

# Chinese Geodetic Coordinate Reference Frame 2000

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# 1. Overview on CTRF2000

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■ **What kind of geodetic reference coordinate system do we need for satellite navigation?**

- **The satellite moves round the Earth mass center — the orbit of the satellite should be expressed in a geocentric terrestrial reference system (TRS).**
- **COMPASS orbit and navigation in China refer to CGCS 2000 — Chinese Geodetic Coordinate System, realized by CTRF 2000.**



# 1. Overview on CTRF2000

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## ■ What does TRF serve for in navigation?

**Terrestrial Reference  
Frame (TRF)  
in navigation**

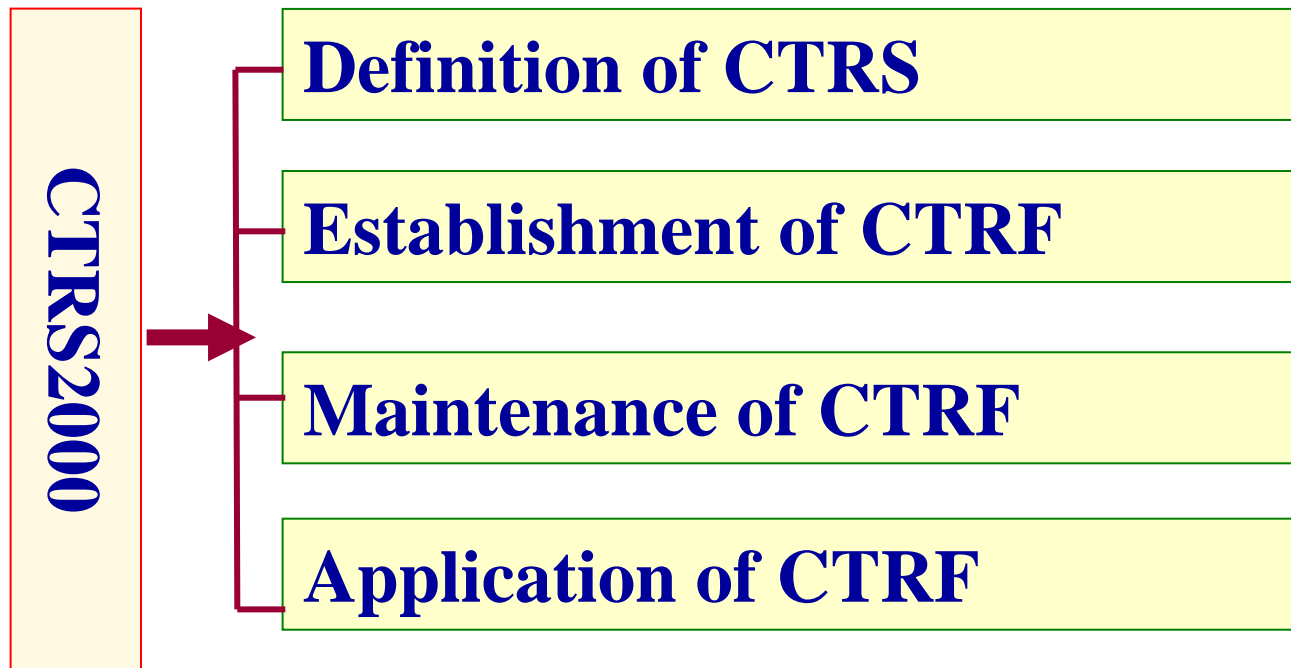


- Tracking the satellite to determine the orbit
- Expressing the coordinate system of navigation system
- Augmenting in local area for satellite navigation
- ...

