



Chinese VLBI Network and its application to eVLBI

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22-26 June 2009 - Madrid, Spain



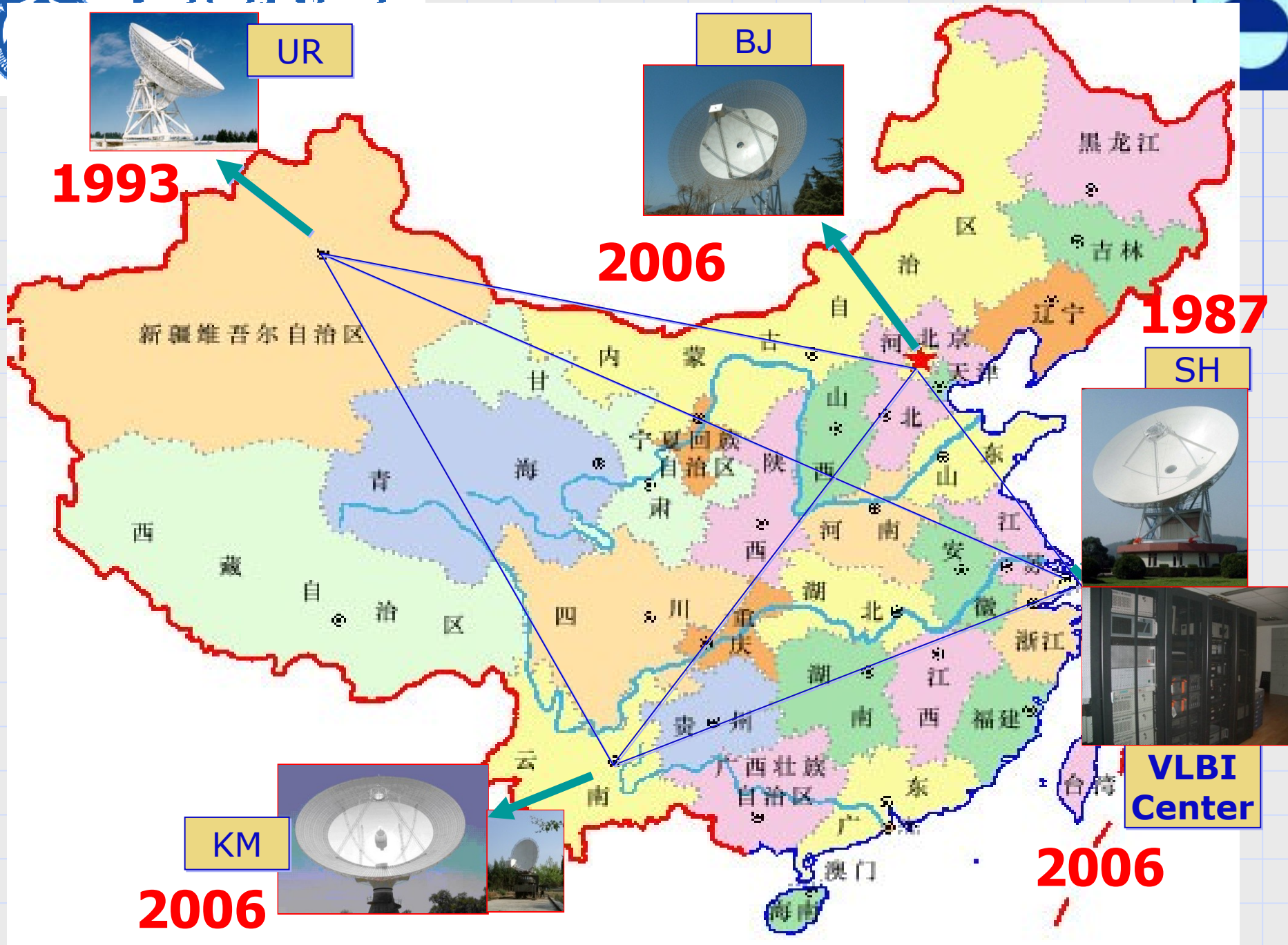
Outline

1. Chinese VLBI Network

- a) – History
- b) – Stations
- c) – VLBI Center at Shanghai

2. eVLBI Application

- a) – Science
- b) – CE-1 Lunar Satellite Tracking Mission
- c) – YH-1, CE-2, CE-3,
- d) – Demoes
- e) – future plan



UR

BJ

SH

KM

VLBI Center

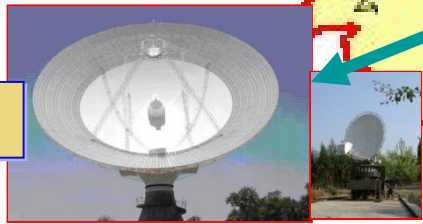
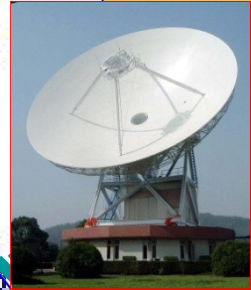
1993

2006

1987

2006

2006





CVN—History

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We started VLBI research led by Madam Ye in 1970s.
First VLBI Experiment between Shanghai and Effelsberg

✂ **1981** Completion of the construction of a 6m radio telescope in SHAO

✂ Carried out the first trans-Eurasian continent VLBI experiment at L-band between 6m telescope, Shanghai and 100m telescope, Effelsberg, West Germany, November, 1981.

Effelsberg 100m



Shanghai 6m



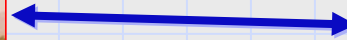


VLBI Experiments between Shanghai and Kashima

✂ 1984/5 Two VLBI experiments at X-band between 6m telescope Shanghai and 26m telescope, Kashima were performed in 1984/1985. The accuracy of the baseline measurements is about a few centimeters.



Shanghai 6m



Kashima 25m



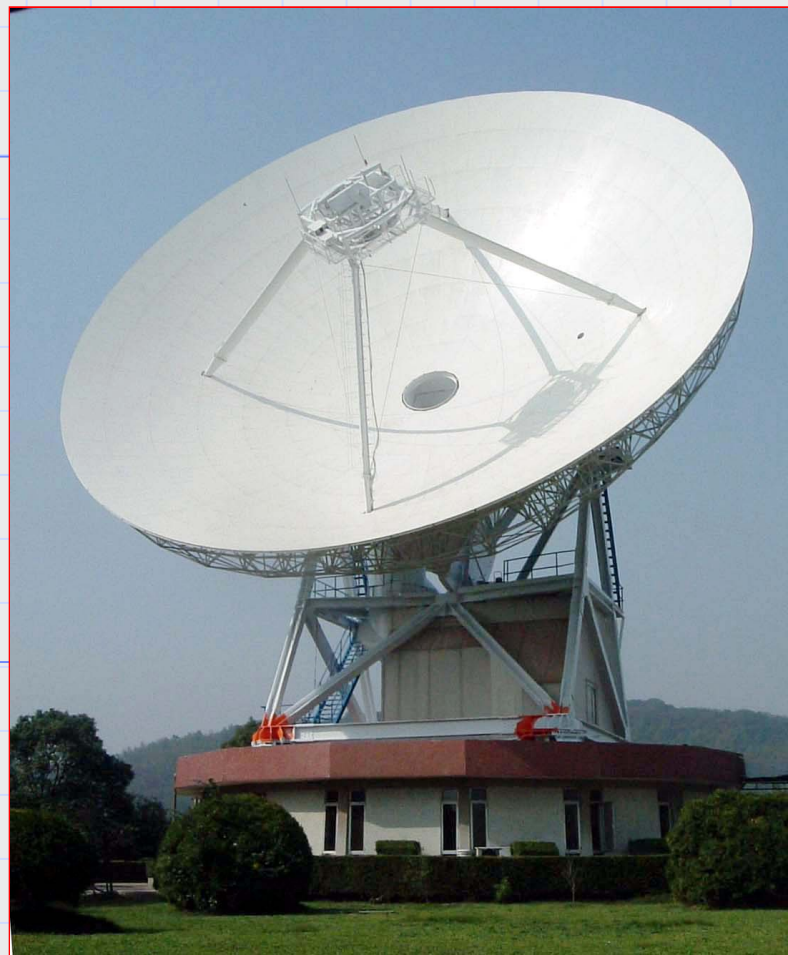
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The 25m antenna was installed in Sheshan site, about 30km far away from Shanghai in 1986/1987 and started routine international VLBI experiments since November, 1987.





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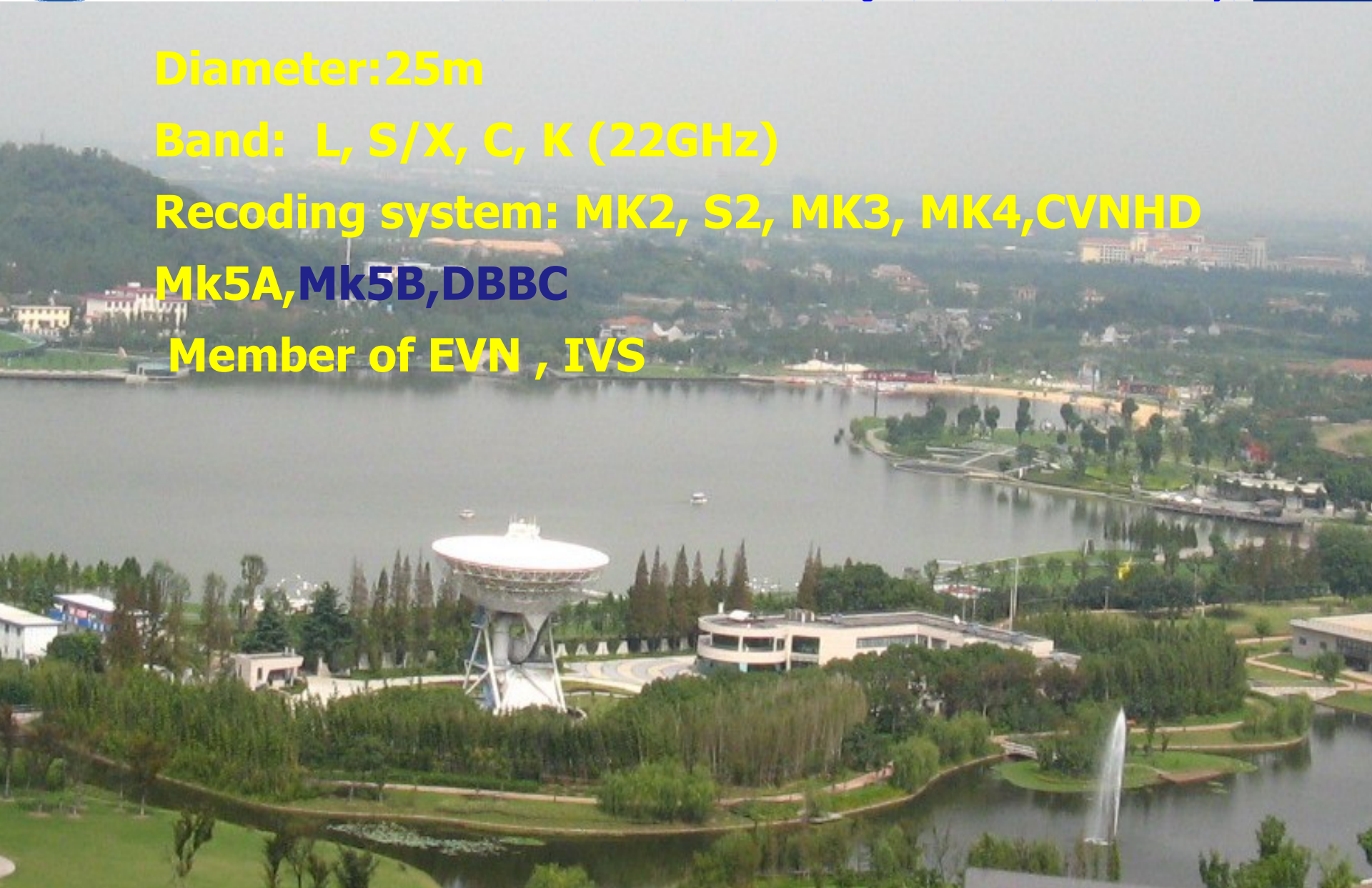
Diameter: 25m

Band: L, S/X, C, K (22GHz)

Recoding system: MK2, S2, MK3, MK4, CVNHD

Mk5A, Mk5B, DBBC

Member of EVN , IVS





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CVN—Urumqi station

November, 1993



November, 1993



September 26, 1992

Diameter: 25m

**Band: P, L, S/X, C, K(22GHz) ,
also 30 and 49 cm**

Recoding system: MK2, MK3, MK4,

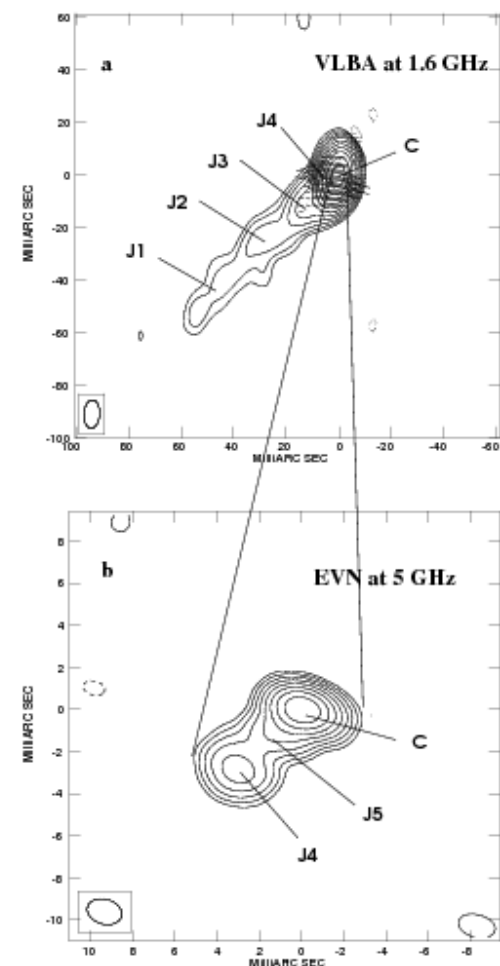
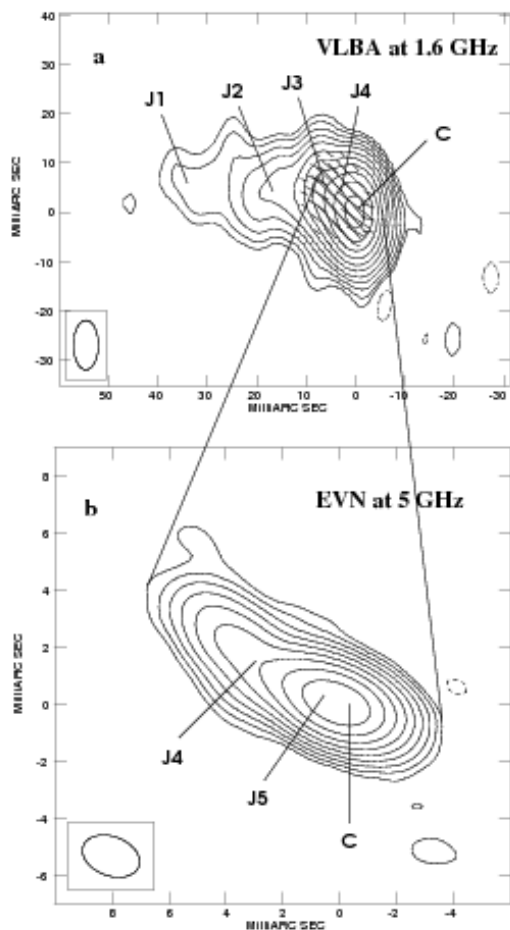
K-4 , K-5, CVNHD, Mk5A , Mk5B, DBBC

Member of EVN , IVS





Sheshan and Urumqi both are the member of EVN and IVS





Mobile VLBI

A Mobile VLBI System with 3m antenna was constructed by SHAO for the Xi'an Surveying and Mapping Institute in 2000 which is located in the Yunnan Astronomical Observatory.





