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Open-Loop Tracking Plays Important Role in Chinese Chang'E Lunar Exploration Missions

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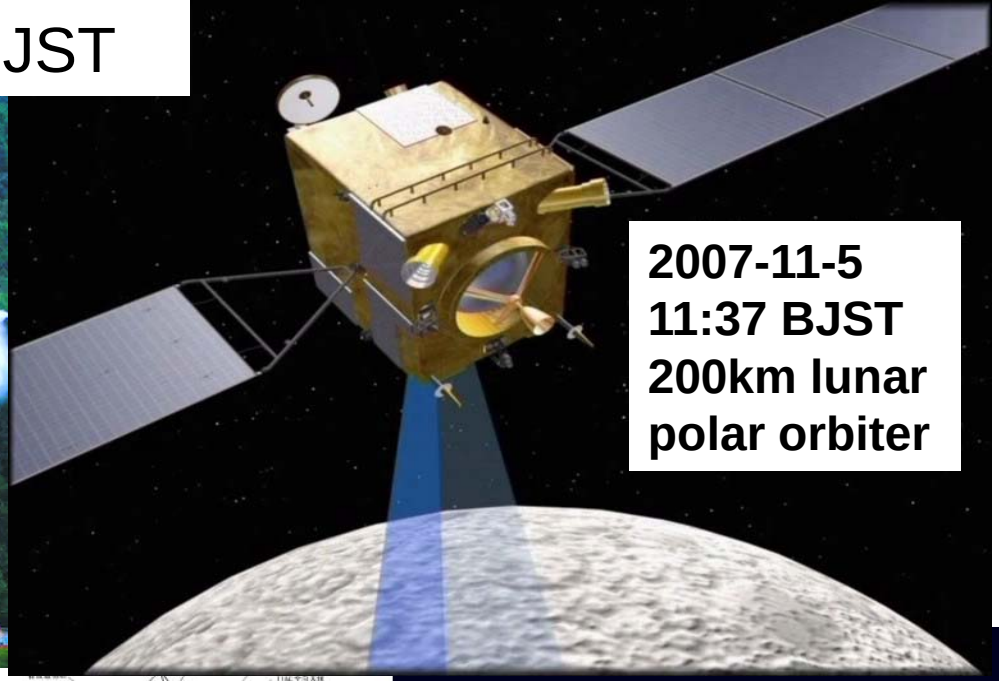
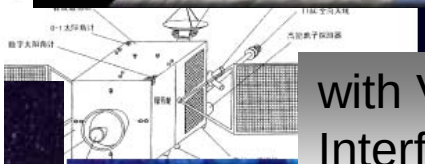
Three Phase of Chinese Lunar Exploration