# 1. Overview on CTRF2000

■ **What does Chinese Geodetic Coordinate System (CGCS) need?**

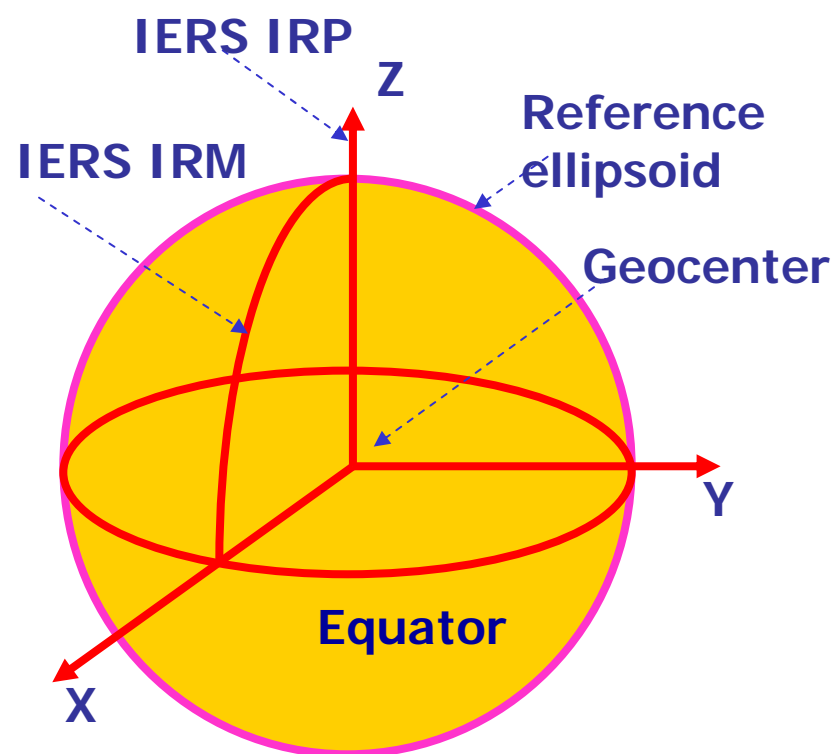
**---Definition, establishment, maintenance and applications.**



# 1. Overview on CTRF2000

## CGCS2000 meets the following rules of IERS :

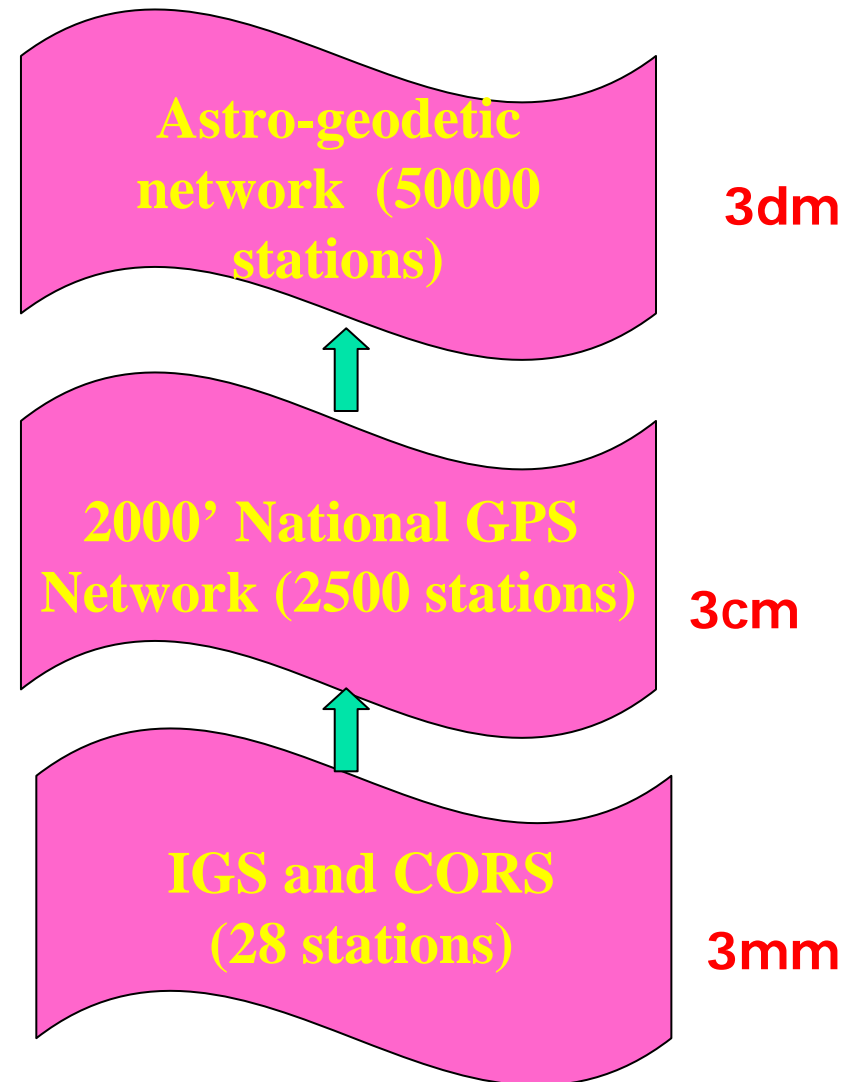
- Its **origin** is at the center of mass for the whole Earth, including oceans and atmosphere;
- **Unit of length**: meter SI, consistent with TCG (Geocentric Coordinate Time);
- The **orientation** is initially given by the BIH orientation at 1984;
- The time evolution in orientation will create no residual global orientation with regard to the crust.