CVN - Kunming station

Antenna Construction

Started at 2005.6

Ended at 2006.5.21





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The Kunming 40-m Radio Telescope

Diameter: 40m

Band : S/X

Recording system: Mk5A,Mk5B,DBBC, Hydrogen maser;
GPS





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CVN – Beijing Station





Diameter: 50m
Band: S/X
Recording system: Mk5A, Mk5B, DBBC
Hydrogen maser; GPS

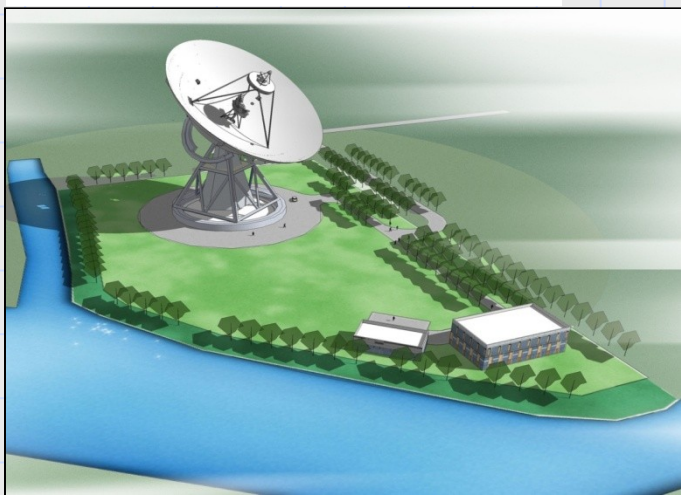


New telescope in Shanghai



- ◆ Diameter: 65m
- ◆ Bands: 8 bands

band	wavelength (cm)	Bandwidth (GHz)	Pol.
L	21/18	1.30~1.75	dual
S	13	2.20~2.45	dual
C	6/5	4.50~7.00	dual
X	3.6	8.00~9.00	dual
Ku	2.5/2.0	12.00~15.00	dual
K	1.35	21.00~24.00	dual
Ka	0.9	30.00~34.00	dual
Q	0.7	40.00~46.00	dual



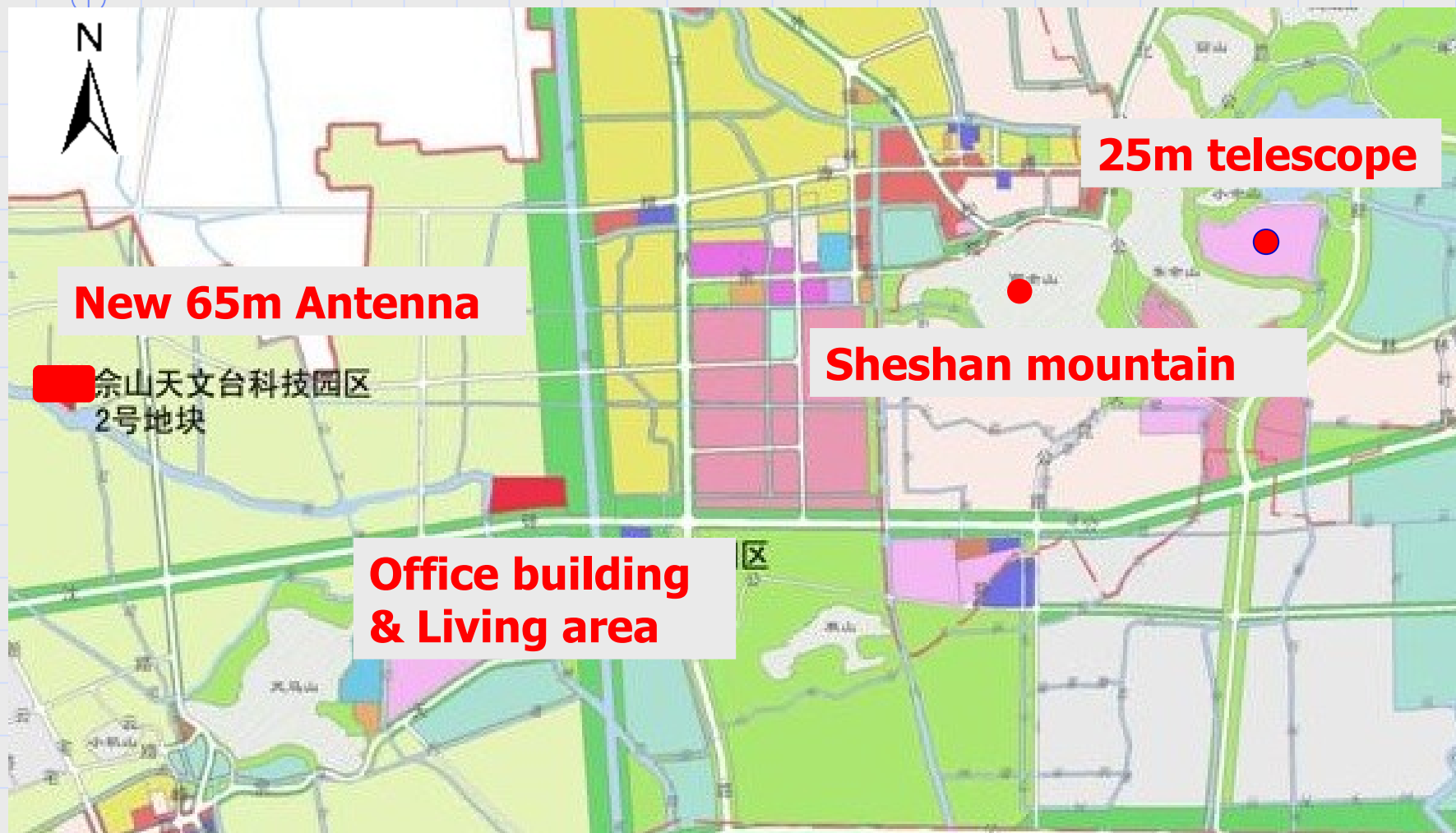


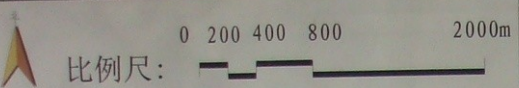
Applications of 65m telescope

- ◆ Astrophysics research with single dish, special for some spectral lines.
- ◆ Astrophysics research with VLBI.
- ◆ Astrometry research with VLBI.
- ◆ Applications for space projects.

