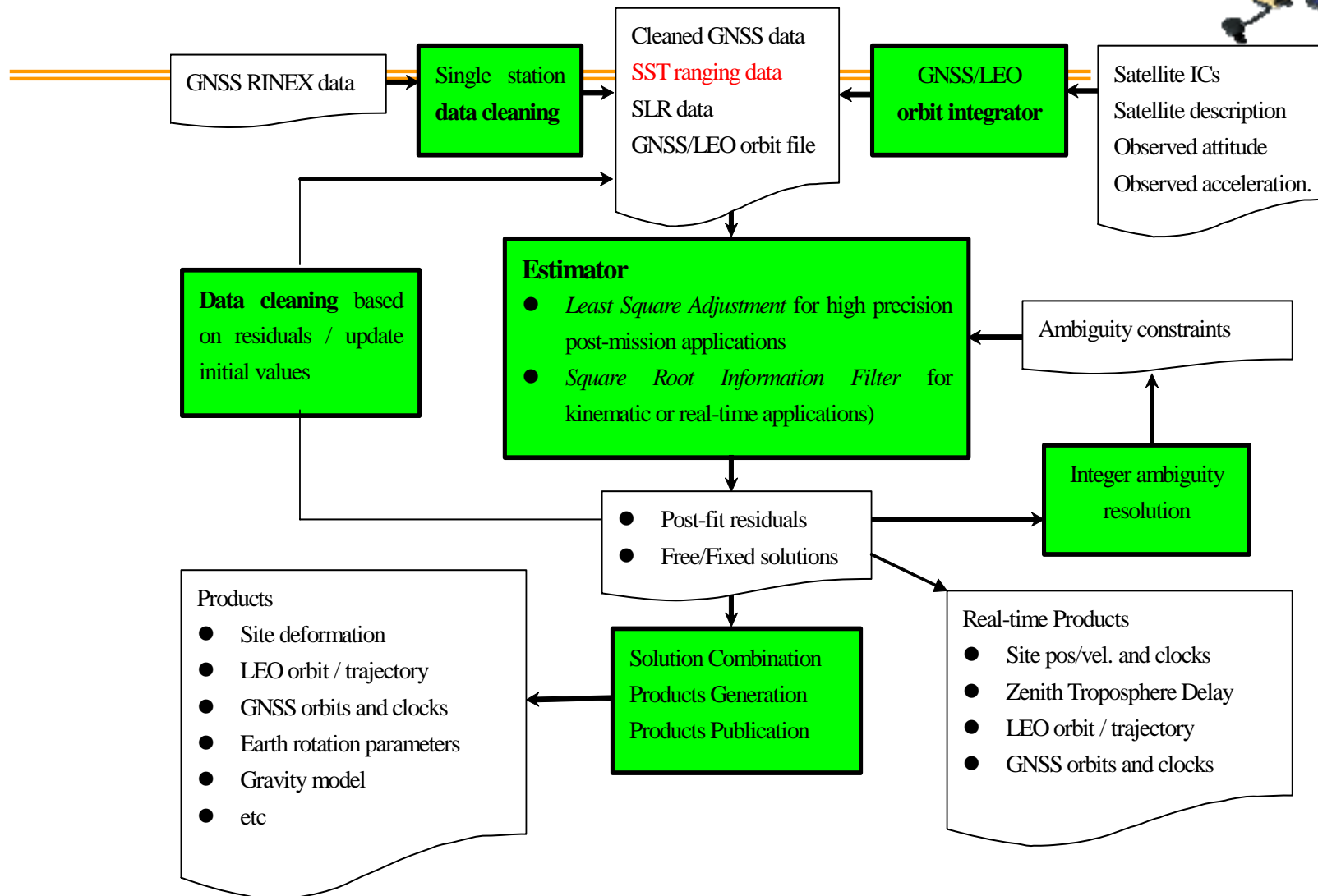
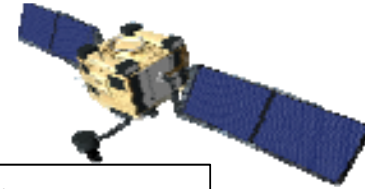
- ✓ a powerful platform for the scientific study
- ✓ required by a number related projects in China

## ✓ Status

- ✓ GPS SLR data
- ✓ Integrated estimation of GPS+LEO orbits, static and kinematic stations
- ✓ Testing IGS like routine data processing
- ✓ Testing real-time IGS
- ✓ Implementing GLONASS and GALILEO

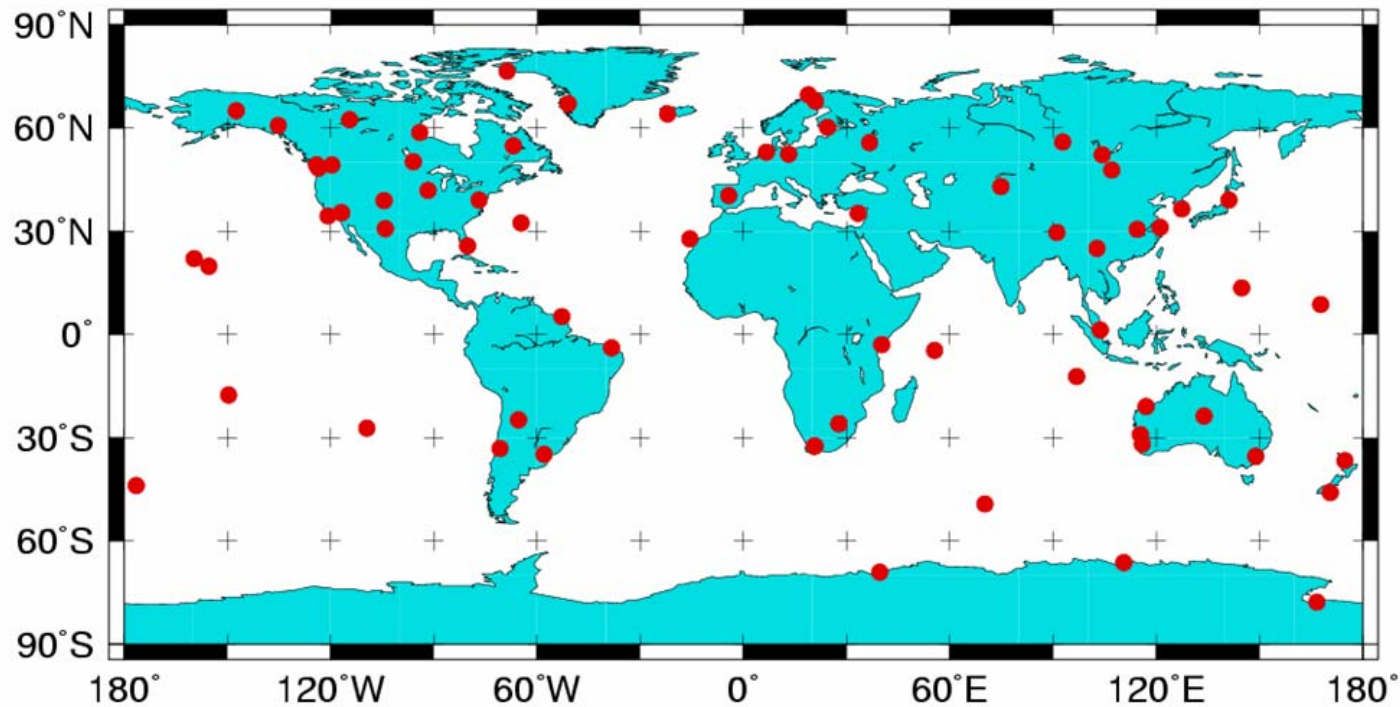


# Software Diagram





# Test: Network and Data

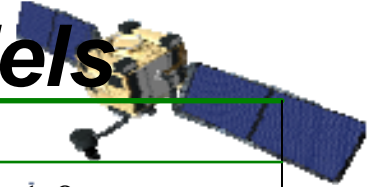


- 68 well-distributed IGS stations
- CHAMP and GRACE onboard receiver are also included for LEO orbit determination test.





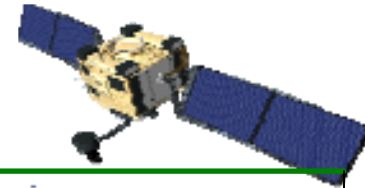
# Test: Observation Models



Parameters	Model	Constraint
Observation	LC and PC	L1 0.02cycle, P1 1.0m
Sampling rate	60 seconds	
Cutoff elevation	10 degree	
Weight	Elevation dependent	elev > 30°, 1; else 2*sin(elev)
Phase center pattern	Relative PCV for receivers	
Phase wind-up	Yes	
Tropospheric delay	Saastamoinen model + process	20cm + 2cm/sqrt(hour)
Ionospheric delay	Eliminated by using LC and PC	
Satellite clock	Broadcast + Process / ALGO fixed	1000m + 10m/sqrt(hour)
Receiver clock	Range estimating + White noise	300m
Station displacement	Solid earth, pole tide, ocean loading	
Station coordinate	Constraint to IGB00	Accordingly
Ambiguity	Estimated or fixed	
Relativistic effects	Yes	
ERP	Solve for x-pole y-pole and rates and LOD	3mars, 0.3mars/day 3ms/day



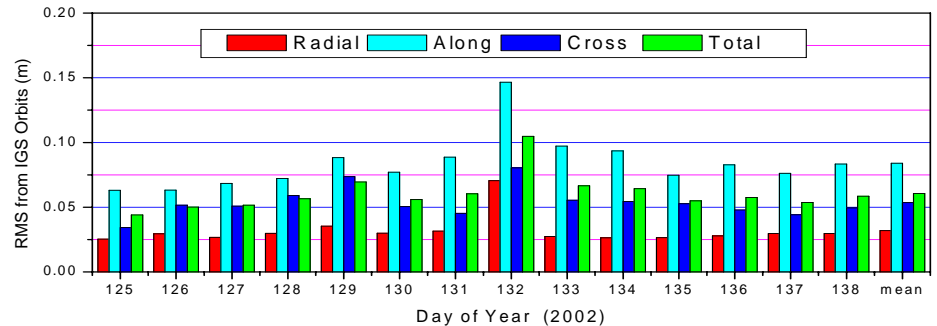
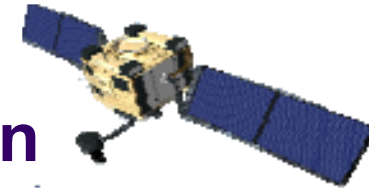
# Test: Dynamical Models