## 2. Structure of CTRF2000

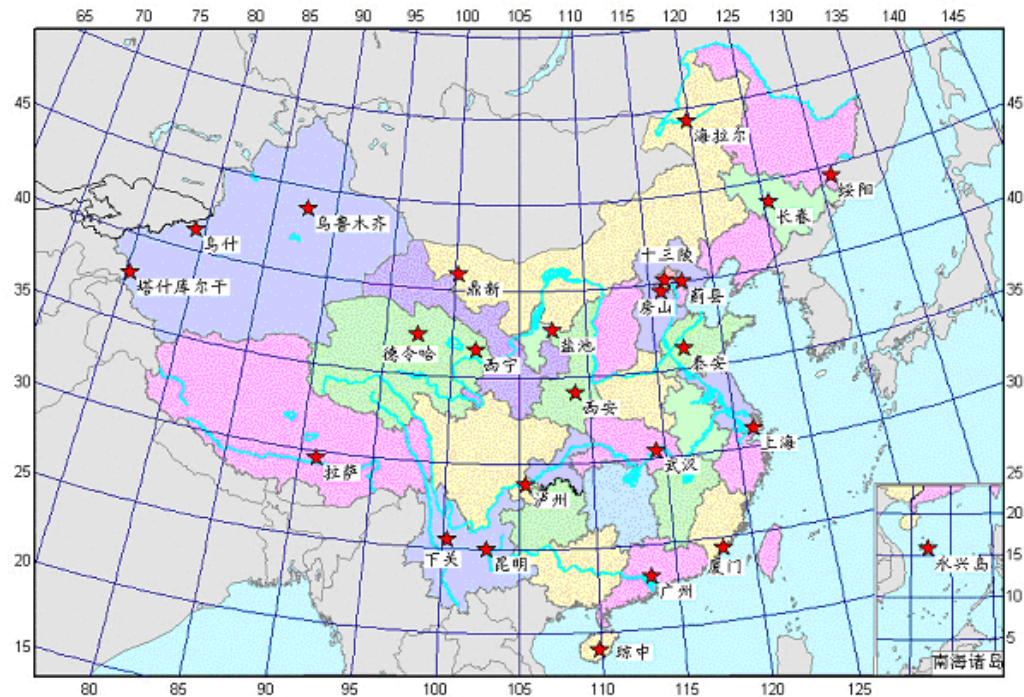
- Reference Frame: ITRF1997;
- Epoch: 2000.0.

- **The first order:** 28 CORS, which is the key frame of CGCS2000 with mm accuracy.
- **The second order:** “2000’ national GPS network”, with about 2500 stations with cm accuracy.
- **The third order:** National astro-geodetic network, with about 50,000 stations with 0.3m accuracy.



## 2.1 The first order frame——28 CORS

- The first order frame is composed of 28 continuous operational stations.
- An integrated adjustment of the CORS in China with selected IGS stations was carried out.
- The accuracy of the coordinates of the adjusted CORS is about 3mm.



## 2.2 The second order frame ——2000' national GPS network



比例尺 1:10,000,000





## 2.2 The Second Order Frame of CGCS 2000

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■ The CTRF 2000 is mainly expressed by 2000' National GPS Network

■ **1. The frame and epoch of the GPS network 2000**

➤ Frame: ITRF97; Epoch: 2000.0.