Launching 2007-10-24 18:05BJST



2007-11-5
11:37 BJST
200km lunar polar orbiter

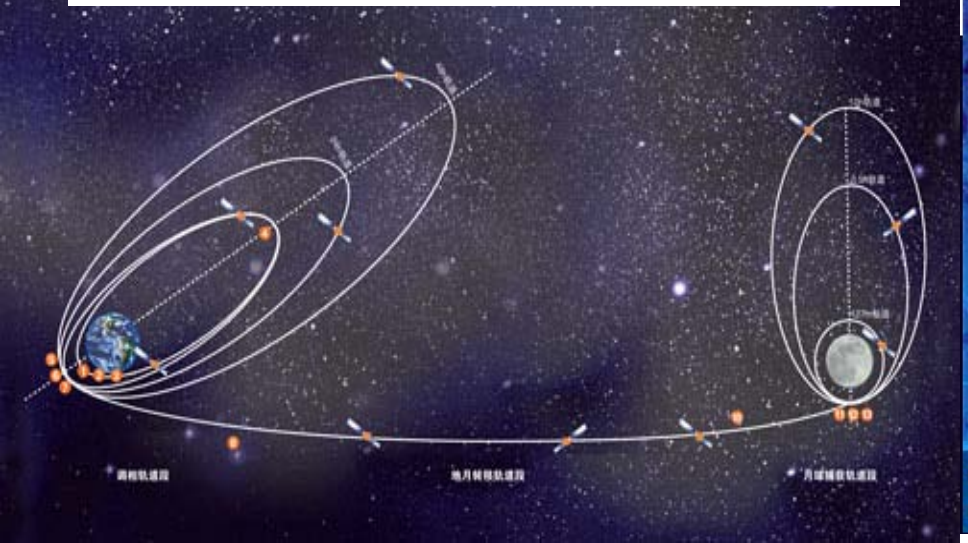


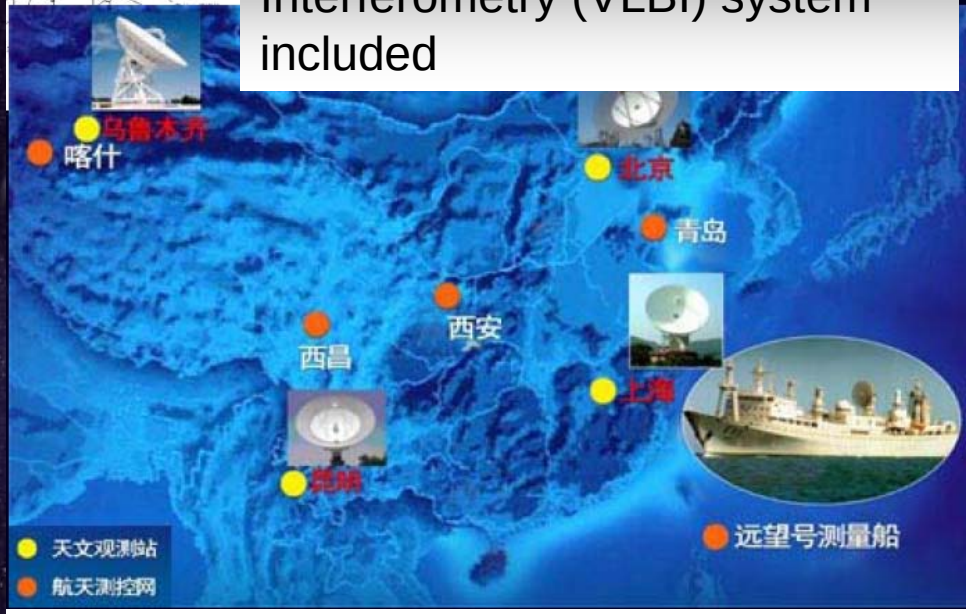
Chang'E tracking network

with Very Long Baseline Interferometry (VLBI) system included

red points: real time

monitoring the flying status





VLBI for lunar and planetary exploration

2006.5 USB + VLBI was adopted to track ESA Smart-1 mission in China, with the support from ESA.

After that, in July 2006, at the 8th ILEWG International Conference on Exploration and Utilization of the Moon Lunar Beijing, meeting declaration appointed：

“ To promote use of standardized telecommunications, navigation, and VLBI support for future orbiter, lander and rover missions. “