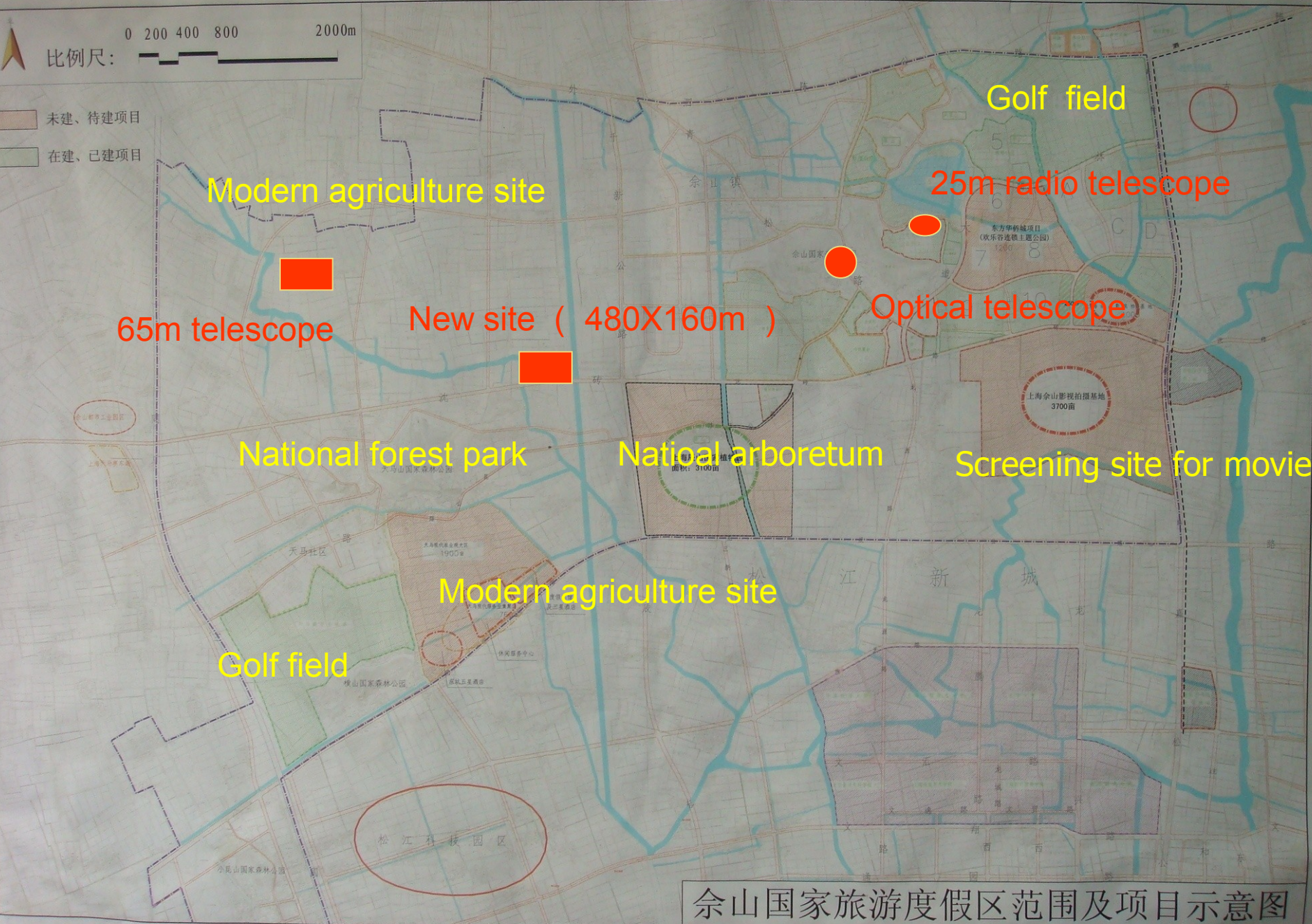


Location





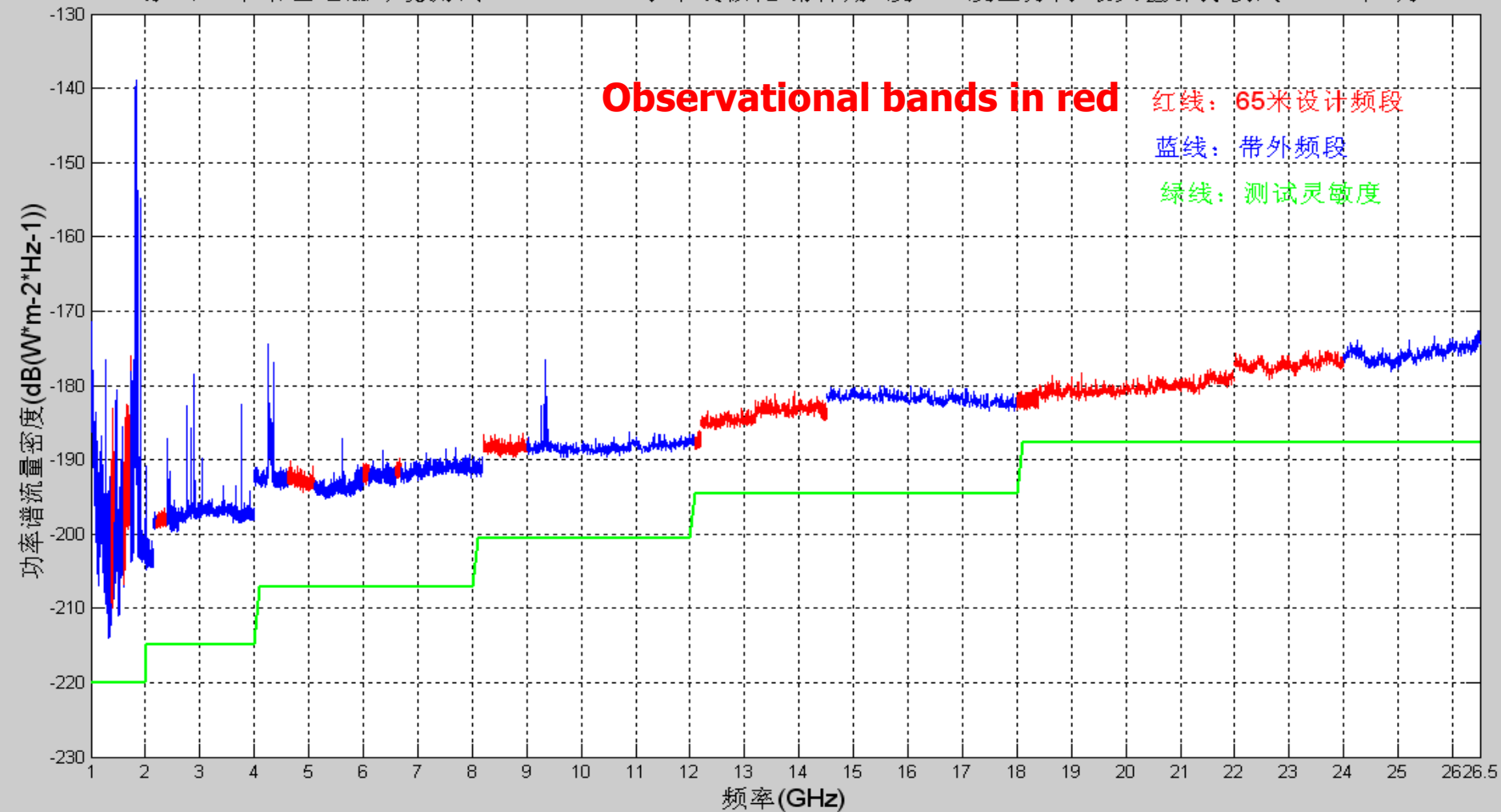
未建、待建项目
 在建、已建项目



佘山国家旅游度假区范围及项目示意图



佘山65米站址电磁环境测试/1~26.5GHz/水平线极化/俯仰角0度/360度全方向/最大值保持模式/2008年5月





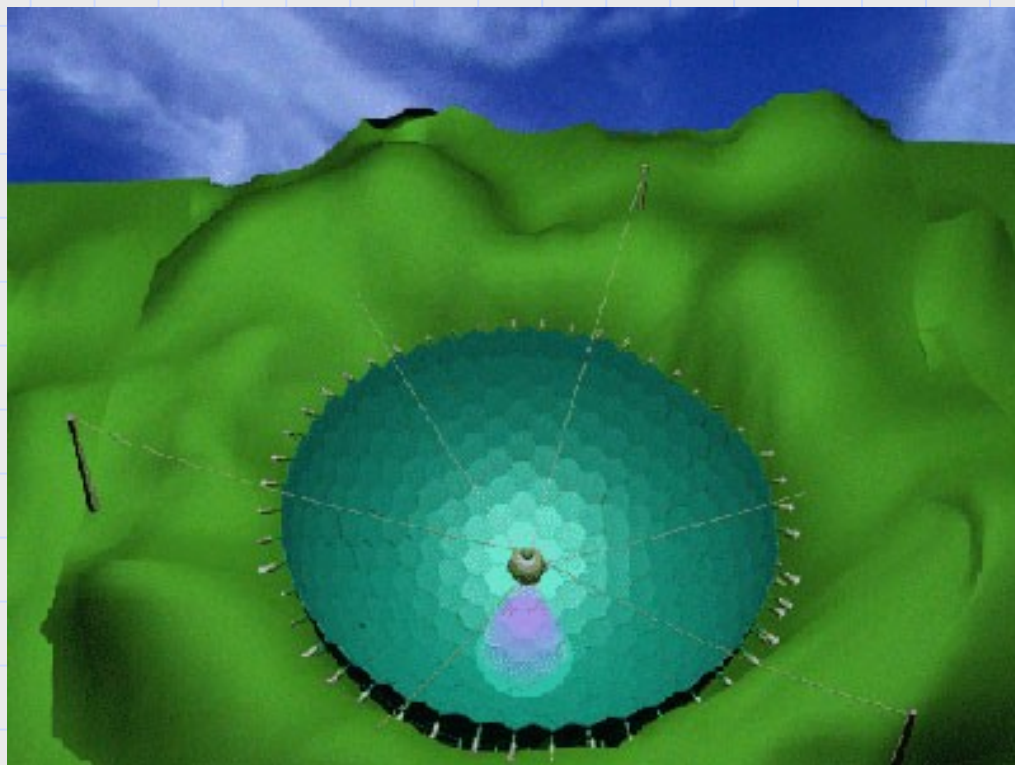
Construction

- ◆ Shanghai government offers us a land about 150X400 m
- ◆ The new telescope will be supported jointly by Shanghai government and Chinese Academy of Sciences.
- ◆ The new telescope should be ready in 2012.
- ◆ Manufacturer choosed, Under designing now



NAO's FAST for VLBI

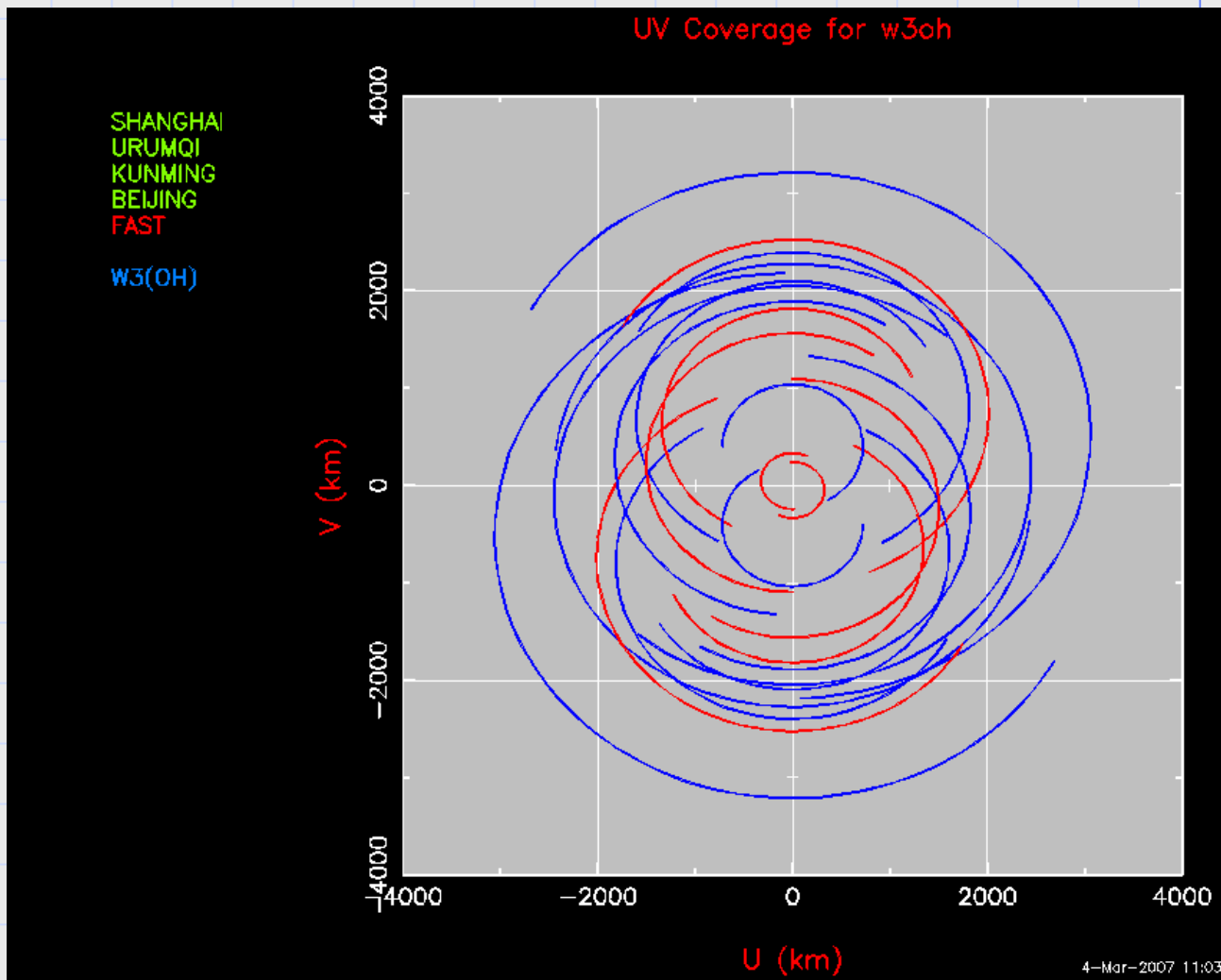
- ◆ Diameter: 500m
- ◆ 70 MHz – 3 GHz
- ◆ Extending to 8 GHz
- ◆ Location:
Guizhou province,
South of China
karst landform





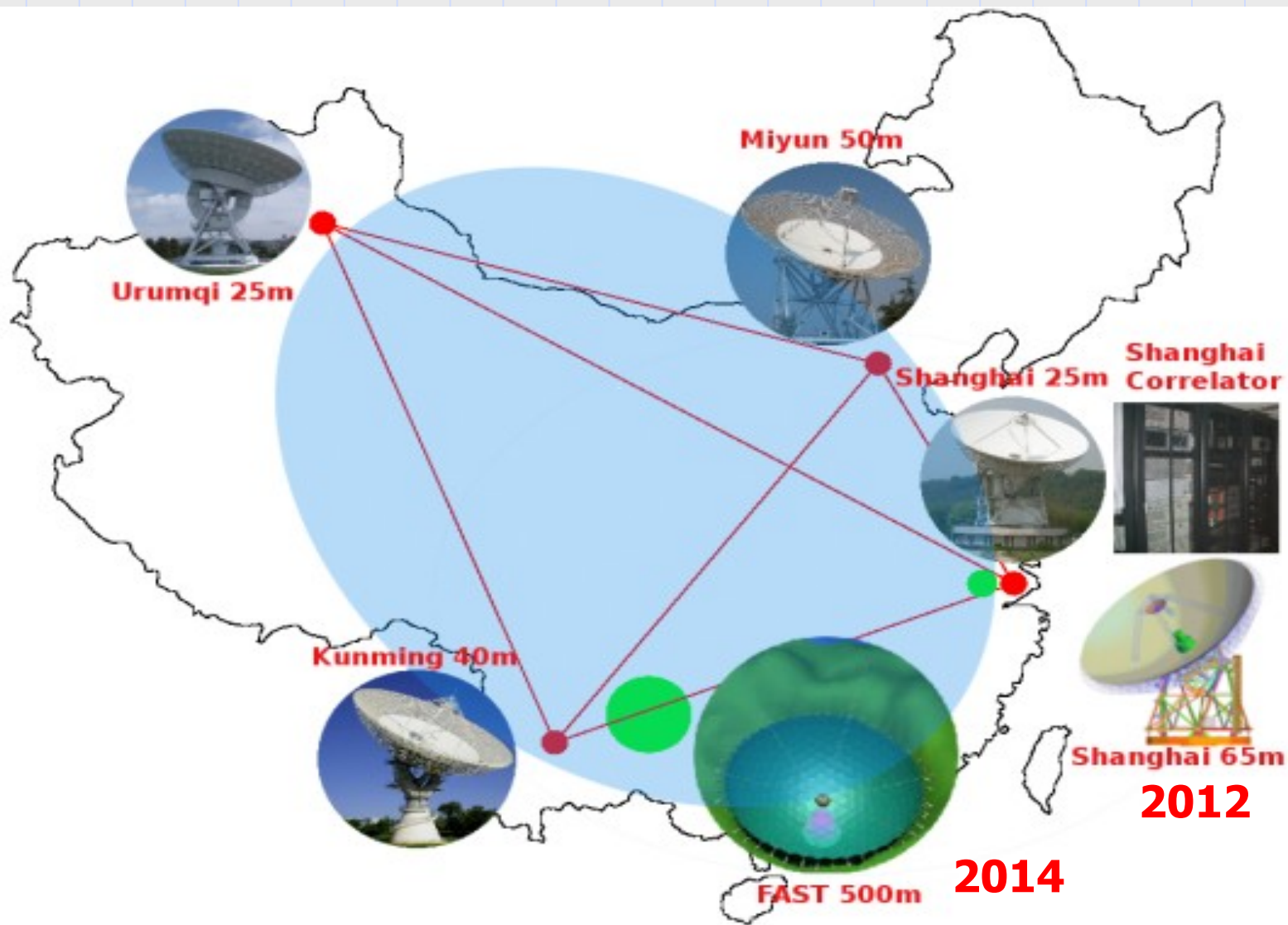
5 stations uv coverage

- ◆ Shanghai
- ◆ Urumqi
- ◆ Kunming
- ◆ Beijing
- ◆ FAST





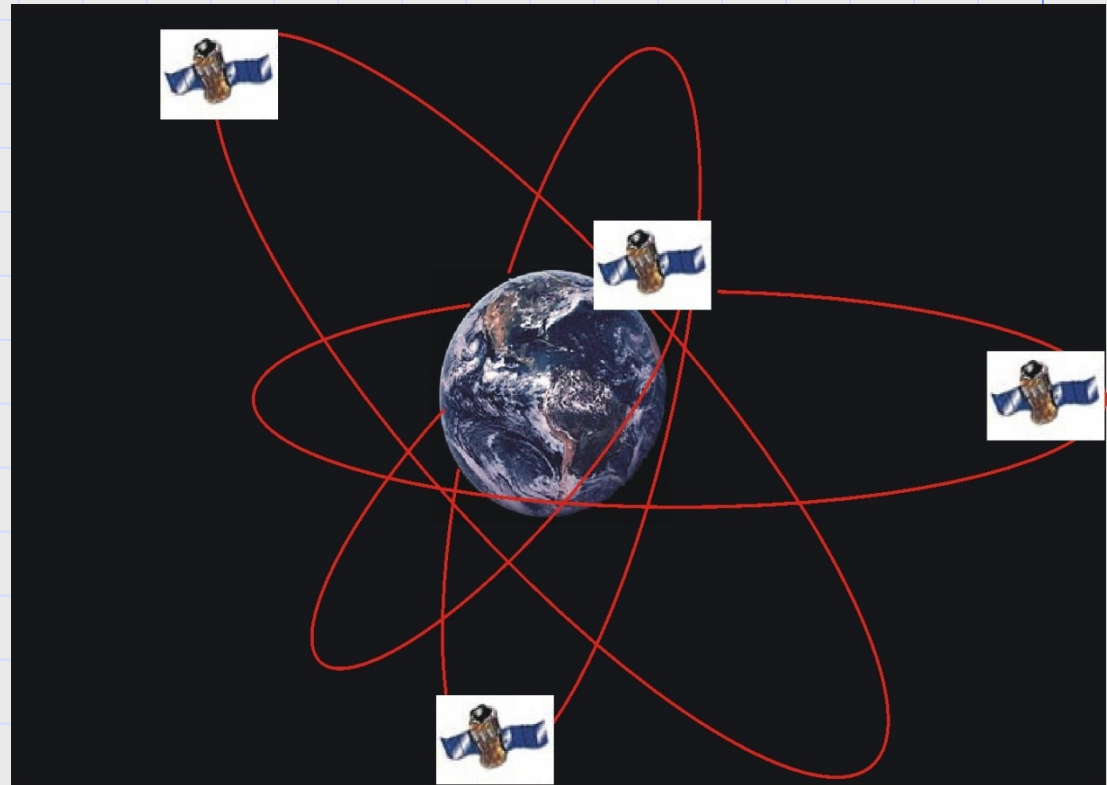
Future VLBI Network in China





Space mm-VLBI array

- ◆ SMVA
(Space mm VLBI Array)
- ◆ 4-6 antennas
- ◆ ~ 20 GHz- ~ THz





CVN -- VLBI data processing center

Hardware correlator (5 stations)