■ **2. What are the initial constraints?**

➤ 47 IGS stations are selected to define the reference frame;

➤ The coordinates of IGS stations with  $1\sigma$  are introduced in the integrated adjustment of GPS networks;

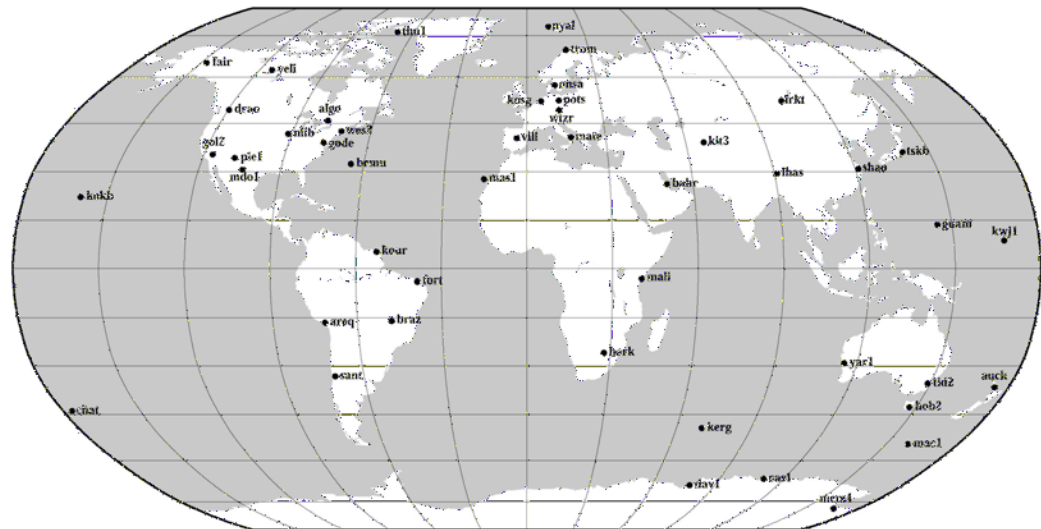
➤ The coordinates are reduced into the epoch 2000.0 according to their velocities.

## 2.2 The Second Order Frame of CGCS 2000



← 2000' GPS network

IGS stations



## 2.2 The Second Order Frame of CGCS 2000

### ■ 3. How to deal with the functional and stochastic model errors?

Systematic parameters are introduced  
in functional model



Variance component estimation based on the  
improved functional model



Robust estimation is applied to the improved  
functional model



To control the cross error influences



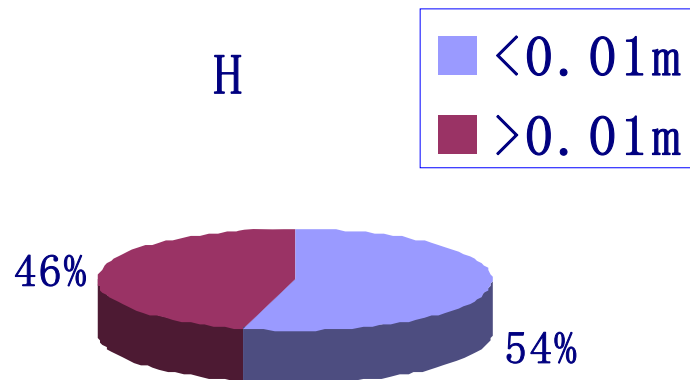
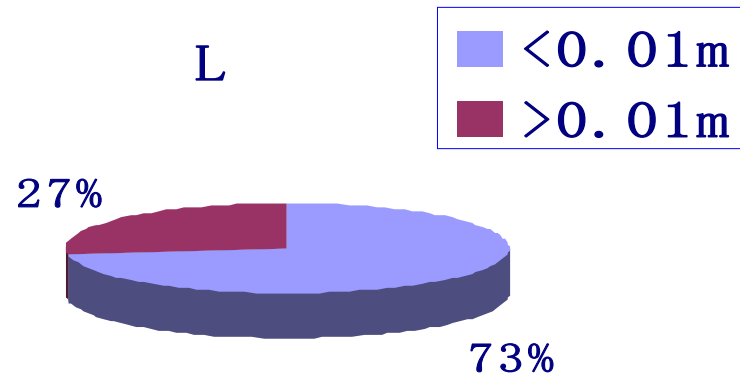
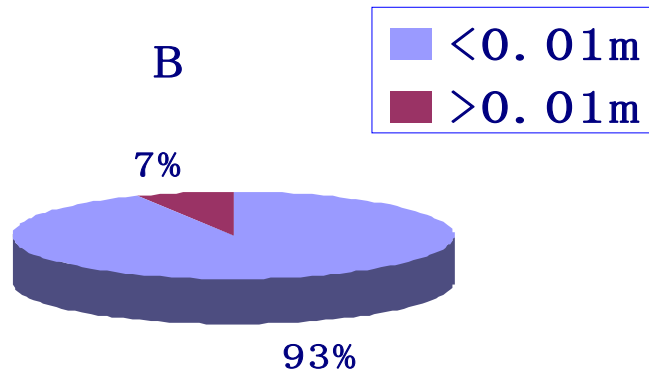
## 2.2 The Second Order Frame of CGCS 2000