IVS also set up working grop 6th for VLBI on Space Science Application

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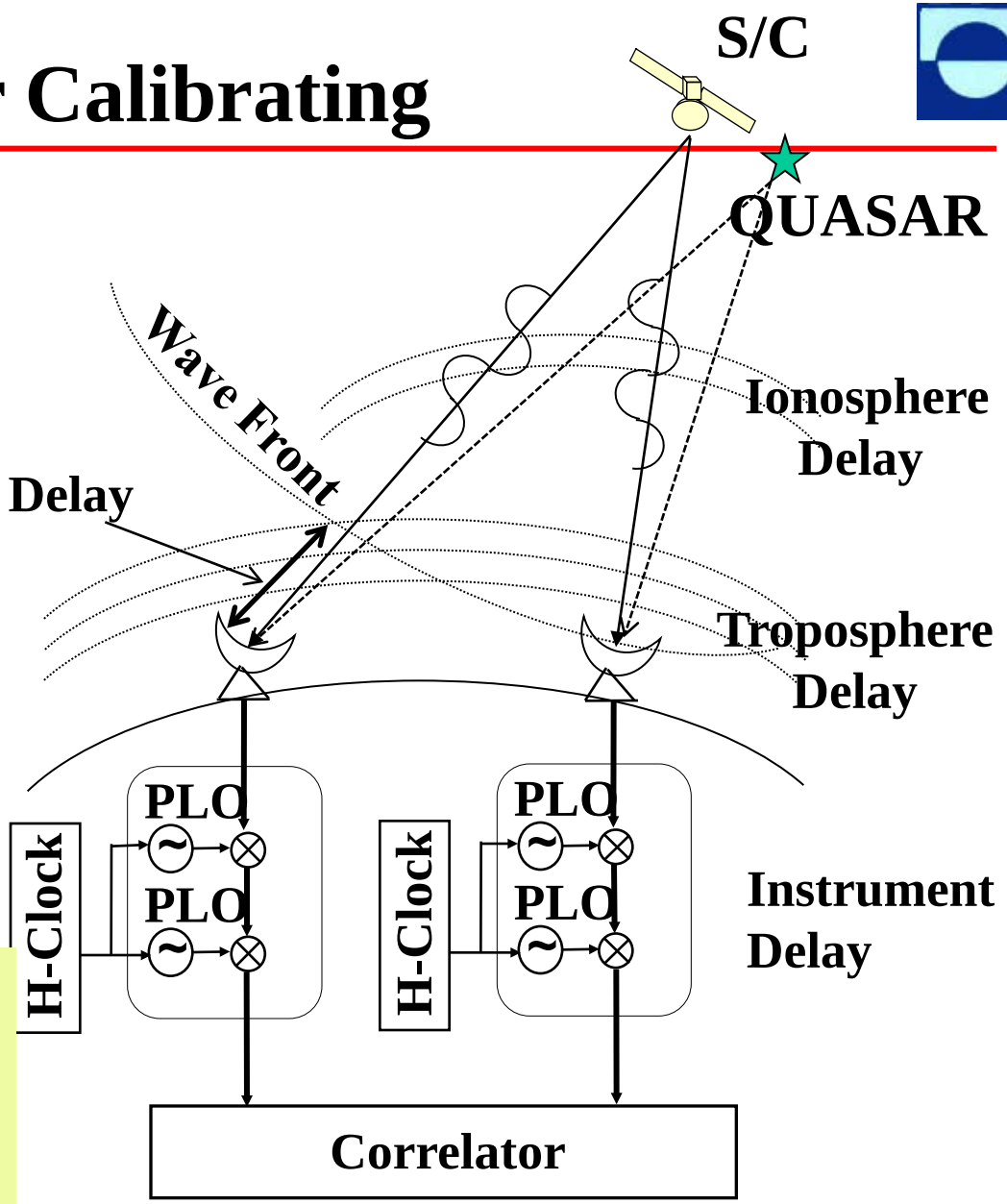
VLBI and Error Calibrating