Software correlator (5~10 stations)

Output data: CE-1 format

FITS format (will be available)

Correlators for CE-1 data processing

**(near real time eVLBI, demand in 10 min,
actually in 5 min.)**





ShAO VLBI Center

◆ Hardware Correlator

- 5 Stations FX Correlator (5 stations, 8 IFs)
- Maximum data rate : 256Mbps (8 channels)
- Input data format: MKIV, MKV
- Data source : Disk Array, Network
- Output: network and disk files
- CE-1 specified



ShAO VLBI Center

◆ Software Correlator

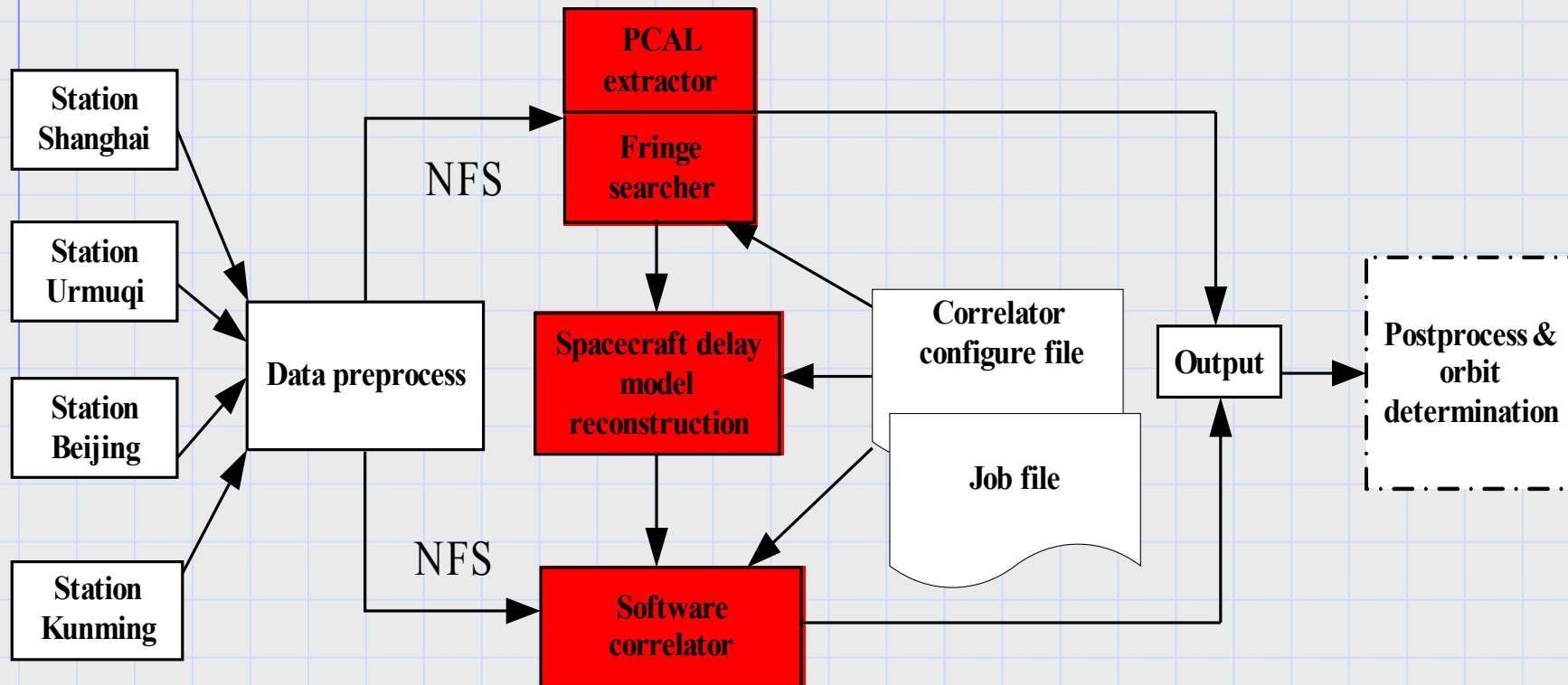
Correlation station number	1~10
IF number	1~16
FFT points/ IF	32 ~65536/IF
Integration period	0.1~60 second
Input data format	Mark5A(1:1, 1:2, 1:4 fanout)
Sampling	1bit, 2 bit
Output data format	CVN (one-minute based)
Fringe search	2-4 stations
Correlation speed	>128Mbps/station (4 stations, 1024/IF)
Data latency	< 3 minutes
PCAL detection	Yes



- Near real time correlation ability (< 3 min)**
- Special functions:**
 1. **Fast satellite fringe search and model reconstruction**
 2. **Full PCAL detection ability, CE-1 mode**
 - ✓ **8 PCALs, 4-channel, BW=2MHz/channel**
 - ✓ **64PCALs, 8-channel, BW=8MHz/channel**
- Correlation speed:**
 - 128Mbps/station, 2bit sample, 4 stations,**
 - on 16-CPU core server**



Block diagram



One-minute based
NFS: Network File System



DBBC

◆ Characteristics

- Four IFs input

Bandwidth: 512MHz/IF , 1024MHz/IF is possible

- Two MK4 interface output to MK4 formatter
- Two VSI interface to MK5B⁺ / MK5C Disk Array
- 10Gbps network connect in plan
- 16/32 channels , 0.5/1/2/4/8/16MHz / ch, 1/2/4 bits/ch
- Frequency resolution : 1Hz / step
- Full compatible FS interface of traditional DAQ (H&S)
- PCAL and auto-spectrum output



DBBC

◆ Characteristics

- Two channel DAC for channel output signal monitor
- Download different FPGA-Core :
 - ◆ compatible with DBE
 - ◆ compatible with DBBC
 - ◆ Different BBC with different band width in same observation time for tracking requirement

(Δ DOR Δ DOD SBI phase reference mode)

◆ Installed at all 4 CVN stations:

SH,BJ,KM,UR as testbed.

◆ Add 10Gbps network interface in plan



CVN

Technical developmemnt

correllator: more stations, 10?
more flexible

FITS format:

digital BBC:

Astronomy application

C band may be possible for BJ and KM in near future?



CVN for Sciences

4 stations VLBI Network

1) 13/3.6 cm (s/x) geodesy , AGN

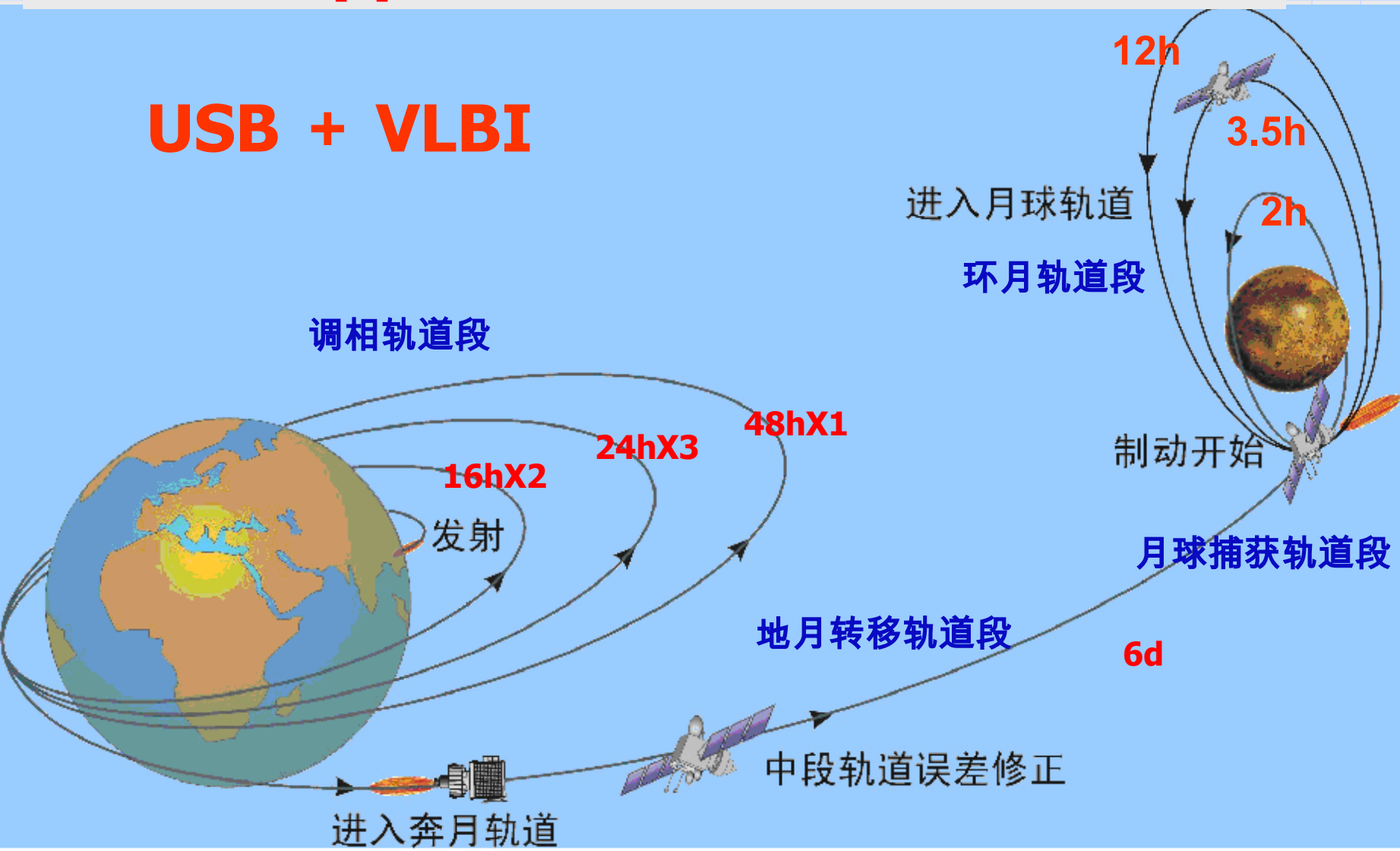
2) 6 cm (C) 4.2-7.7 GHz
AGN , Pulsar , CH₃OH