### ■ 4. Results of the GPS network 2000

	X/cm	Y/cm	Z/cm	B/cm	L/cm	H/cm	Position
Mean Std	0.90	1.57	1.06	0.37	0.77	1.92	2.13cm

- Average standard deviation for **horizontal position** is about **0.5cm**;
- Average standard deviation for **height** is about **2cm**;
- Average standard deviation for 3D position is better than **2.5cm**.

## 2.2 The Second Order Frame of CGCS 2000





## 2.3 The third order frame — Astro-geodetic network





## **2.3. The Third Order Frame of CGCS 2000**

### **---Astro-Geodetic Network**

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- **The third order frame of CGCS 2000 is the astro-geodetic network with about 50 000 stations.**
- **The astro-geodetic network itself cannot be employed as reference frame.**
- **Combined adjustment of astro-geodetic network and 2000' GPS network can provide unified coordinates of stations in a given reference system.**
- **The combined adjustment can improve the coordinate accuracy of the astro-geodetic network in controlling of the high accurate GPS network.**

## 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

### ■ 1. Main strategies of the adjustment

**Coordinate datum**

The uncertainty of the coordinates of the GPS network 2000 was given  $1\sigma$  to propagate the datum

**Crust deformation and other systematic errors**

Parameters to compensate the systematic errors are introduced

**Effects of outliers**

Outlier diagnosis and robust estimation are used

**Inconsistent inner precision**

Variance component estimation (VCE) is used





## **2.3. The Third Order Frame of CGCS 2000**

### **---Astro-Geodetic Network**

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#### **■ 1. Main strategies of the adjustment**

##### **(1) Datum and systematic errors**

- **2000' GPS network acts as a reference of the combined adjustment, thus the coordinates given by the combined adjustment will refer to the same datum as that of the 2000' GPS net.**
- **The systematic errors of the astro-geodetic network are mainly controlled by the GPS network.**



## 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

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### ■ 1. Main strategies of the adjustment

#### (2) Functional model of the combined adjustment

- The parameters are the 3D coordinates.
- The height fixed 3D model is employed if the stations have no vertical angle measurements.
- Some systematic parameters are introduced in the functional model:
  - 1 orientation parameter is introduced to adjust the orientation error;
  - 8 scale parameters are introduced to compensate distance errors.



## 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

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### ■ 1. Main strategies of the adjustment

#### (3) Stochastic model

- The initial weights are the inverses of the variances;
- Variance component estimation is applied to the combined adjustment in order to adjust the inhomogeneous accuracies of the measurements.
- By iteration 2 times, all the variance components are nearly equal to 1 (the prior assumption value).

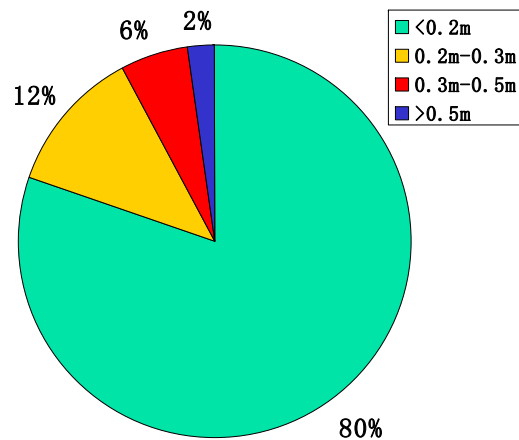
## 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