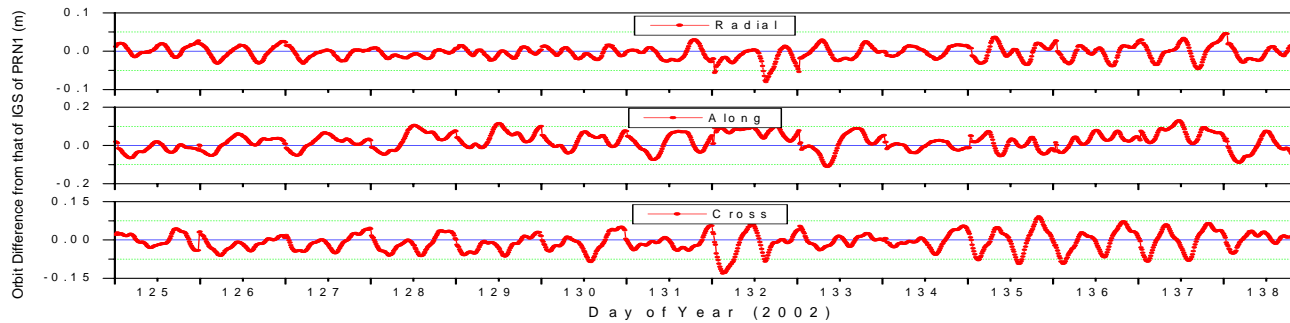
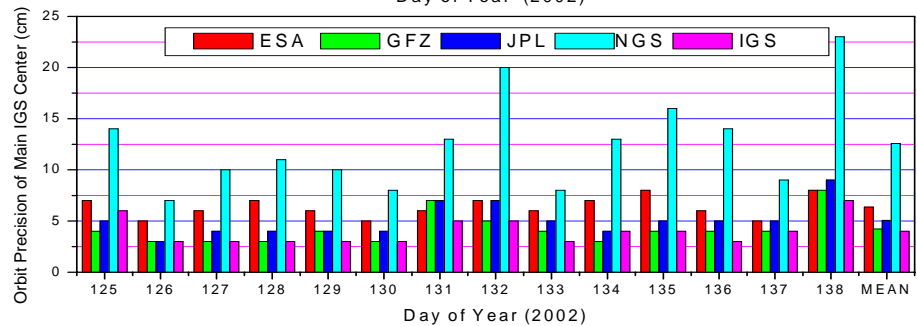
Parameter	GPS	LEO without ACC data	LEO with ACC data
Gravity	EIGEN GRACE02S 8x8	EIGEN GRACE02S 120x120	
Point mass	Earth, Sun and Moon	Earth, Sun, Moon and Planets	
Tides	Solid Earth tides, Pole tides	Solid Earth, Pole and Ocean 30 x 30	
Relativistic effects	Yes	Yes	
Solar radiation	Bern model with 9 model parameters	Integrated over all areas without estimated parameter.	No
Atmospheric drag	No	DTM94, one drag parameter every 4 hours	No
Empirical model	No	Bias and periodical in radial, along-track and cross track are	No
Acceleration	No	No estimated per revolution.	Yes, with one bias and one rate parameters for each component



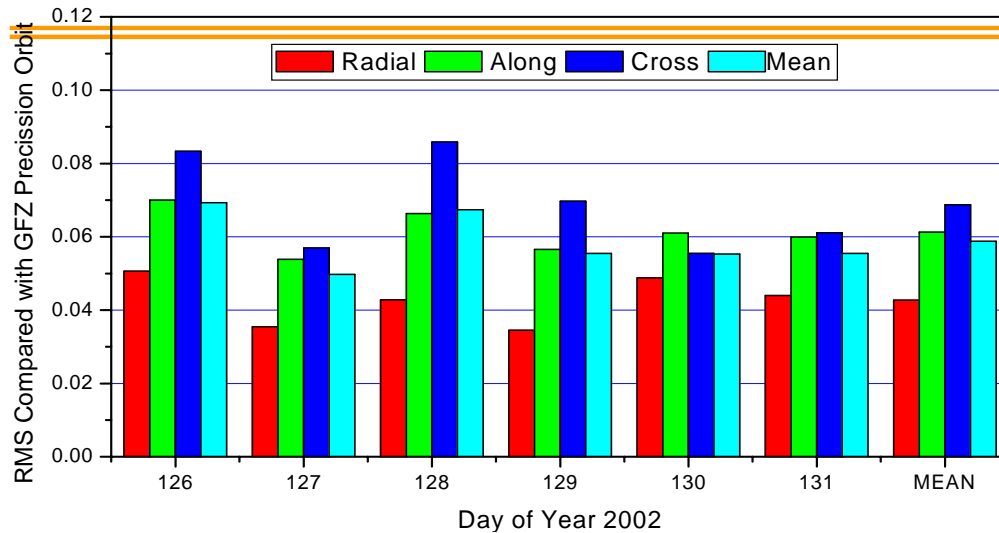
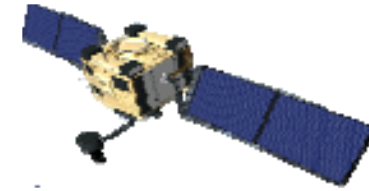
# Result for GPS satellite orbit determination



PANDA  
 Three days result vs IGS final  
 Radial: 3cm  
 Along: 6cm  
 Cross: 5cm

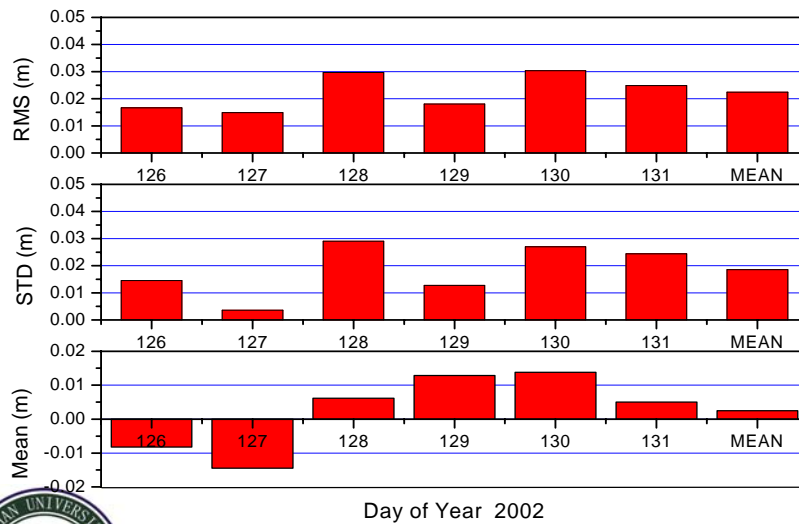


# Result for CHAMP(1)

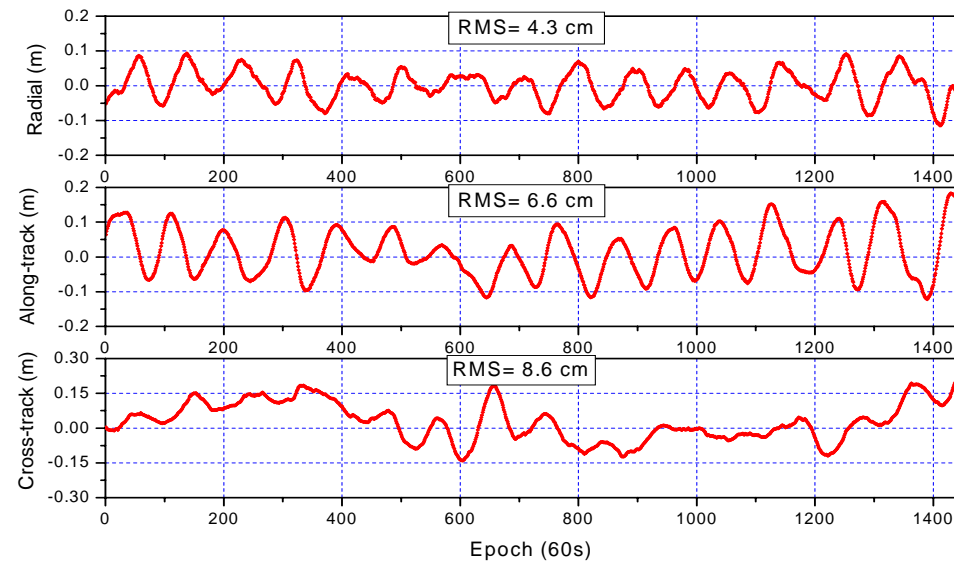


CHAMP orbit vs. GFZ PSO  
Without accelerations  
5.8cm (3D)

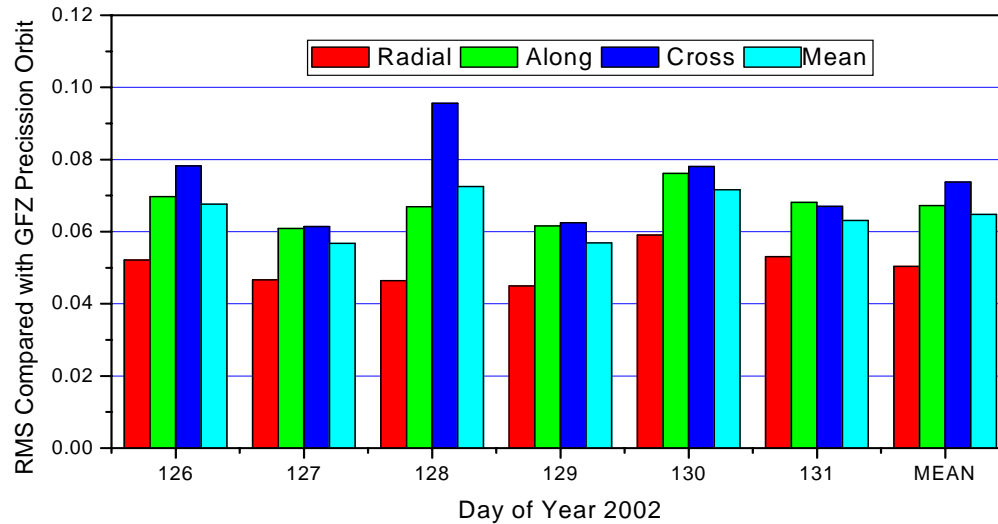
Orbit residuals compare with  
GFZ PSO of day 128 2002



SLR residuals

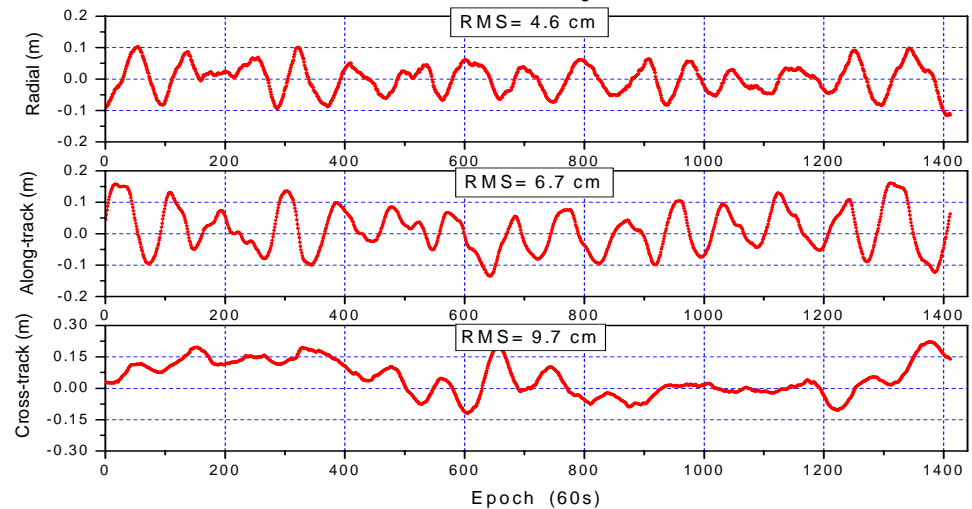
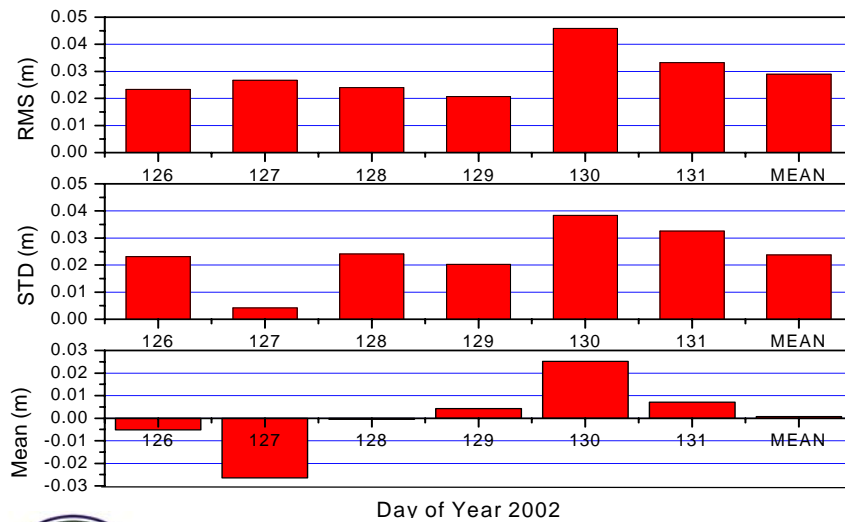