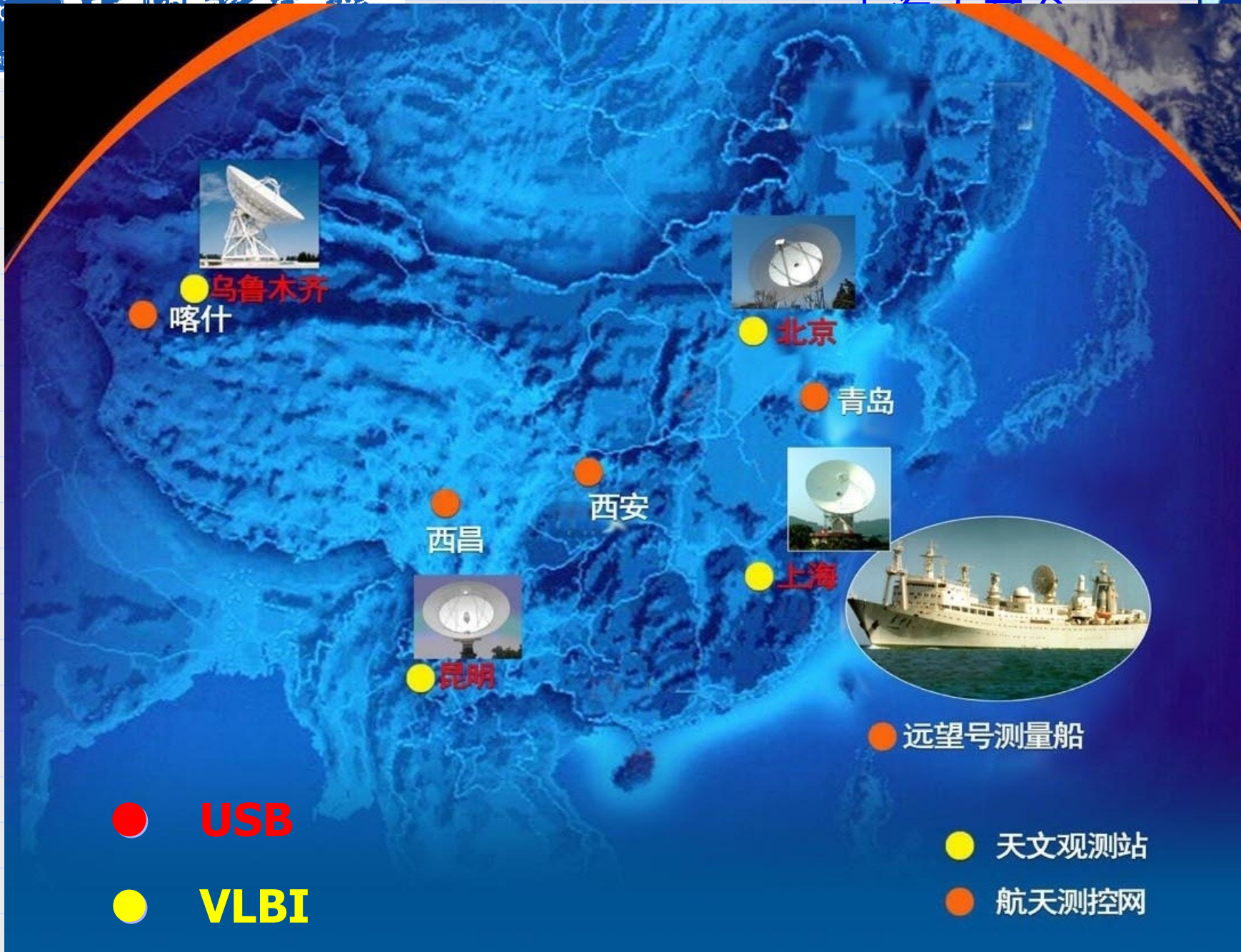
3) 18 、 20 cm (L) AGN , Pulsar , OH



CVN -- Application for CE-1

USB + VLBI





● USB

● VLBI

● 天文观测站

● 航天测控网

● 乌鲁木齐

● 喀什

● 北京

● 青岛

● 西安

● 西昌

● 上海

● 昆明

● 远望号测量船



1) stations



2) Network 16Mbps

3) VLBI center



VLBI data

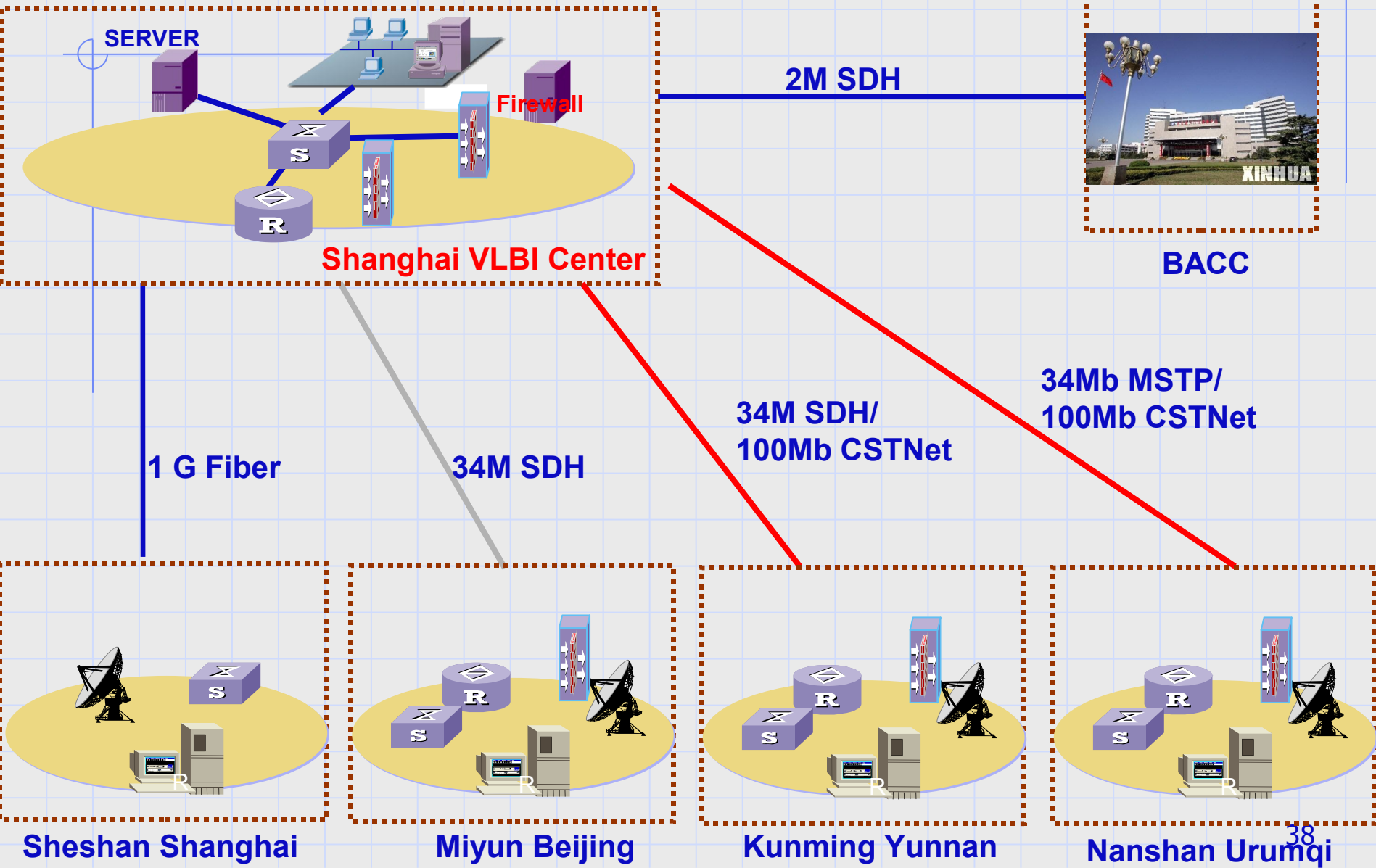
In 5 min.

USB data

Beijing center

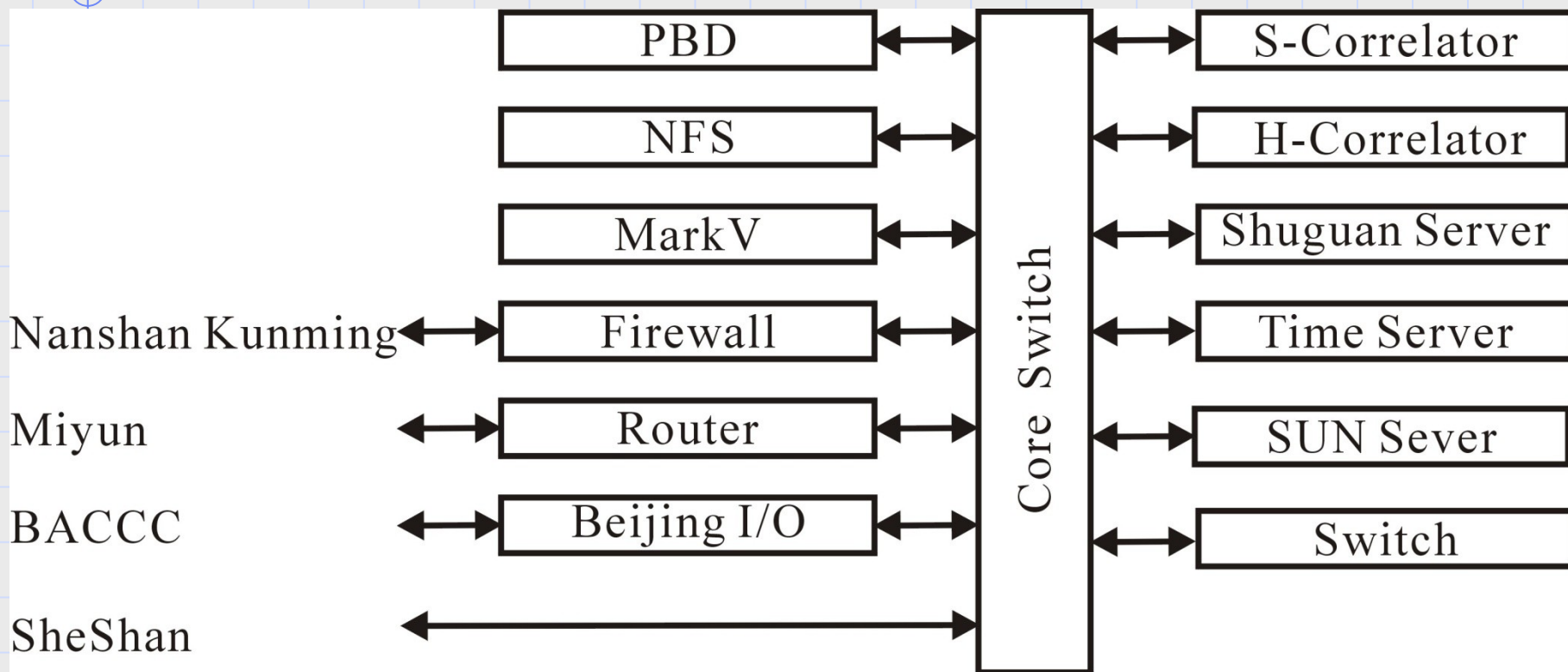


Network of CVN for CE-1





Network of VLBI Center





CE-1 Tracking

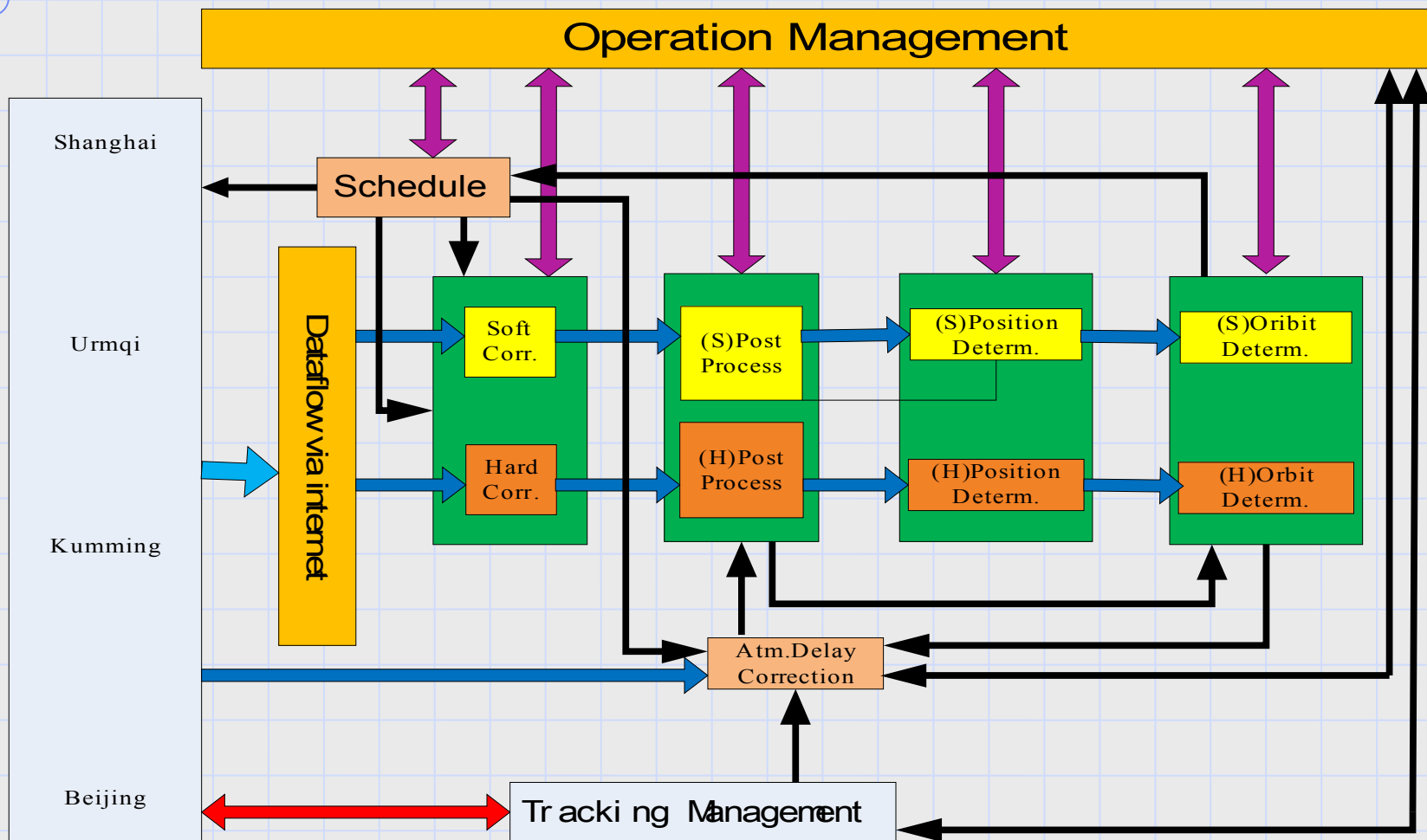
- ◆ Orbit determination: USB+VLBI
- ◆ VLBI tracking
 - distance $> 20000\text{km}$
 - elevation > 5 degree
 - output data: baseline delay
 - baseline rate
 - angular position
 - output delay time: $< 10\text{minutes}$

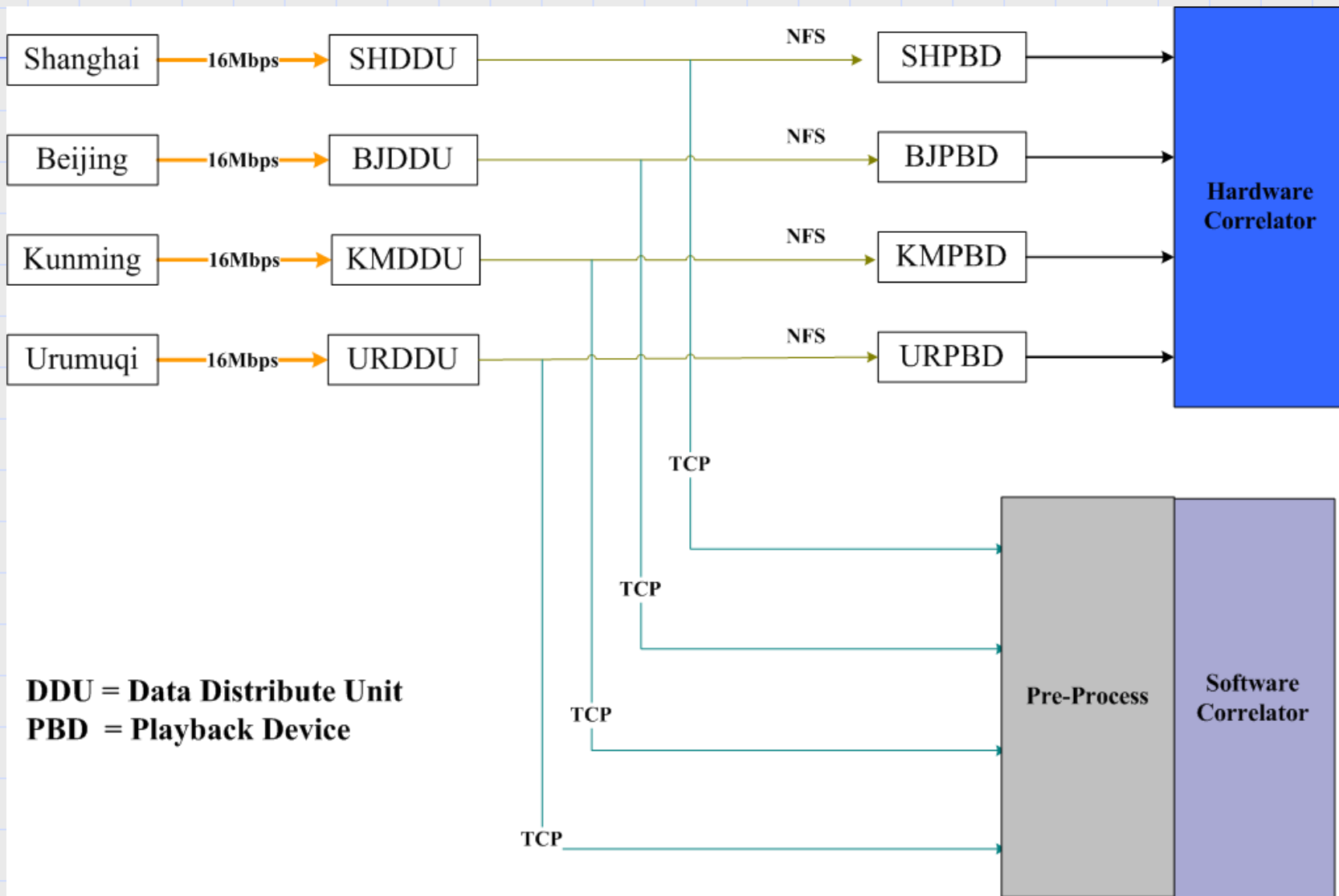


- ◆ correction for the clock and instruments
delay:
Quasars observation
- ◆ Correction for atmospheric effect:
GPS & station weather parameters