### ■ 2. The results and quality

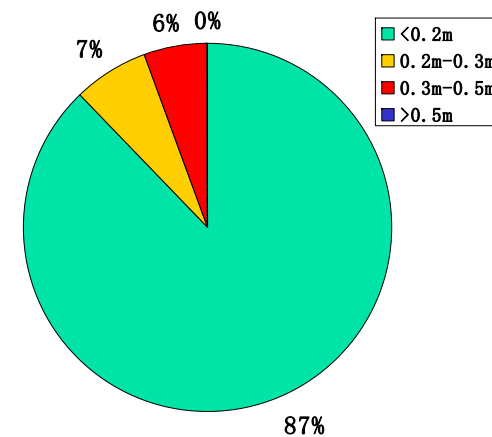
#### ■ Precision of 3D position

- The standard deviations of 38693 (80.2%) stations are smaller than **0.2m**;
- Std of 44384 (92.1%) stations are smaller than **0.3 m**;
- Average std is **0.15m**.

3D positional std

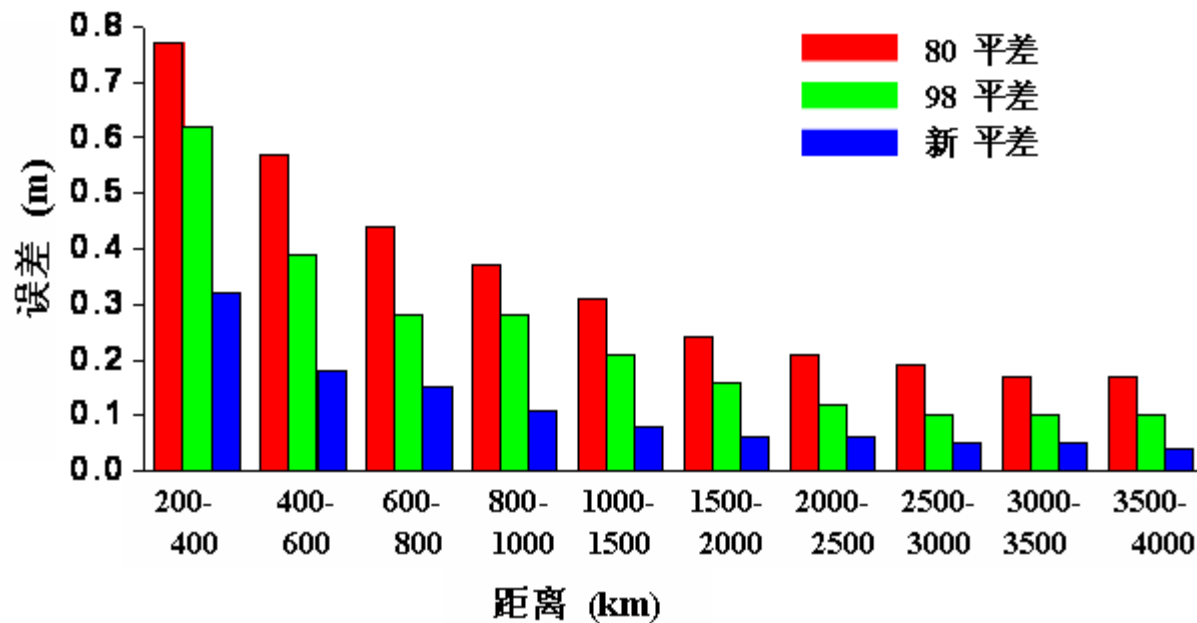


Horizontal std



## 2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network

### ■ Relative precision comparison with old adj. (ppm)



The relative precision is **1/4-1/2** as much as that of the adjustment carried out in 1980 and 1998.