# Result for CHAMP(2)



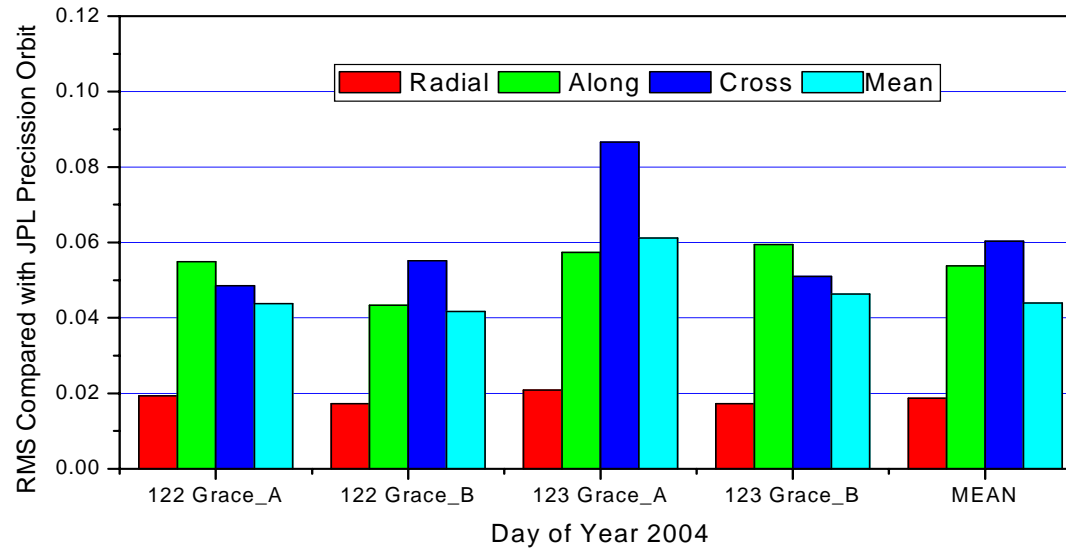
CHAMP orbit vs. GFZ PSO  
With accelerations  
6.4cm (3D)

Orbit residuals compare with  
GFZ PSO of day 128 2002



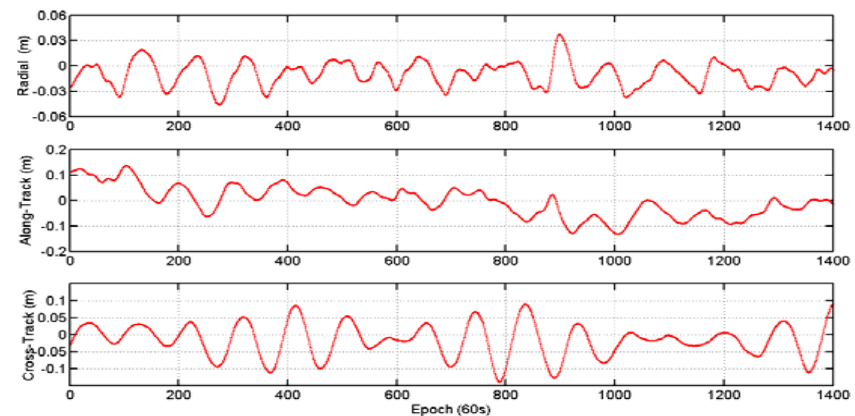
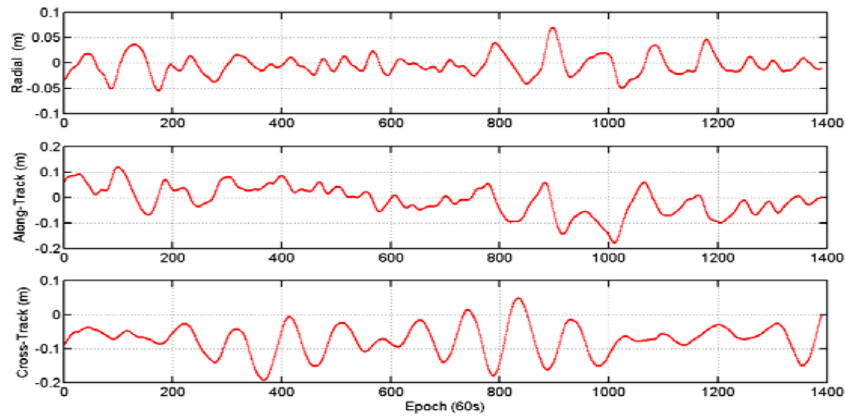
SLR residuals

# Result for GRACE



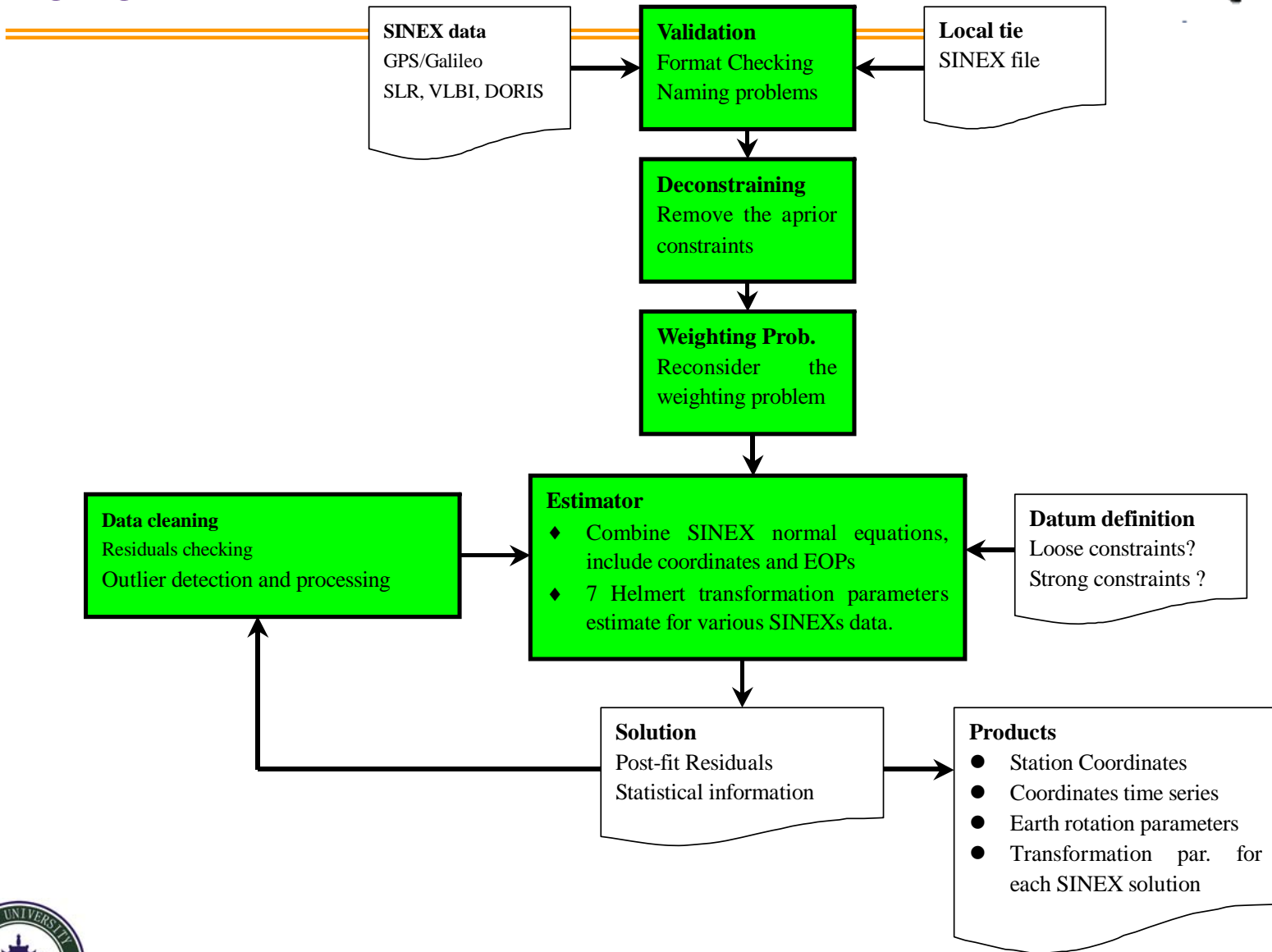
GRACE orbit vs. JPL

4.5cm (3D)