Software correlator + hardware correlator





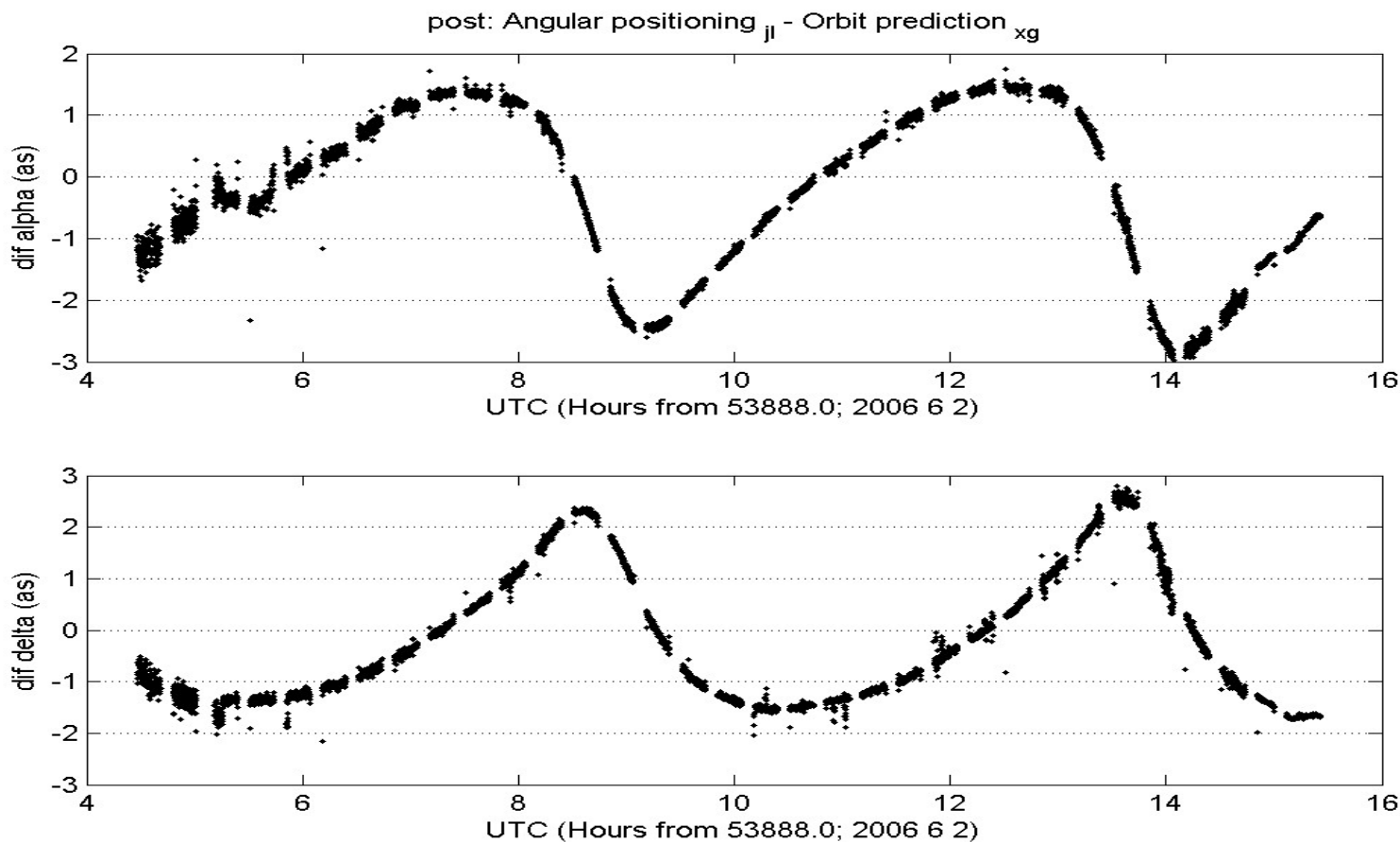


CE-1 Track activities

- ◆ 27 Oct.– 30 Nov. 2007
near real time mode tracking, 16Mbps
- ◆ From Dec.2007: 2 days/week
recorded in the Mark5A disks, 128Mbps
output data : two weeks late
- ◆ 1 March, 2009:
Hit on the moon, successfully ended mission
ftp fringe check -> disk recorded



2 June 2006 Smart-1:
Angle differences between VLBI measured and predicted values

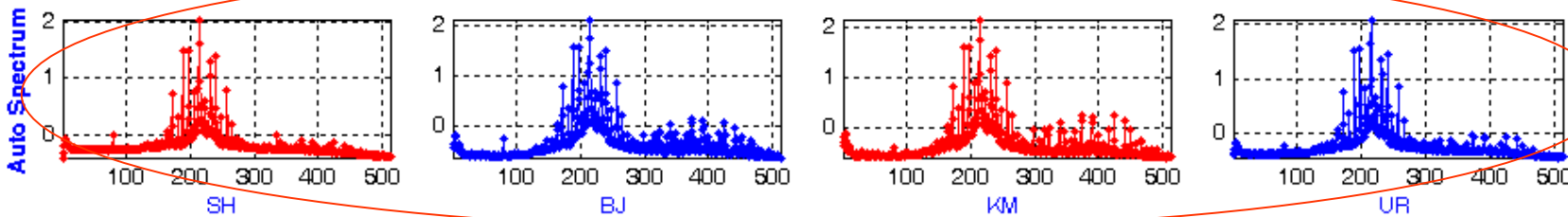




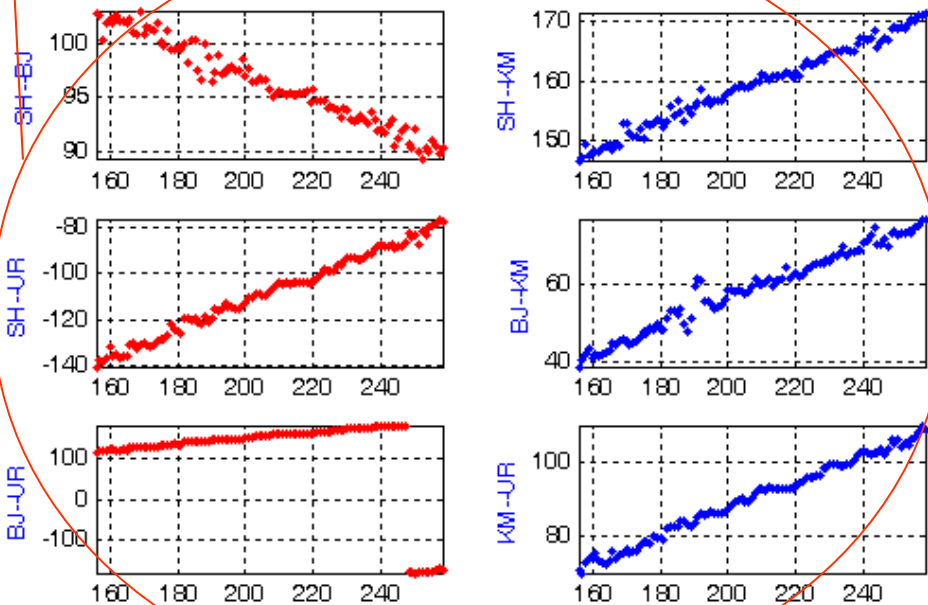
S band signal

delay

Auto spectrum



===Baseline Cross

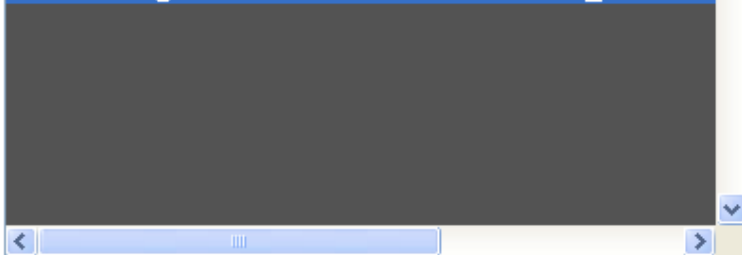


S.Interval(s)	6	NFFT Avg. to	-1
BandWidth(MHz)	2	Nfft	512
Int.Time(s)	1.048576	FFTPages	57

BBC Freq. Setup:

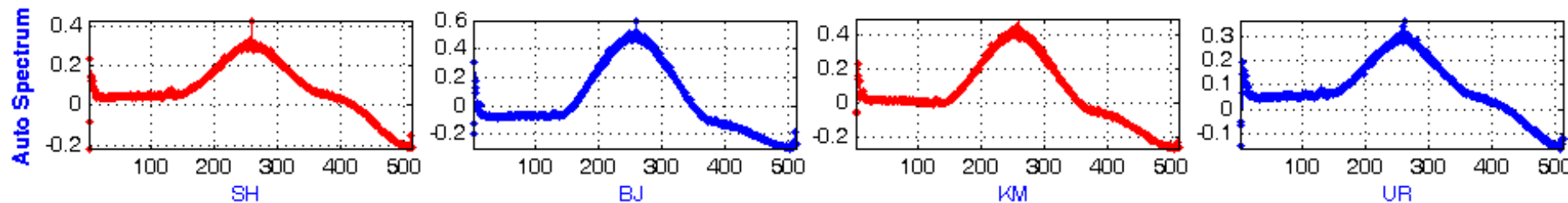
01#2233.69; 02#2209.99; 03#8439.01; 04#8459.01;

Processing FILE 203 2007310233300000_SAT-CE

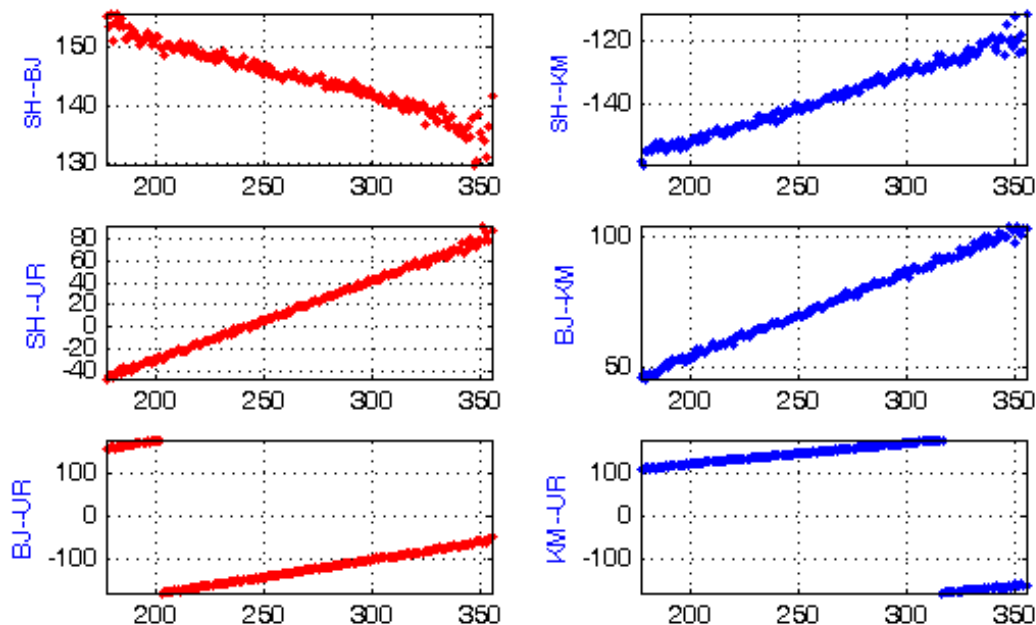




X band signal



===Baseline Cross Phase===



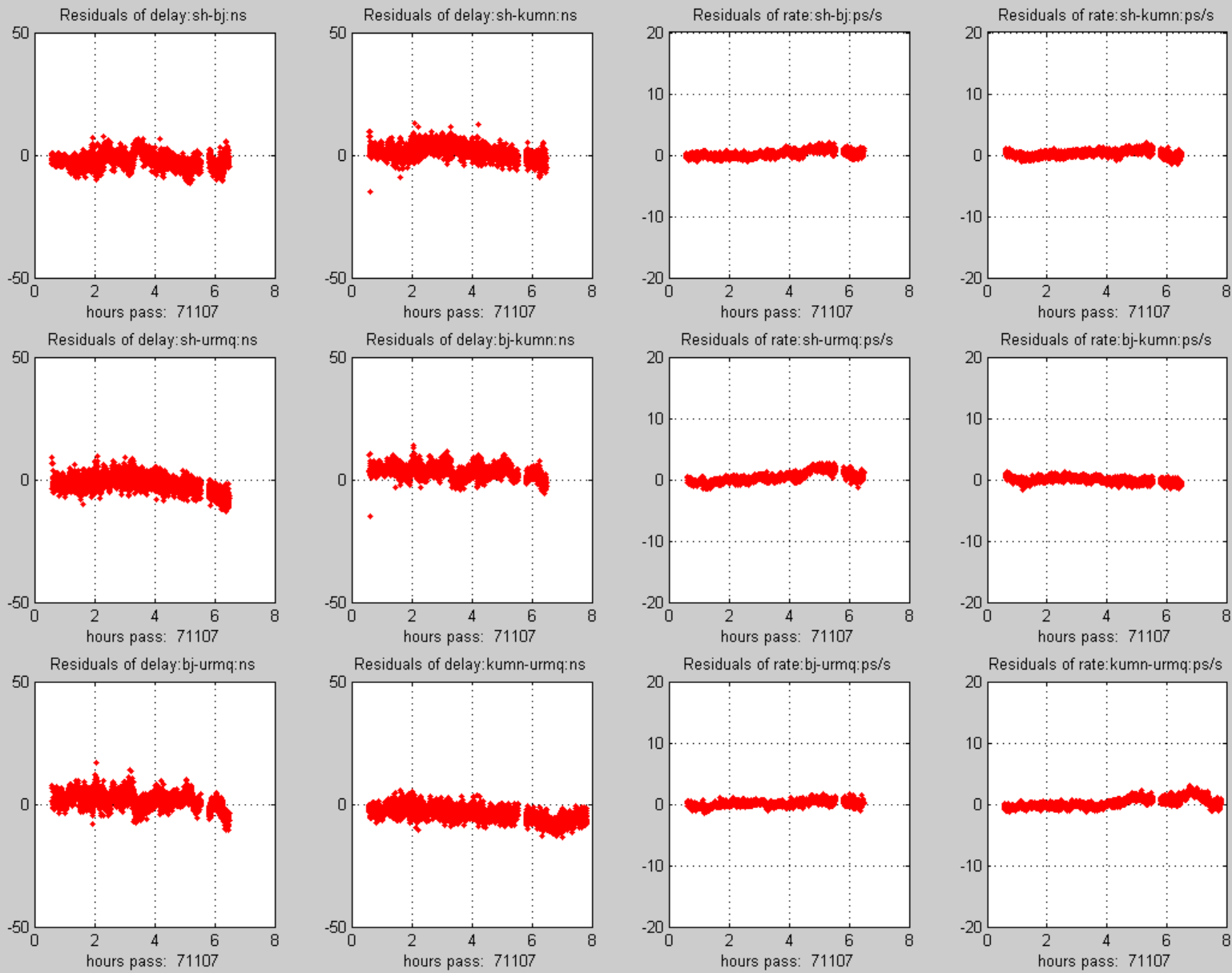
S.Interval(s)	6	NFFT Avg. to	-1
BandWidth(MHz)	2	Nfft	512
Int.Time(s)	1.048576	FFTPages	57