VLBI Obs.: Time Delay

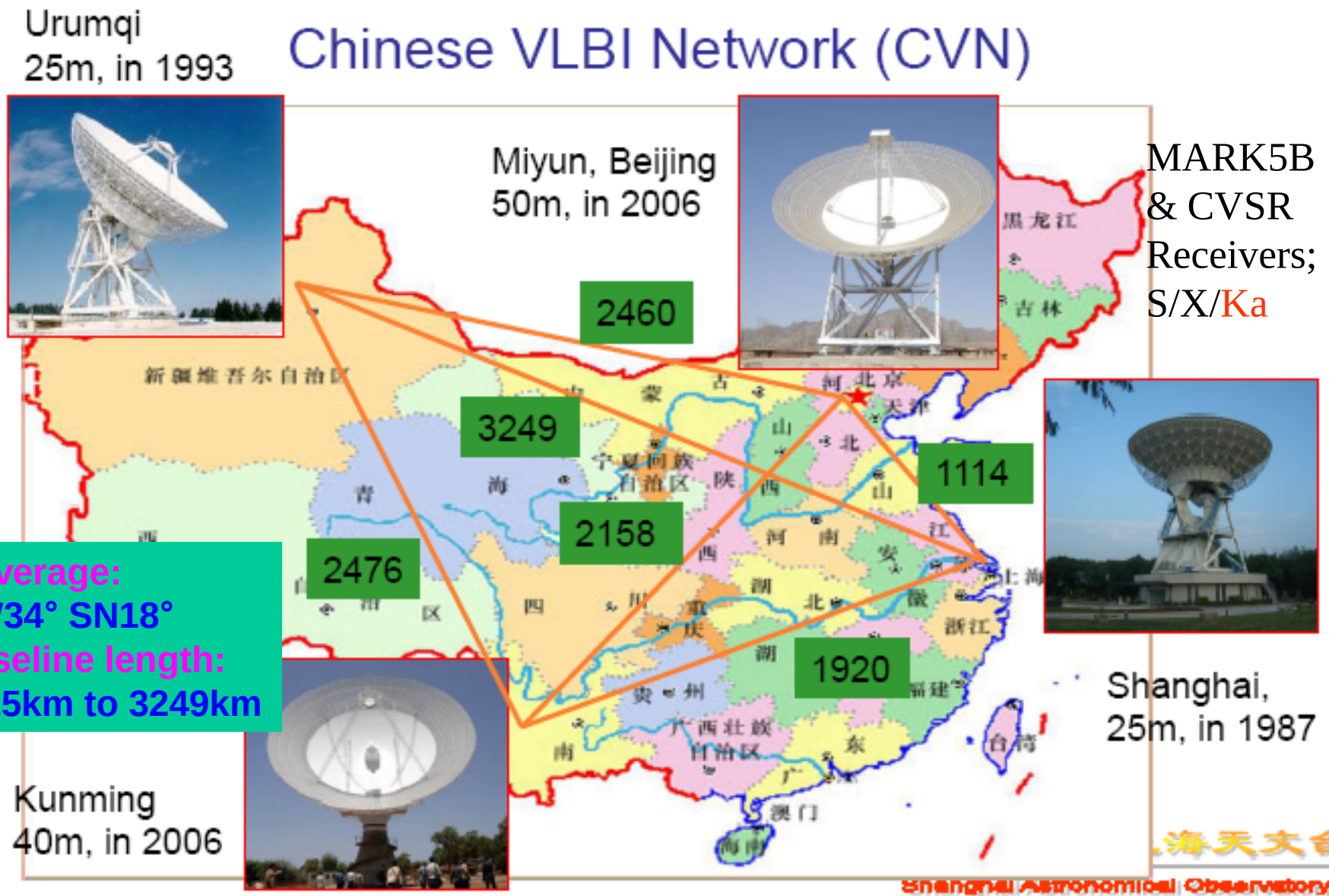
Error from: Atm, Iono, Instrument

Delta Obs. Between S/C and QUASAR to Remove Errors



CVN has contributed to the orbit monitoring of the CE-1 satellite for all the stages including phase, transfer, capture, mission and landing.

Current status of CVN



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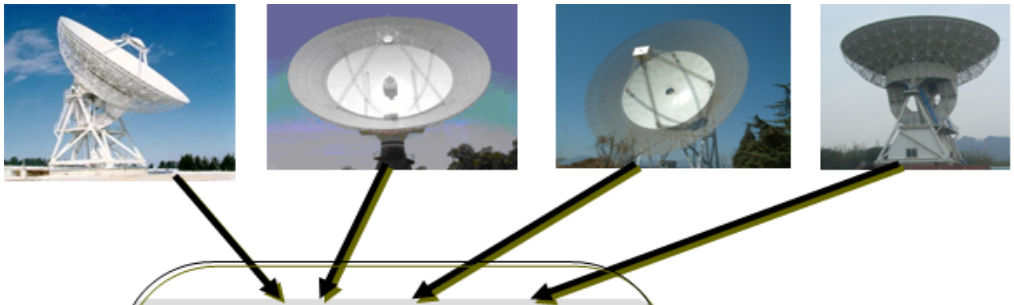
Data flow of CVN for CE-1 tracking



VLBI Correlator

Data reduction

delay | delay rate

Angle position calculation

R.A. | Dec.

Orbit determination

Beijing Center

VLBI center

Near Real-time processing

A Conner of VLBI Center

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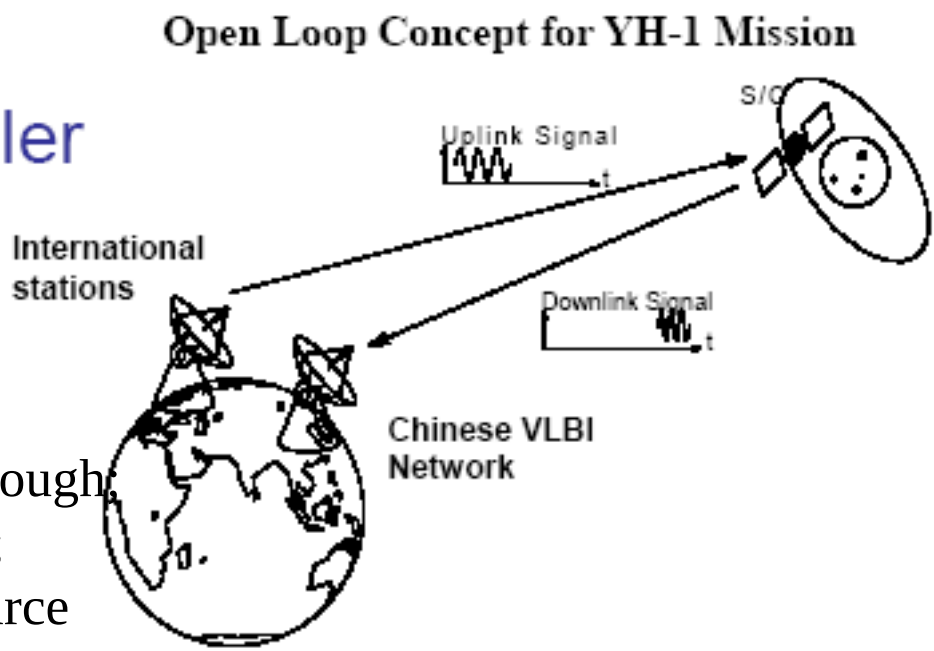
天文台 Observatory Sciences