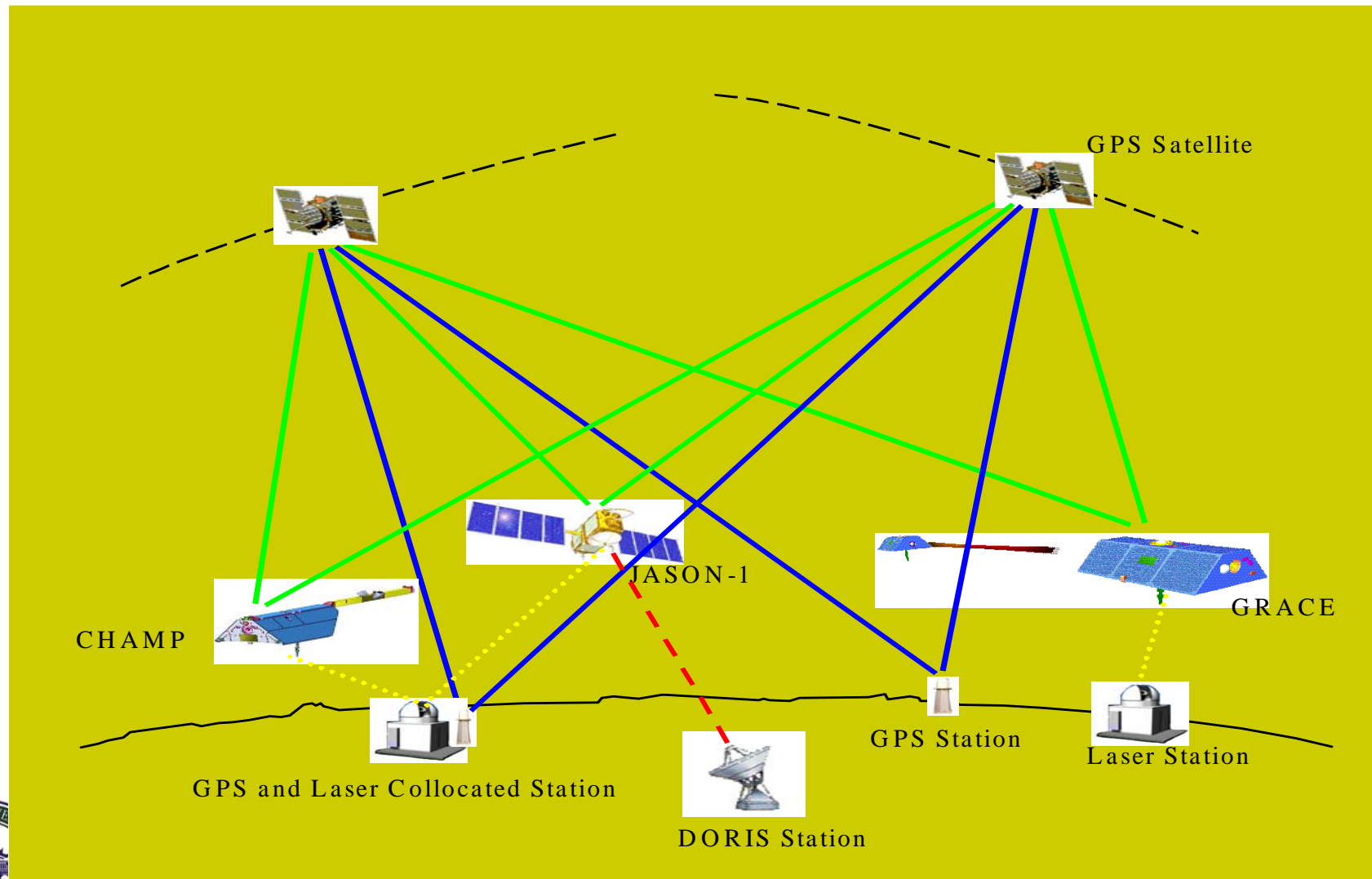
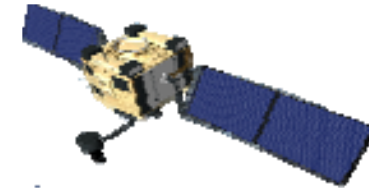




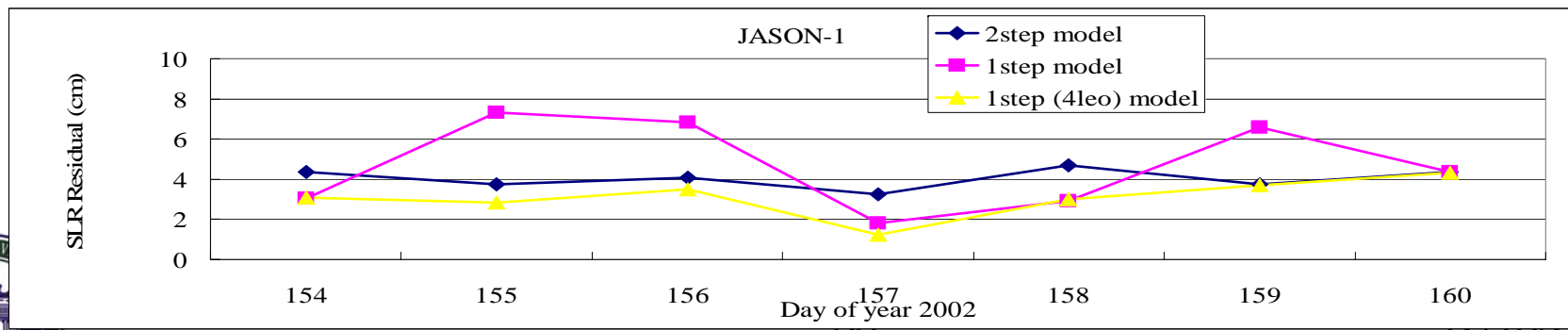
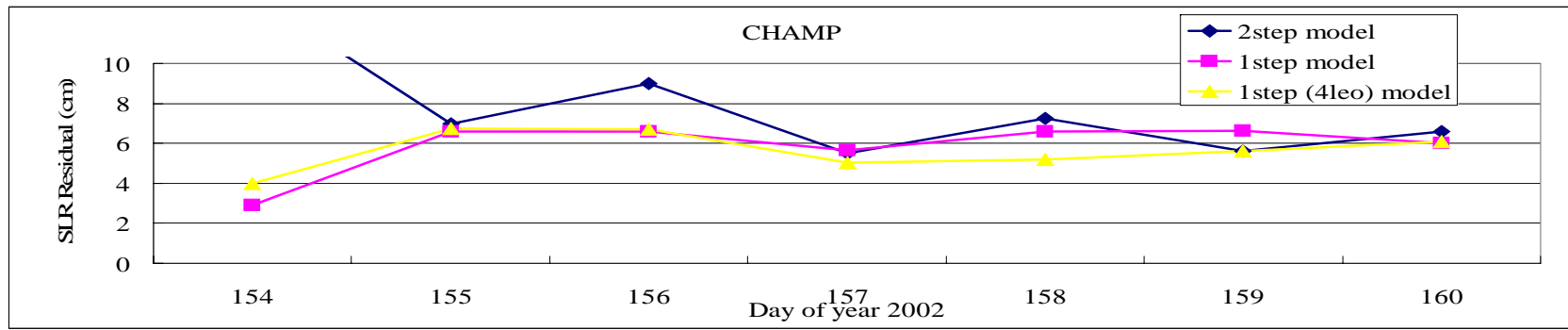
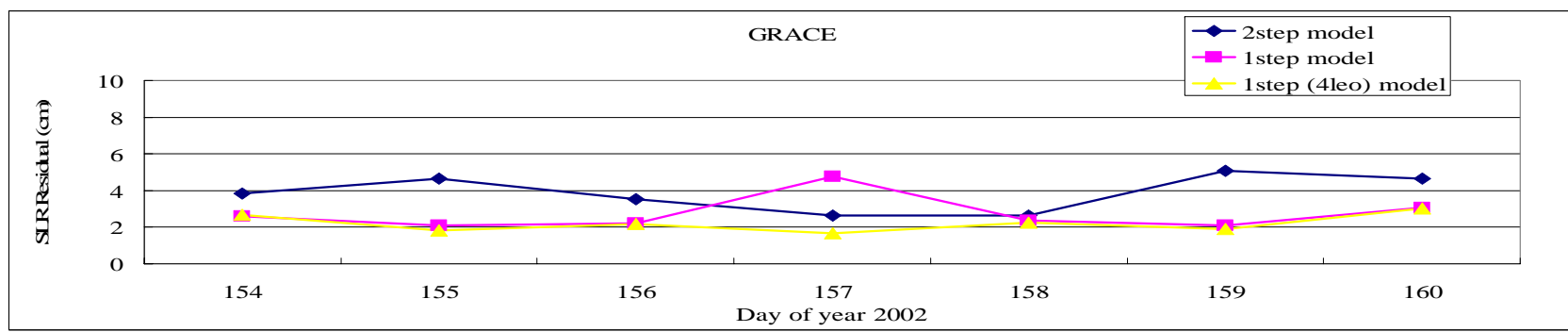
# Multi-technique data combination in SINEX level



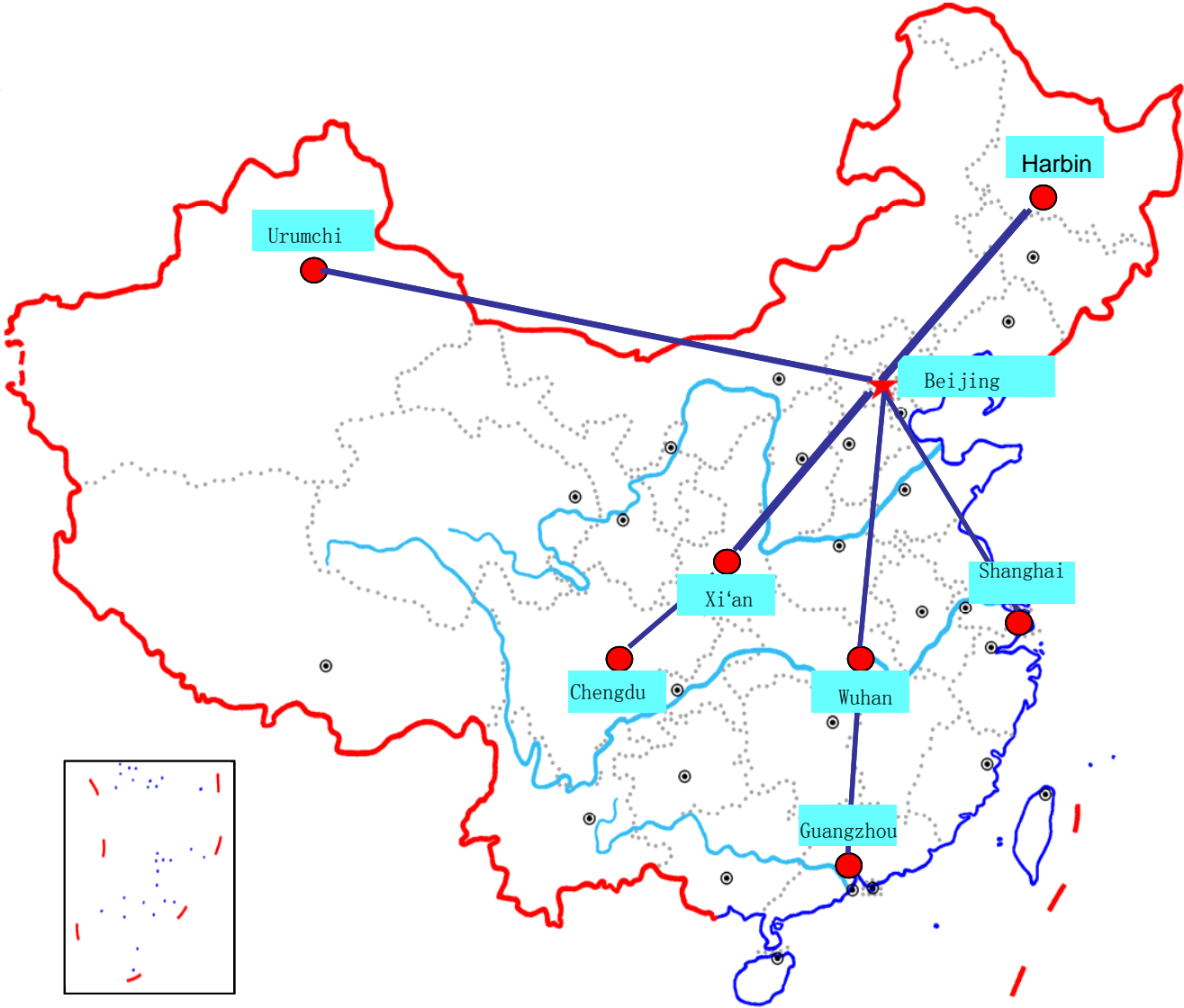
# CHAMP, GRACE, JASON AND GROUND STATIONS (1)