## **2.3. The Third Order Frame of CGCS 2000 ---Astro-Geodetic Network**

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### **■ 3. Main achievements of the project**

- **The geodetic measurements lasting more than 70 years in China are integrated and adjusted.**
- **The reference datum is unified, and some systematic error influences are controlled.**
- **The CTRF 2000 has been established and strengthened with higher precision and more density.**
- **The relative precision is 4 times better than that of the project carried out in 1980.**

### 3. Main technical progress of the CTRF 2000

➤ **2D+1D geodetic networks**

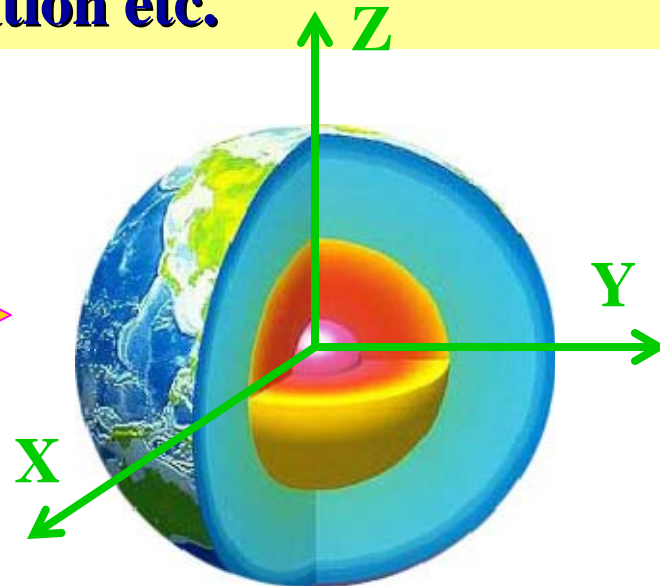
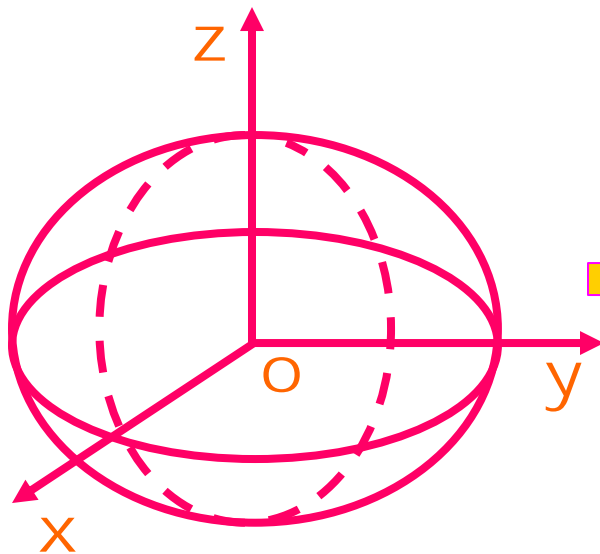


➤ **3D geodetic network**  
➤ **It is suitable for space geodesy**

➤ **Non geocentric coordinate system**



➤ **Geocentric coordinate system**  
➤ **It is suitable for aerospace and navigation etc.**



### 3. Main technical progress of the CTRF 2000

➤ **Original accuracy 5-10m.**



**New accuracy 3cm-0.3m**

➤ **Inhomogeneous accuracy of the frame with the error more than 10m in the boundary area of the country.**



**Homogeneous accuracy without significant systematic errors (the error of boundary stations is about 0.5m)**

➤ **Least squares adj.**



**LS + VC + robust estimations  
Reliability has been improved**

**CGCF2000 is an alignment of ITRF, it will be updated to new ITRF series.**





## 4. Main problems of CTRF 2000

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- The accuracy of the CTRF is not so homogeneous, compared to the ITRF.
- The CTRF 2000 cannot provide accurate velocities at present stage.
- There are many continuously operating reference stations (CORS) in China have not been integrated in the unified coordinate frame, which results in sources waste and the datum confusion.
- The fundamental control stations are too few, the structure of 2000' GPS network is quite weak for the large territory.



## 4. Main problems of CTRF 2000

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- **The structure of the CTRF in the west part of the country is very weak.**
- **The control stations in the overlapping areas of lands and seas are less.**
- **The geodetic control stations in island and reef are nearly empty.**
- **The tracking stations of COMPASS have not integrated in the CGCF 2000, which will be modified in the future.**



## 4. Main problems of CTRF 2000

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### ■ Conclusion

- CGCS — has got great progress**
- heavy tasks to strengthen and maintain**
  - a long way to go!**

*Thank you for  
your attention*