Why open loop

Simple & Easy

- Challenges:
  - No powerful (to Mars) uplink system in China
  - No transponder onboard
    - receiver and transmitter on-board
    - USO-based 1-way open loop concept
- Measurements:
  - 1-way open loop Doppler
  - DOD & DOR
  - Same Beam VLBI



- Onboard USO/clock is stable enough;
- Advanced Software Radio Tech;
- Save transferring time and resource

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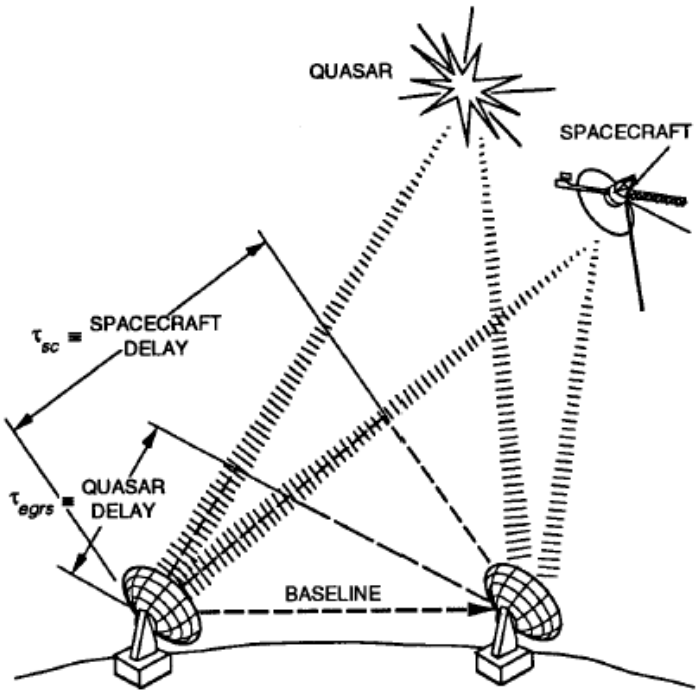
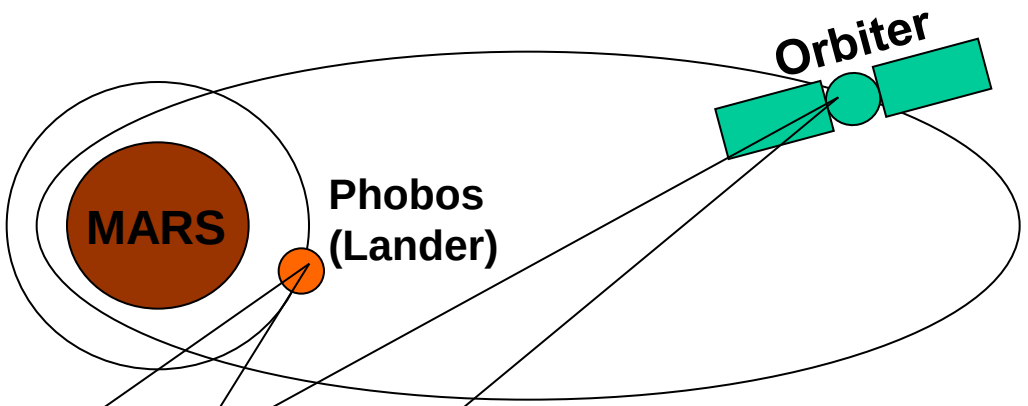
Delta-VLBI
DDOR/DDOD





Same Beam VLBI For
Mars Missions
& CE-3 Landing Mission

3-way open loop experiments
Chang'E-1 & Mars Express

- 3-way experiments to test 1-way
  - Chang'E-1
    - Chinese 1st lunar orbiter
  - Mars Express
    - ESA's Martian orbiter
- Experiment was started in
  - May, 2008