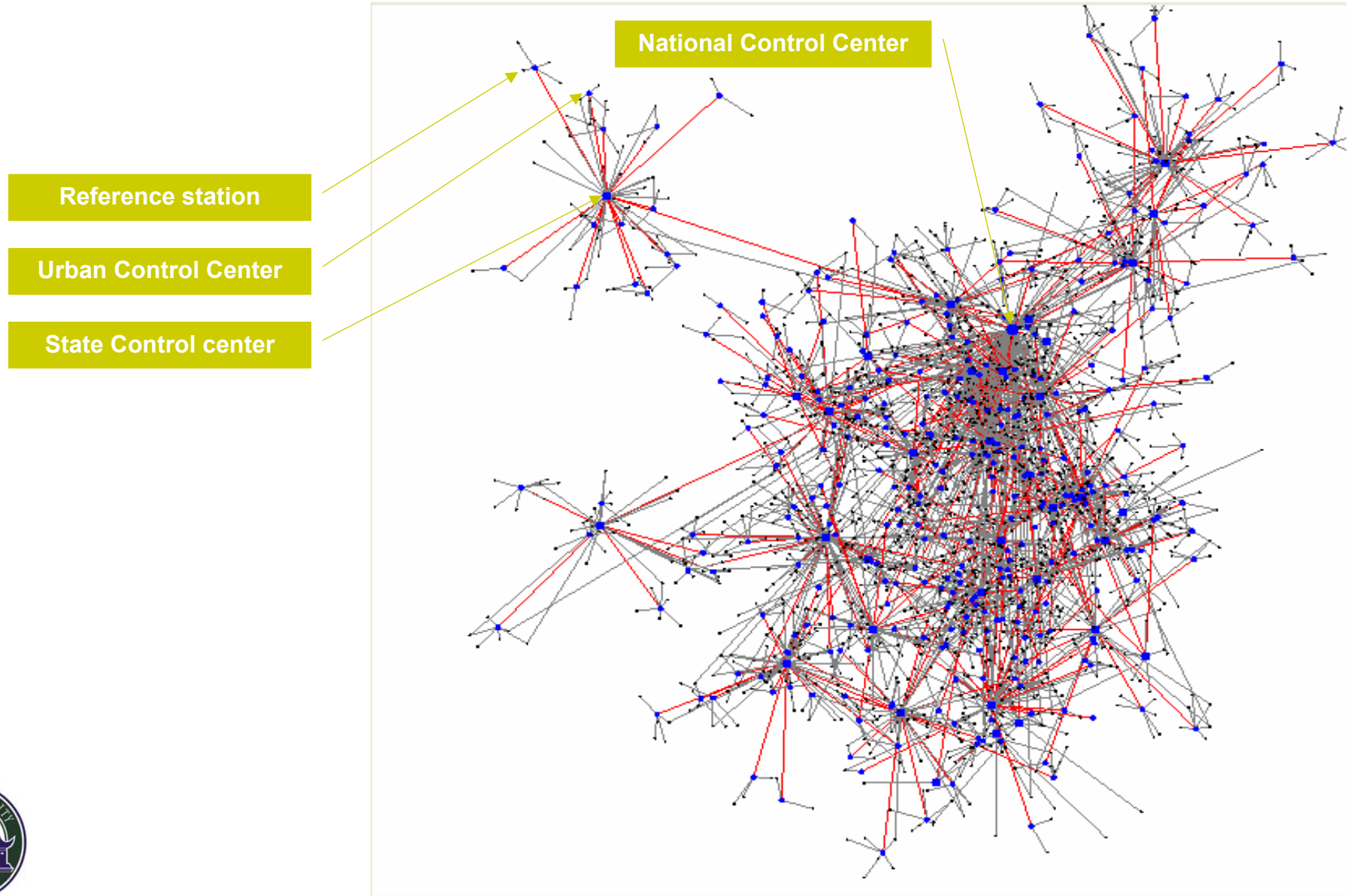
# CHAMP, GRACE, JASON AND GROUND STATIONS (2)



# China CORS

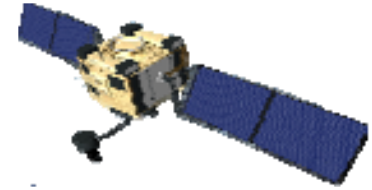


# CNCORS Map (design)



# Province CORS and Urban CORS

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- **Province CORS**

- Guangdong Province CORS-GDCORS
- Hebei Province CORS-HBCORS
- .....

- **Urban CORS**

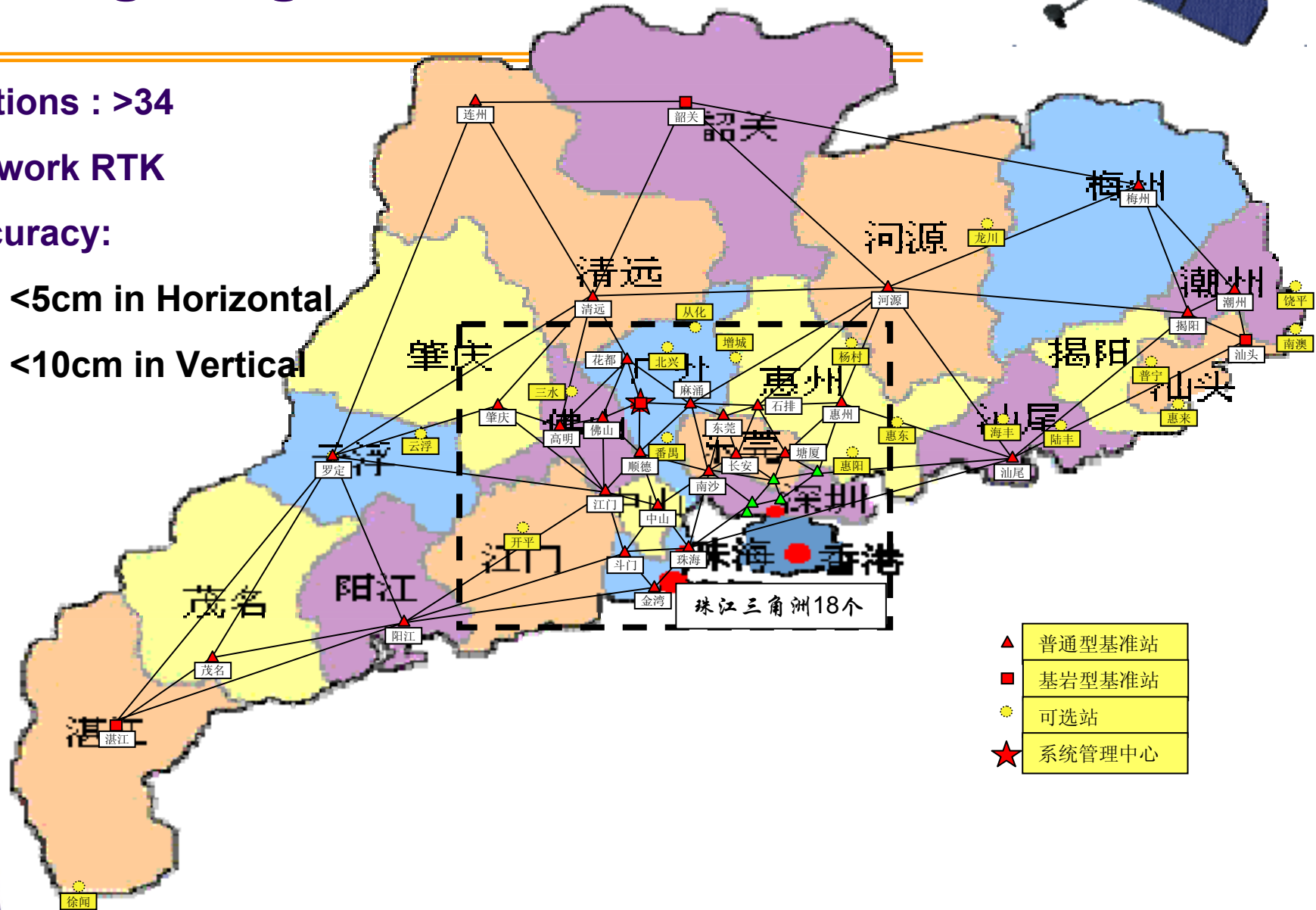
- Shenzhen CORS-SZCORS (Network RTK)
- Beijing CORS-BJCORS(RTK)
- Dongguan CORS-DGCORS (Network RTK)
- Kunming CORS-KMCORS (Network RTK)
- Wuhan CORS-WHCORS (Network RTK)
- .....