BBC Freq. Setup:

01#2233.69; 02#2209.99; 03#8439.01; 04#8459.01;

Processing FILE 364 200731102150000_SAT-CE01.dat
Warning: insufficient data points: 4 File: 364 Baseline: 1
S-band freq is not in order

after orbit determination

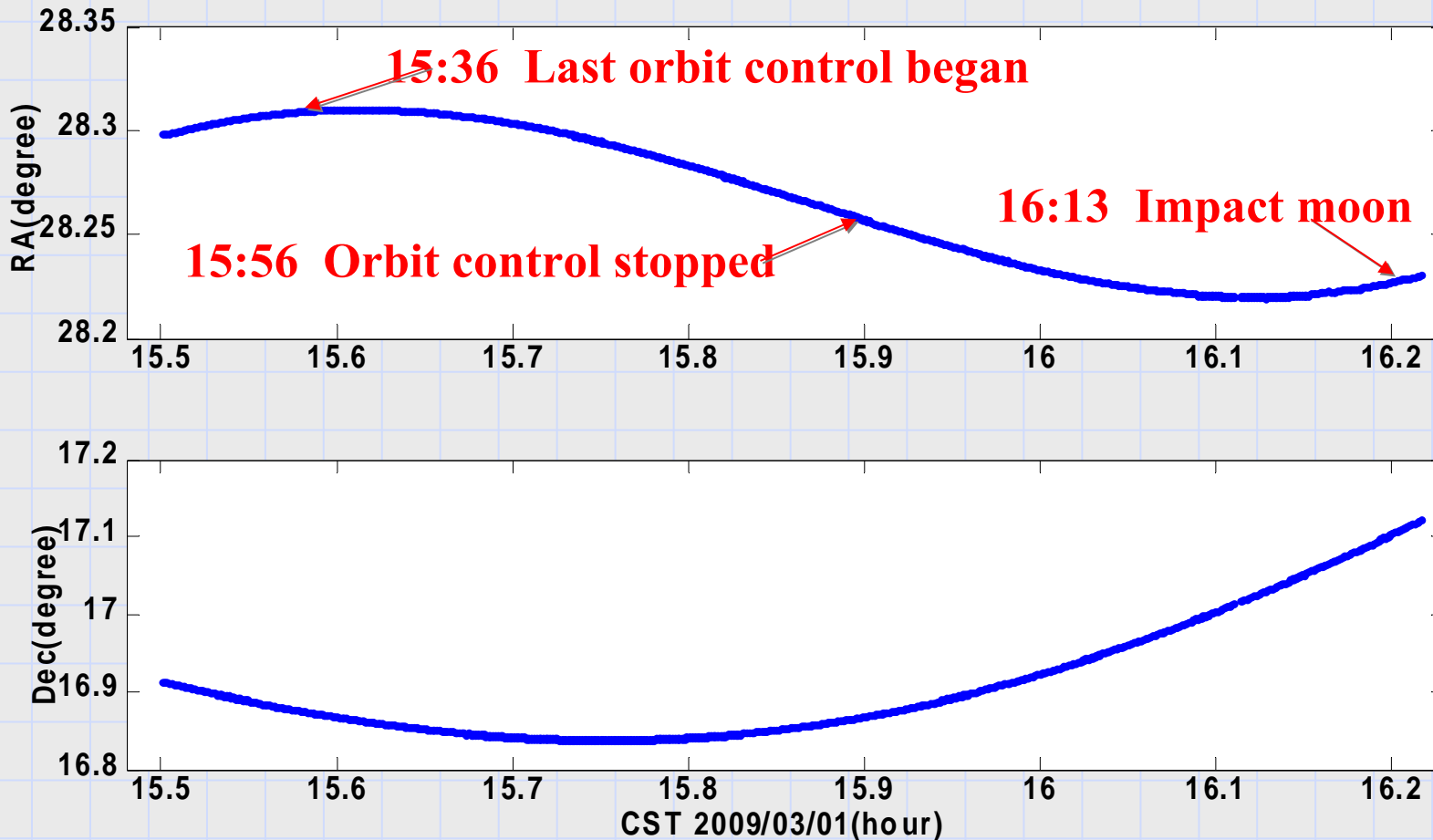


delay

rate



Angle position of CE-1 in moon impact





VLBI in CE-1 project

- Reliable, flexible, Important in CE-1
- Processed 1006.9 hours data
- Critical flying mission
 - 36 near-real time experiments, 336.55 hours sent out 336.55 hours
- Long-term in-orbit operation
 - 113 experiments, 670.35 hours sent out 434.02 hours
- ✓ Including real-time CE-1 maneuver tracking
- ✓ Geodesy (CVN station position)



Space exploration missions

- ◆ YH-1 Oct, 2010 (Mars explorer)
Sino-Russian, Disk-based
- ◆ CE-2 2012, orbiting
Near Real-time tracking, like CE-1
- ◆ CE-3 2013, 2014 landing
Real-time, 128Mbps



eVLBI Demo

First e-VLBI data from China-Australia, China-Europe and Australia-Europe baselines in the Oct. of 2007





Demo

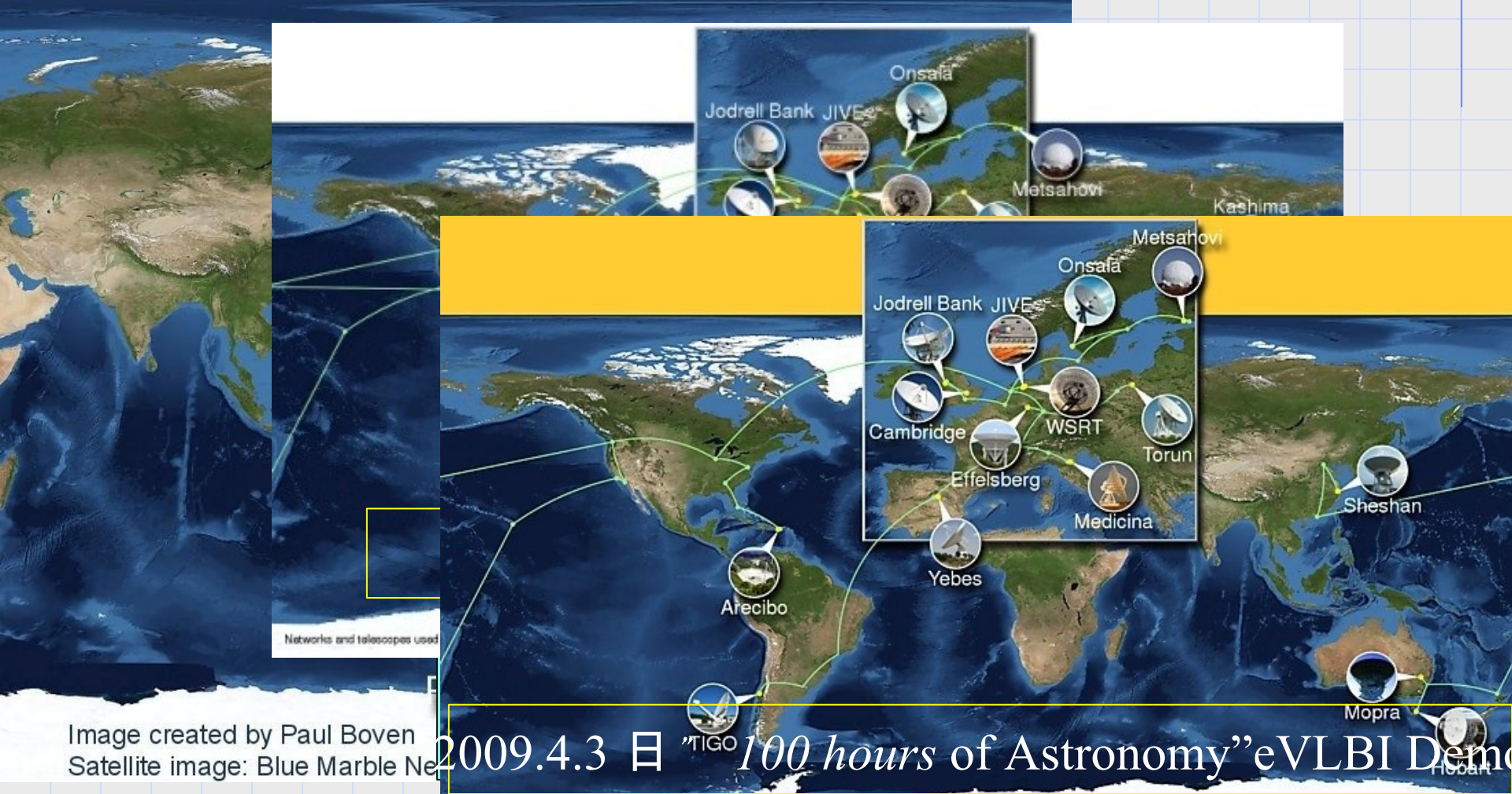
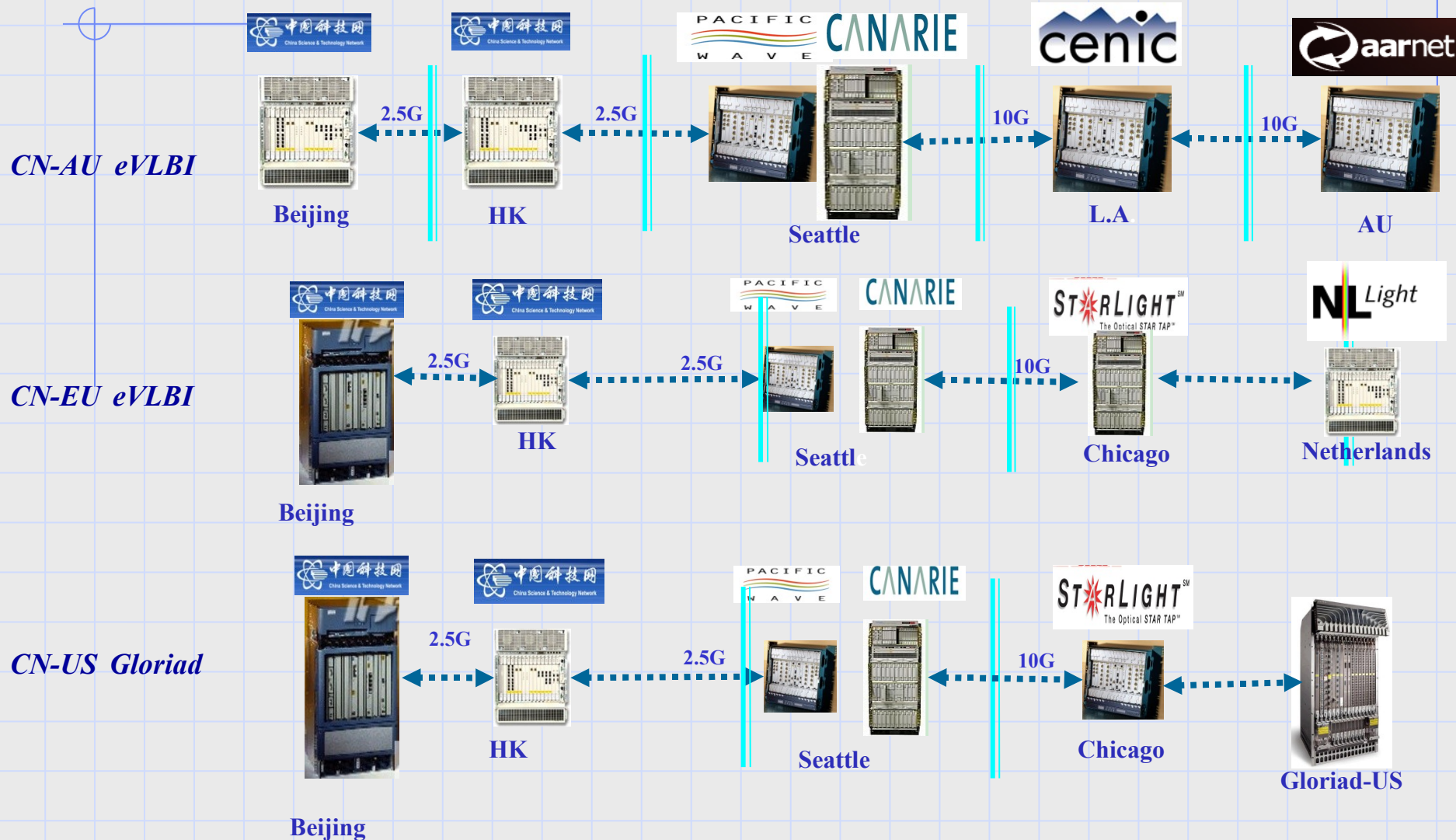