# Guangdong Province CORS

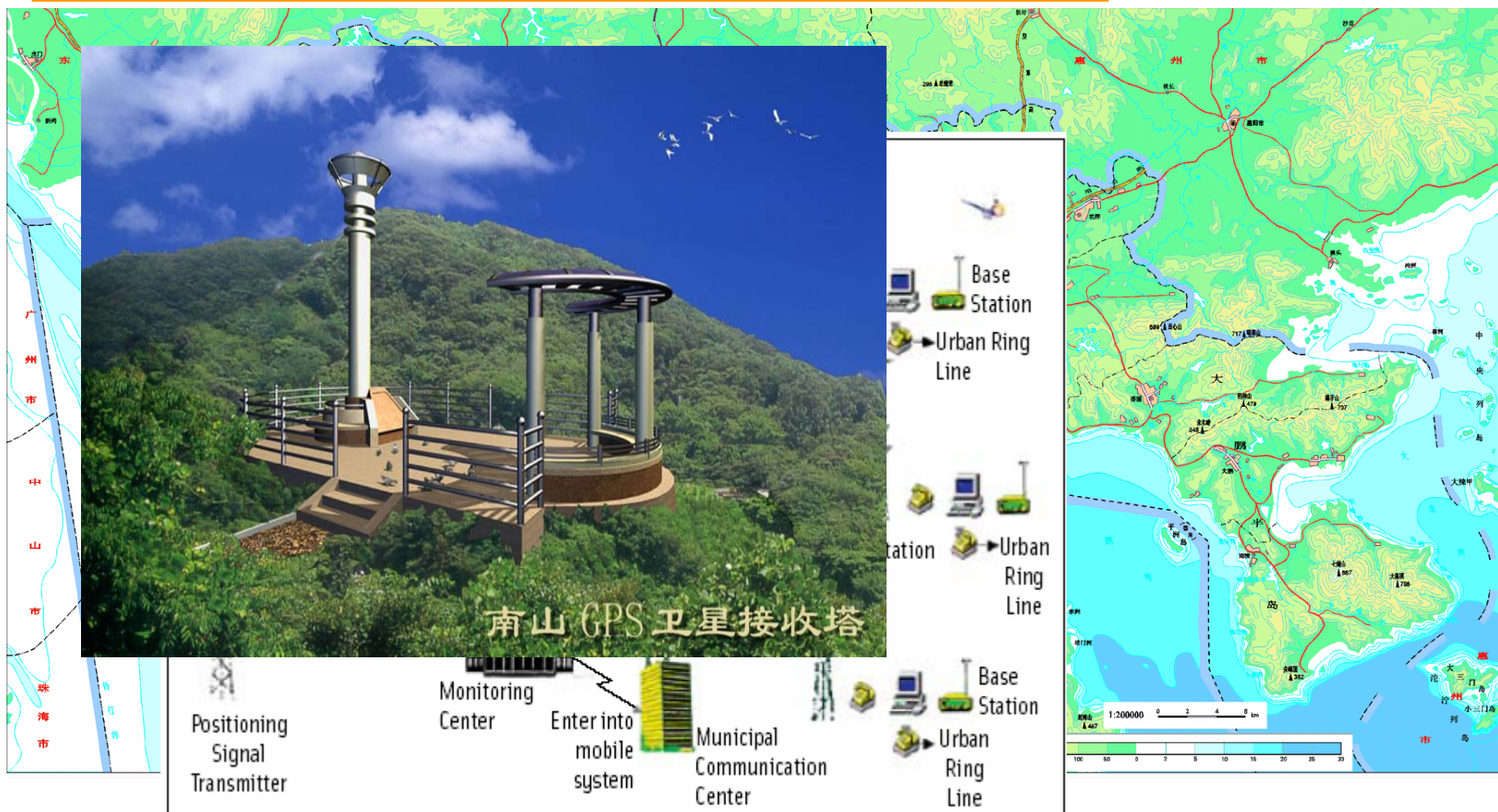


- ▶ Stations : >34
- ▶ Network RTK
- ▶ Accuracy:
  - ▶ <5cm in Horizontal
  - ▶ <10cm in Vertical



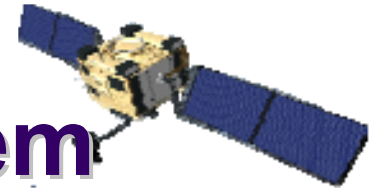


# Shenzhen CORS



Layout of CORS Network in Shenzhen

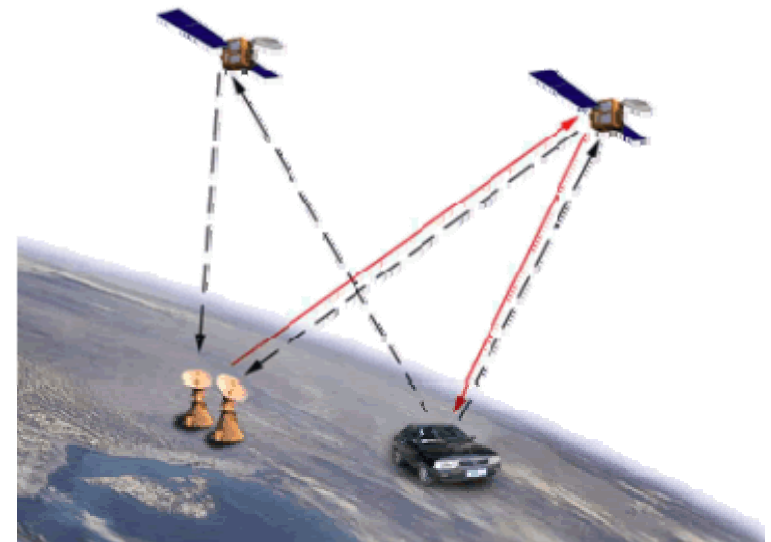




# China Satellite Navigation System

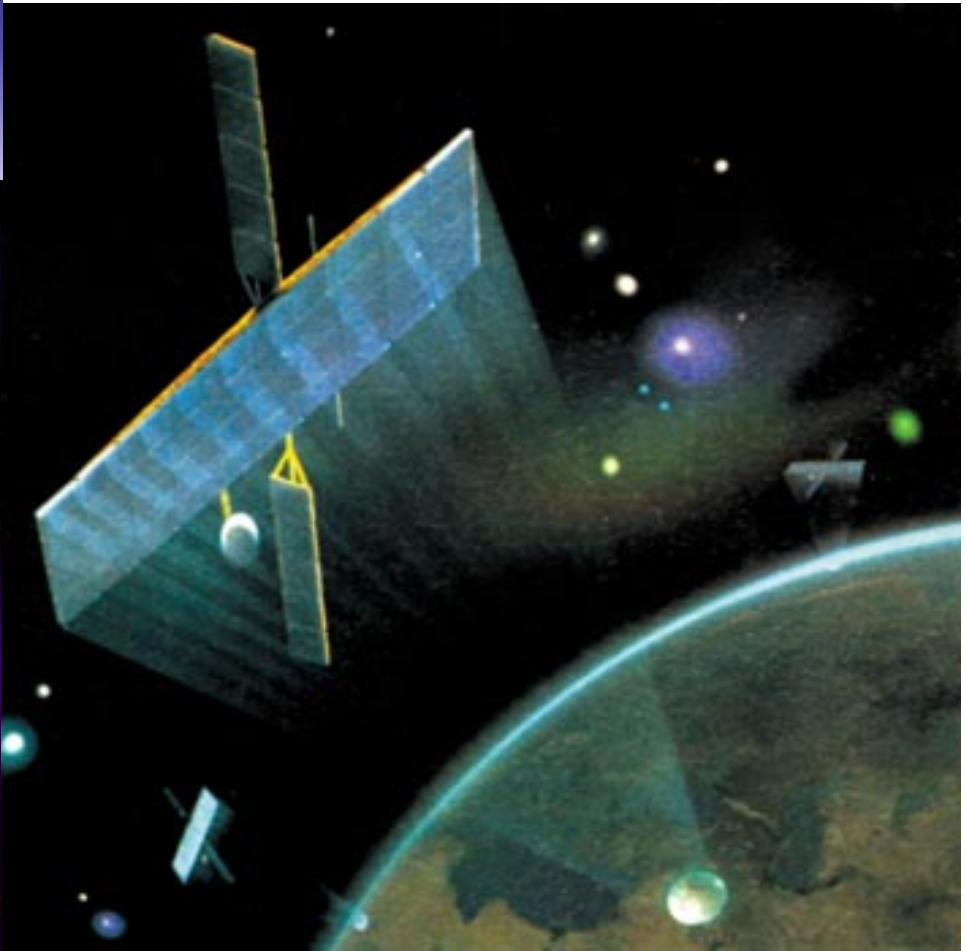
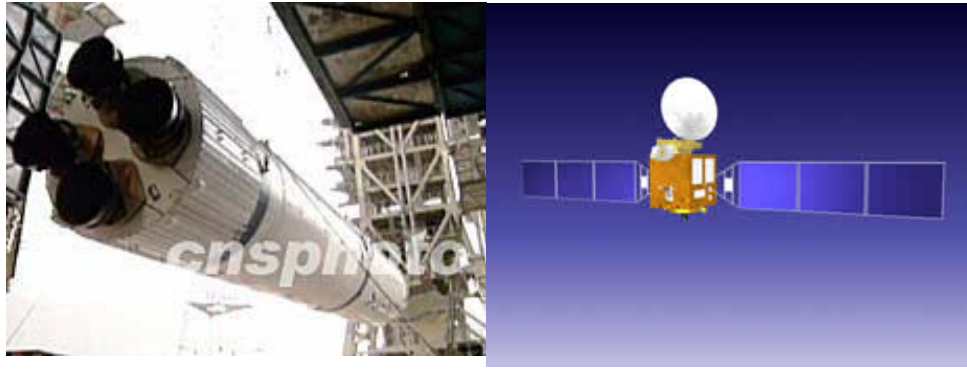
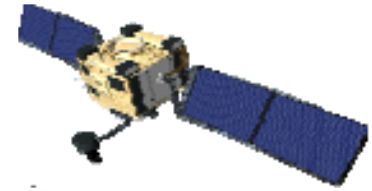
## Beidou System (COMPASS):

- **Double GEO Satellite positioning system for China Regional Navigation**
- **Initiative Positioning Mode**
- **Beidou satellite -1/2/3**
  - Accuracy: <30N <30m Real time;
  - >30N <25m Real time
- **Beidou Wide Area Differential GPS System**
  - Accuracy: better than 5m;
- **Short Message Communication**



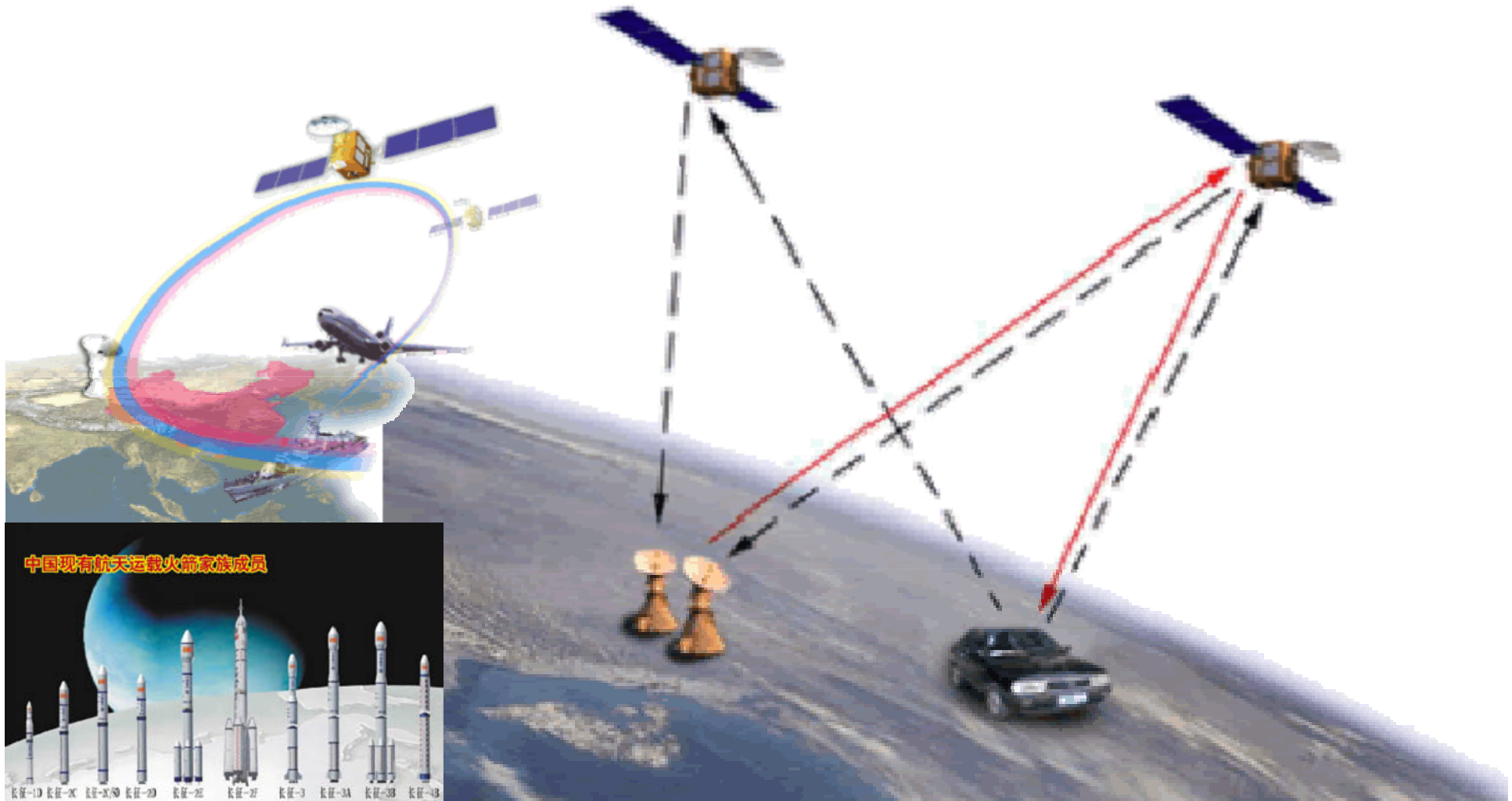
# China GNSS project Beidou-1 Satellites

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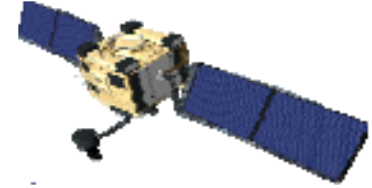


# China GNSS project: Beidou-1 Satellites



# Future Projects

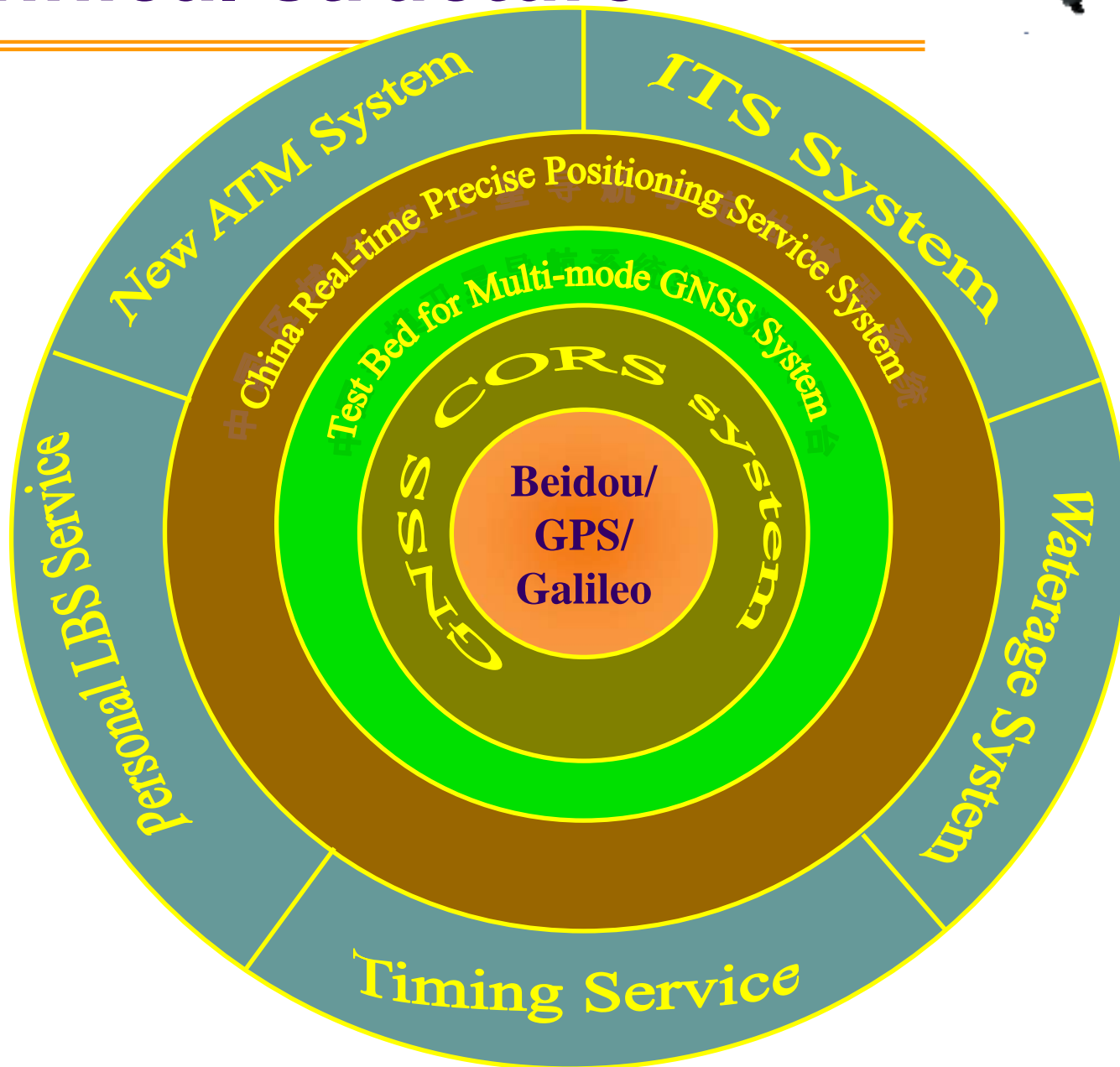
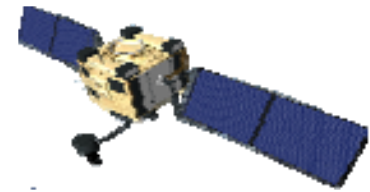
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- **Integrated GNSS Applications**
- **The New System Upgrading Beidou**
- **China Real-time Precise Positioning Service System**
- **New Generation ATM System**
- **Joint Galileo Projects in China**

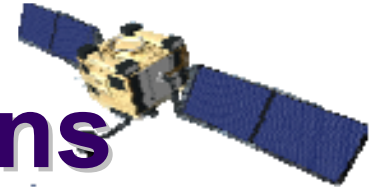


# Technical structure



# Integrated GNSS Applications

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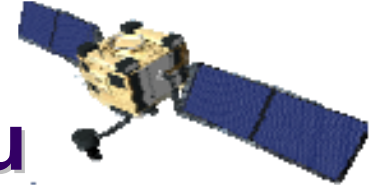


- **Resource Sharing**
  - Satellite signal (GPS/Galileo/Beidou)
  - Reference stations
  - ....
- **User interface unify**
  - Same quality of service (Qos)
  - User requirements driven
  - Service mode
    - Free service
    - Payment service
- **System specifications upgrading**
  - Increase stability, reliability and availability
  - .....





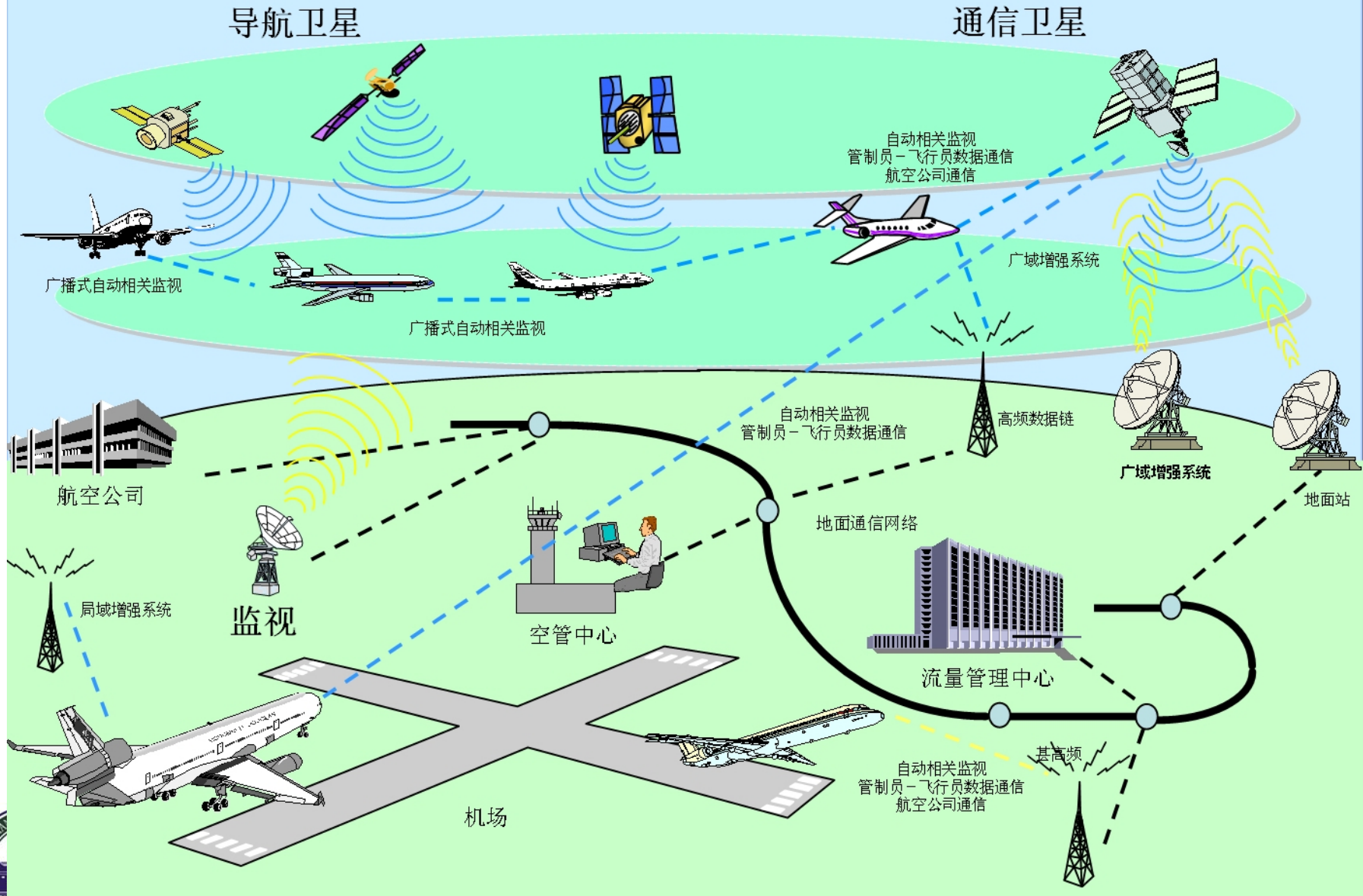
# The New System Upgrading Beidou



- **The upgrading of Beidou: The New Generation Navigation System in China**
  - **Passive positioning mode**
  - **Constellation: multi-satellite orbits**
  - **Augmentation: GPS ,GALILEO and BD**
  - **Covered area: larger than former Beidou**