Image created by Paul Boven
 Satellite image: Blue Marble Next Generation

2009.4.3 日 "TIGO 100 hours of Astronomy" eVLBI Demonstration

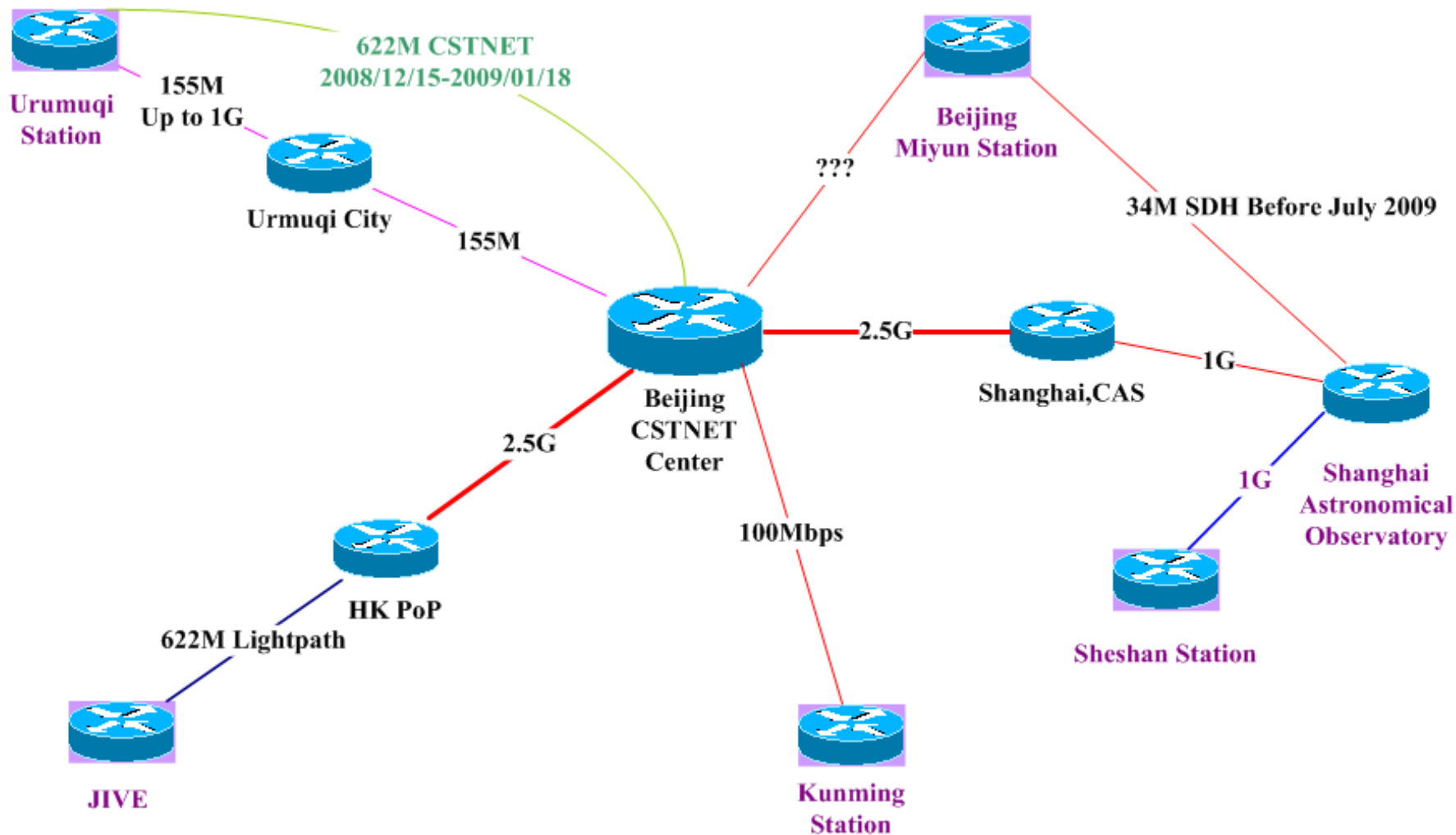


eVLBI Internet Lightpath



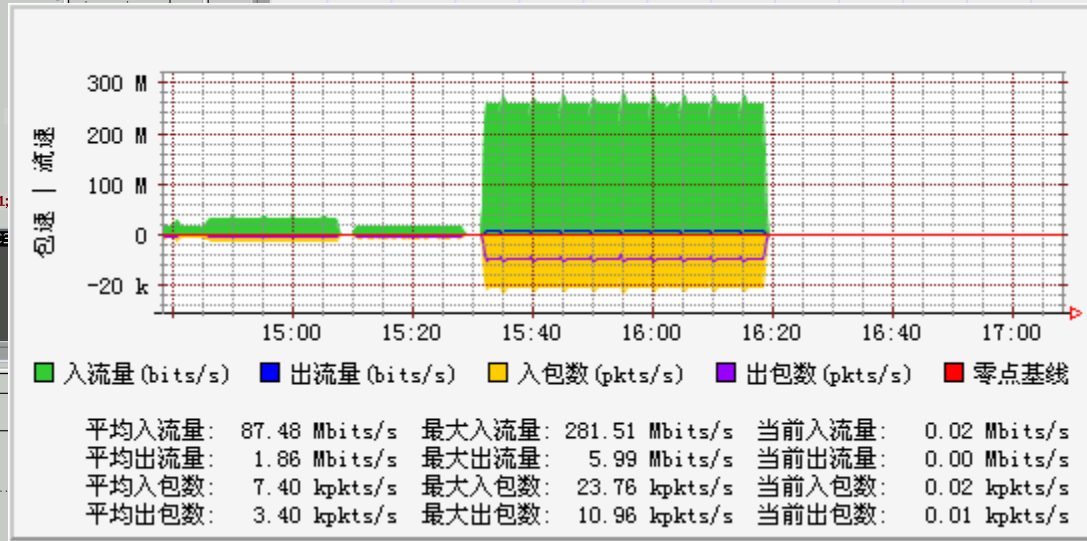
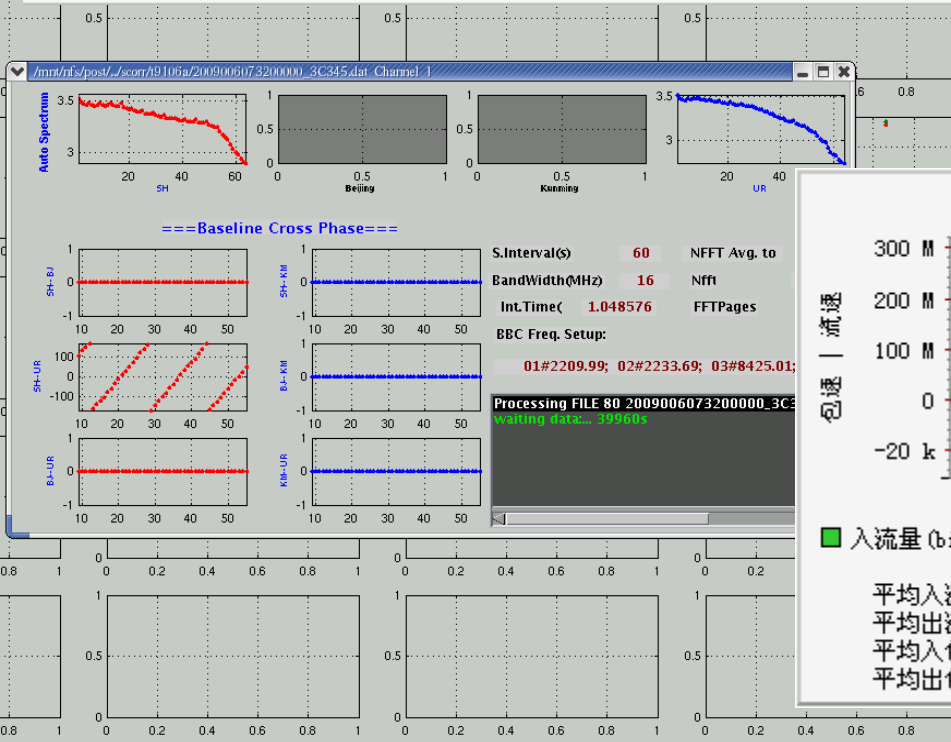
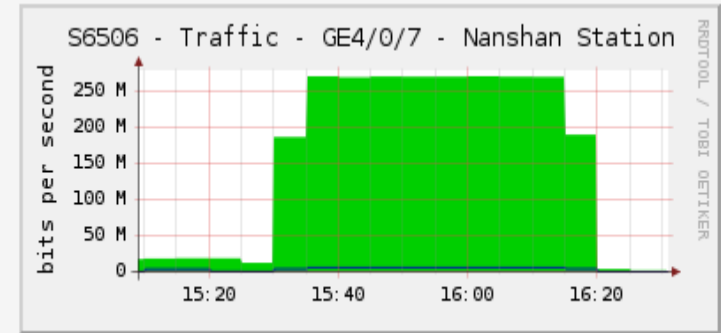
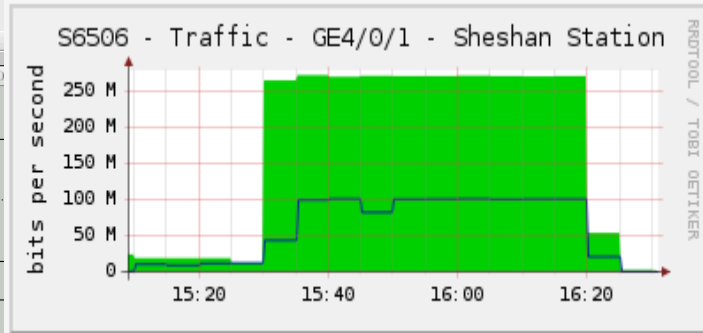


Network Bandwidth





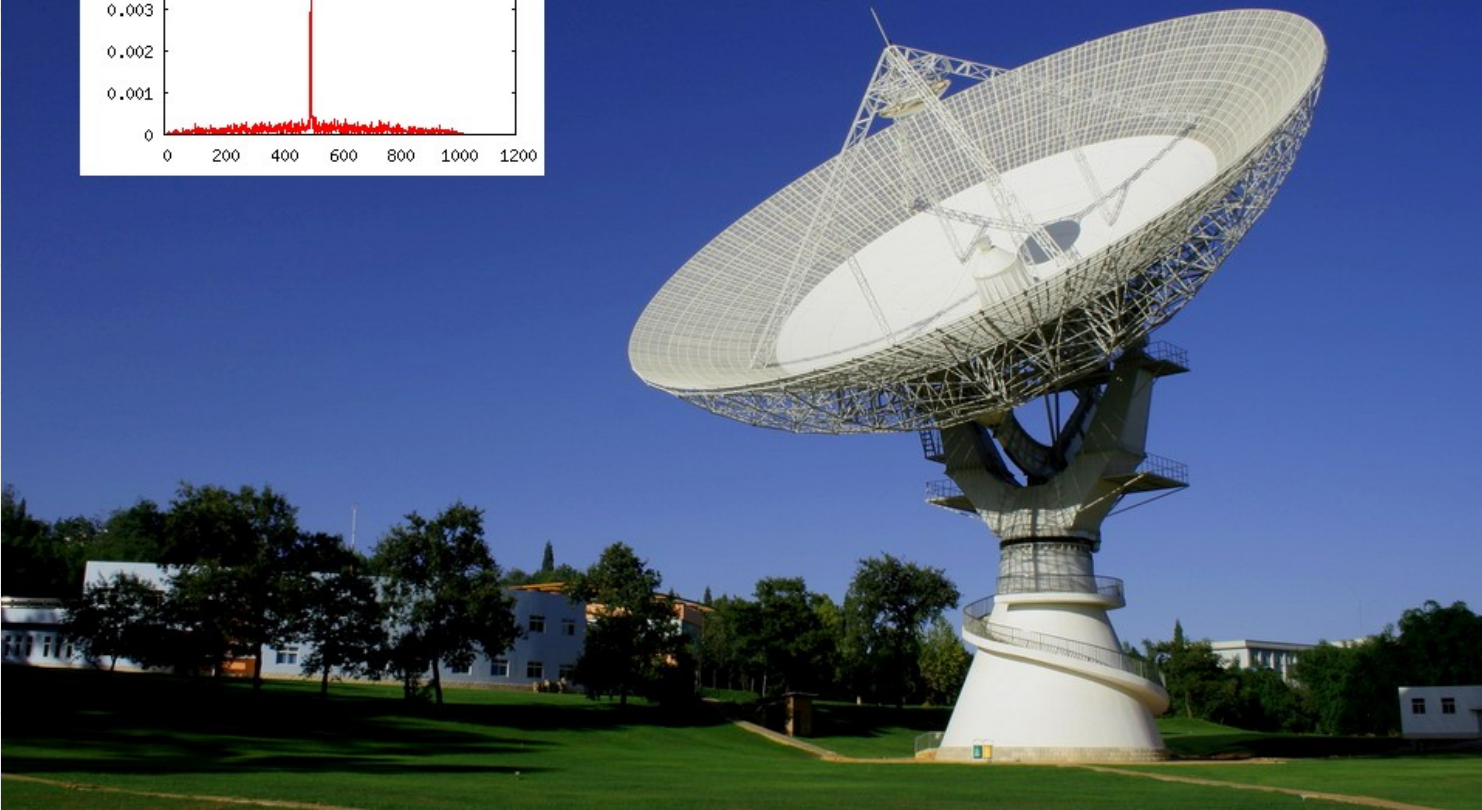
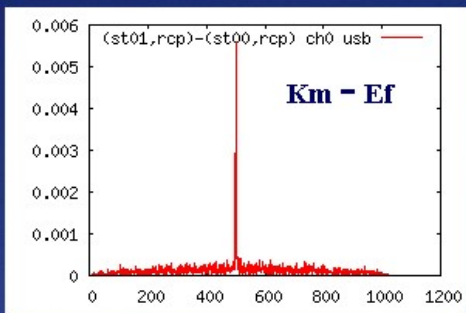
First time Sh-Ur 256Mbps e-VLBI demo





First time Kuming station fringe

First fringes to the new Kunming 40-m Radio Telescope





CVN Future

- ◆ Telescope: 6 stations with DBBC
- ◆ VLBI center
- ◆ Software correlator: cluster + GPU (?)
- ◆ eVLBI application:
 1. Astronomy
 2. Geodesy
 - Project: Crustal Movement Observation Network of China
- ◆ Deep space exploration
 - Lunar Project, Mars probe tracking YH-1
- ◆ Network
 - Broad bandwidth & budget?



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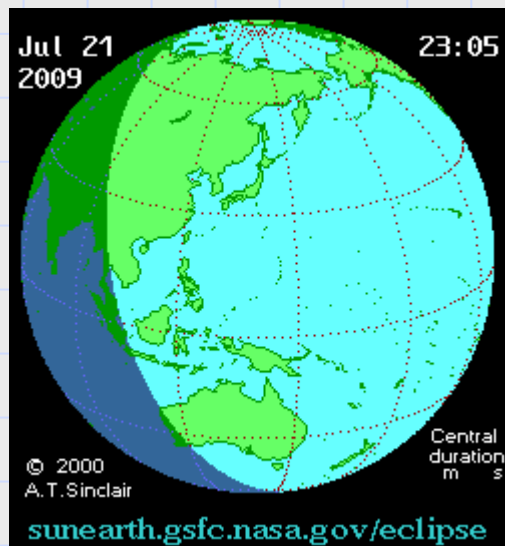
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Reminder

◆ 22 July, 2009





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Thank you! 😊