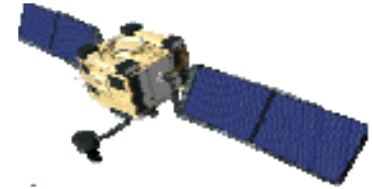


# New Generation ATM System



# Galileo Projects

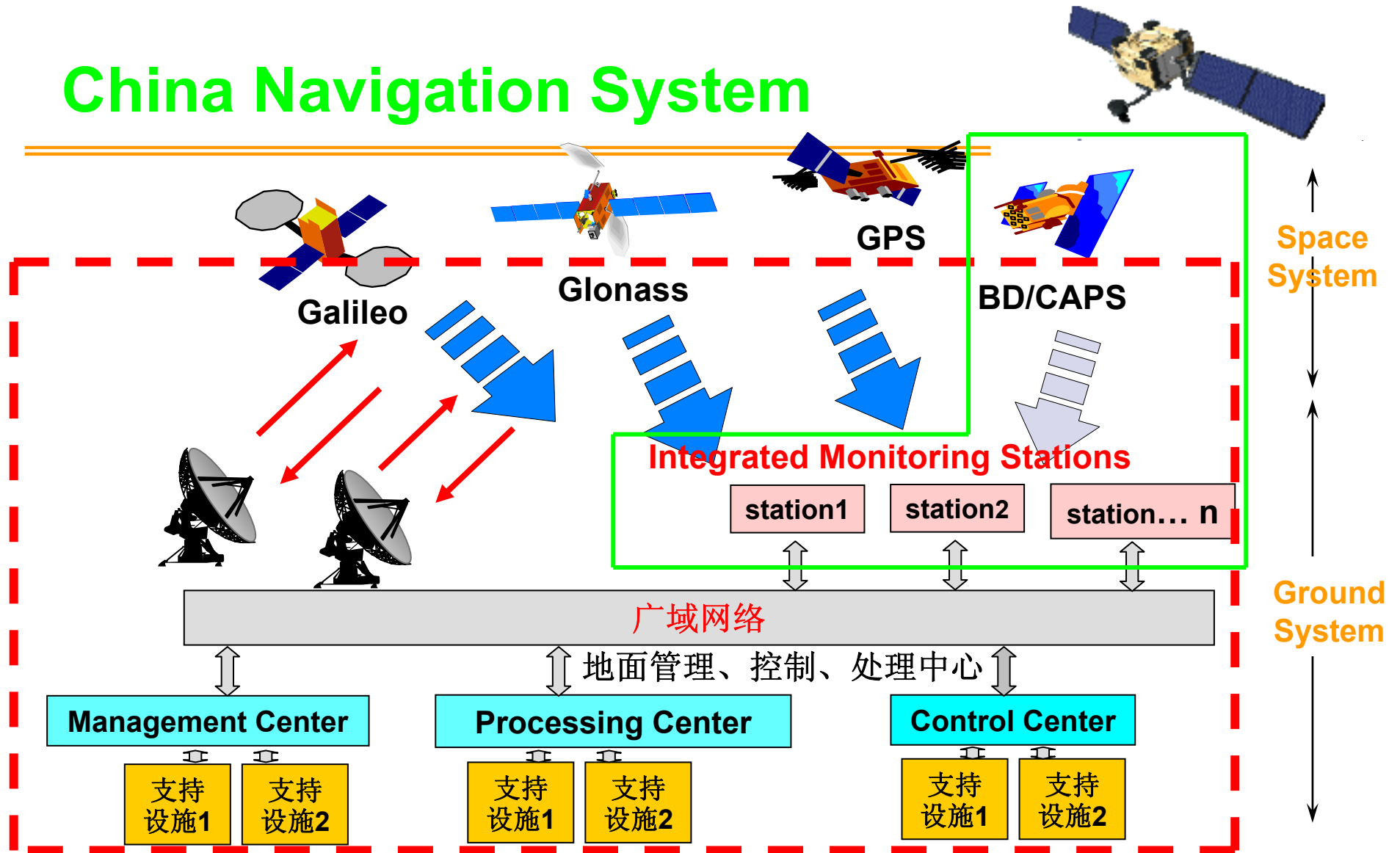
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- **Fishery Application System**
- **China Galileo test range**
- **Ionosphere**
- **Satellite laser ranging**
- **Early Galileo service in China (TBD)**
- **ERIS**



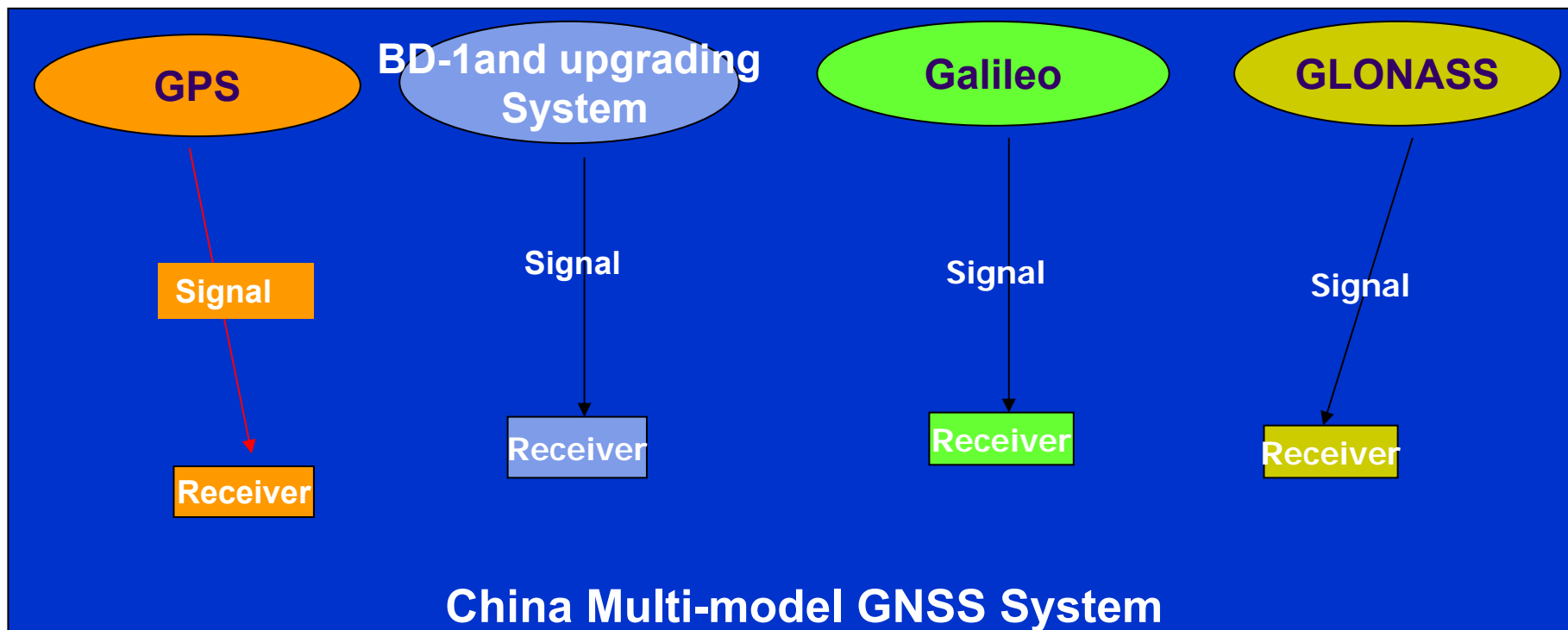
# China Navigation System



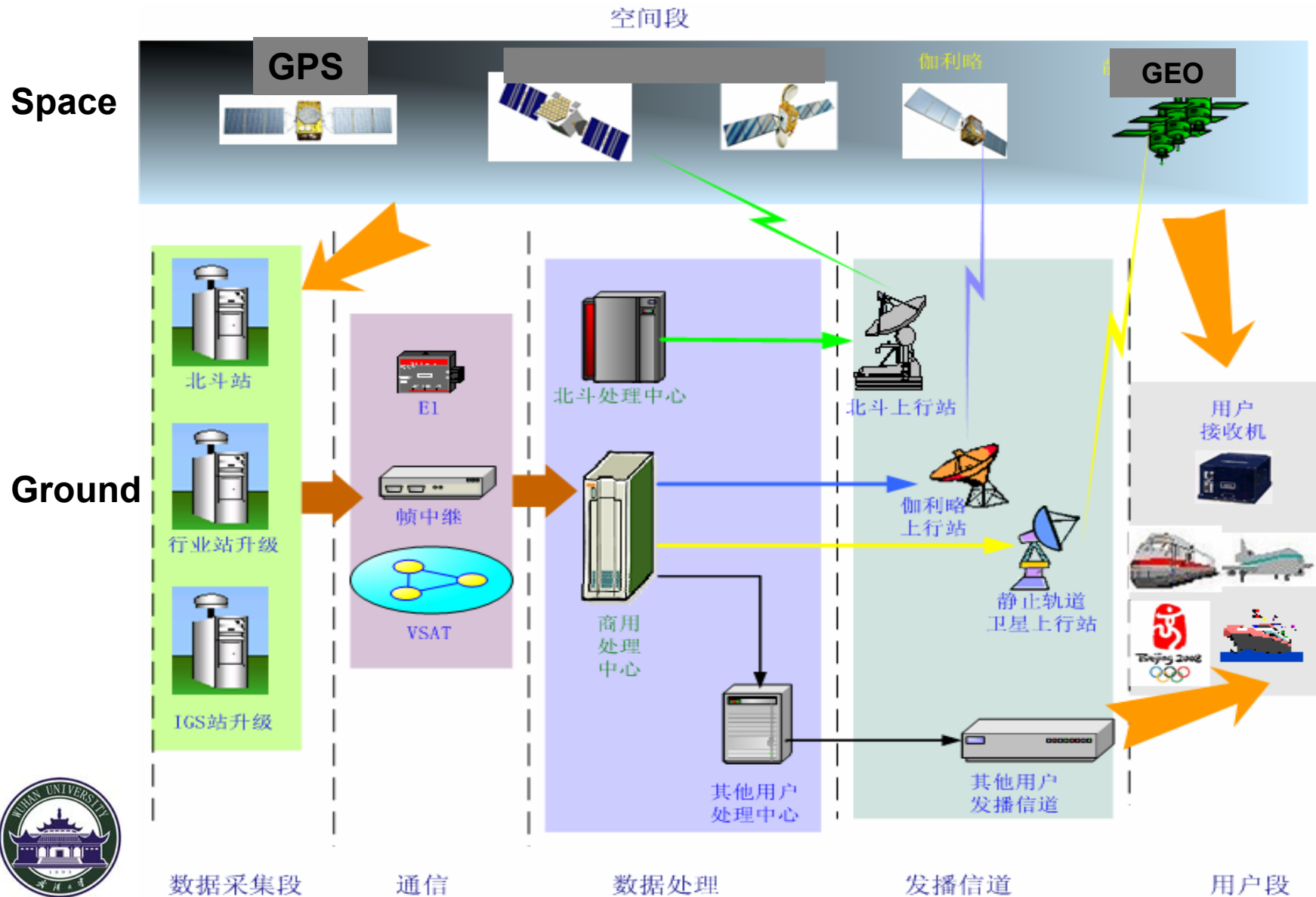
## The Frame of System



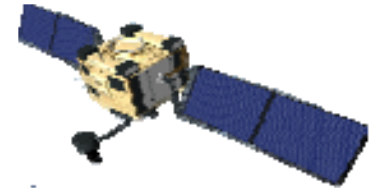
# Integration of Various Systems



# Chinese Regional Multi-mode Satellite Navigation Augmented System







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**Thank you for your attention!**