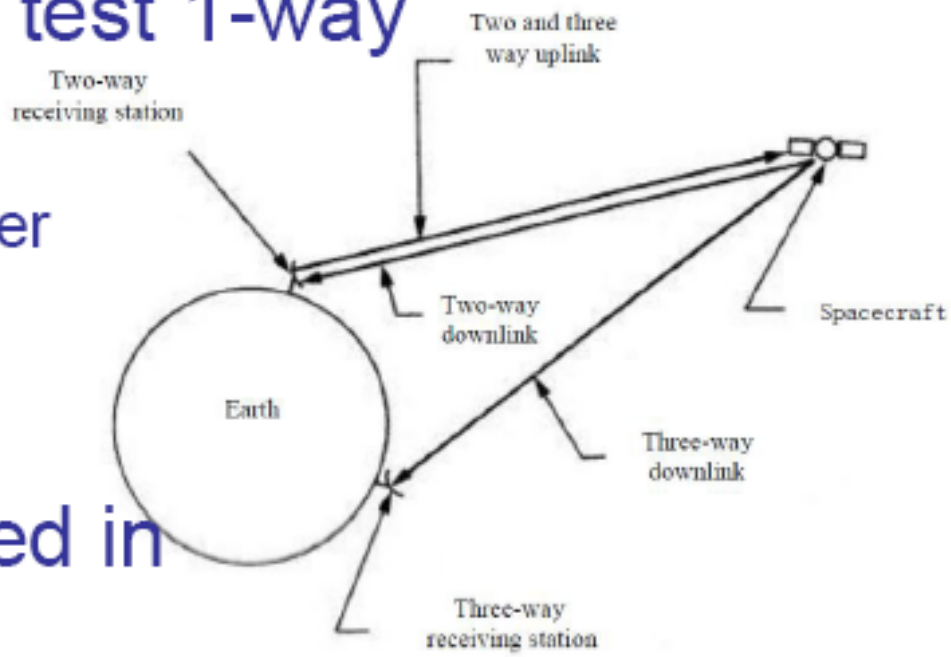


Figure 1 configurations of one-way, two-way and three-way tracking system

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Radio Science in Deep Space Mission

May Affect Navigation (Basic Works)

- lunar/planetary gravity, topography
- Lunar/Planets rotation and nutation
- Celestial reference frame (tie ?)
- Planetary atmosphere, Ring…
- Solar winds
- Test experiments of relativity: Cassini Huygens

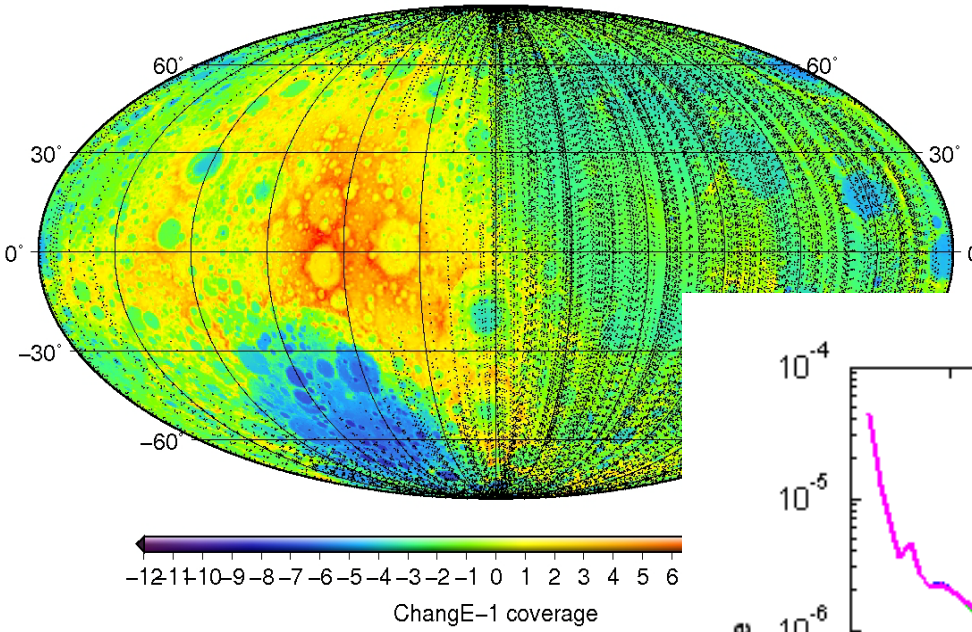
Advantages: share TT&C system, without new payload

Disadvantages: need state-of-art time-frequency techniques

Improving Lunar Gravity by CE Missions

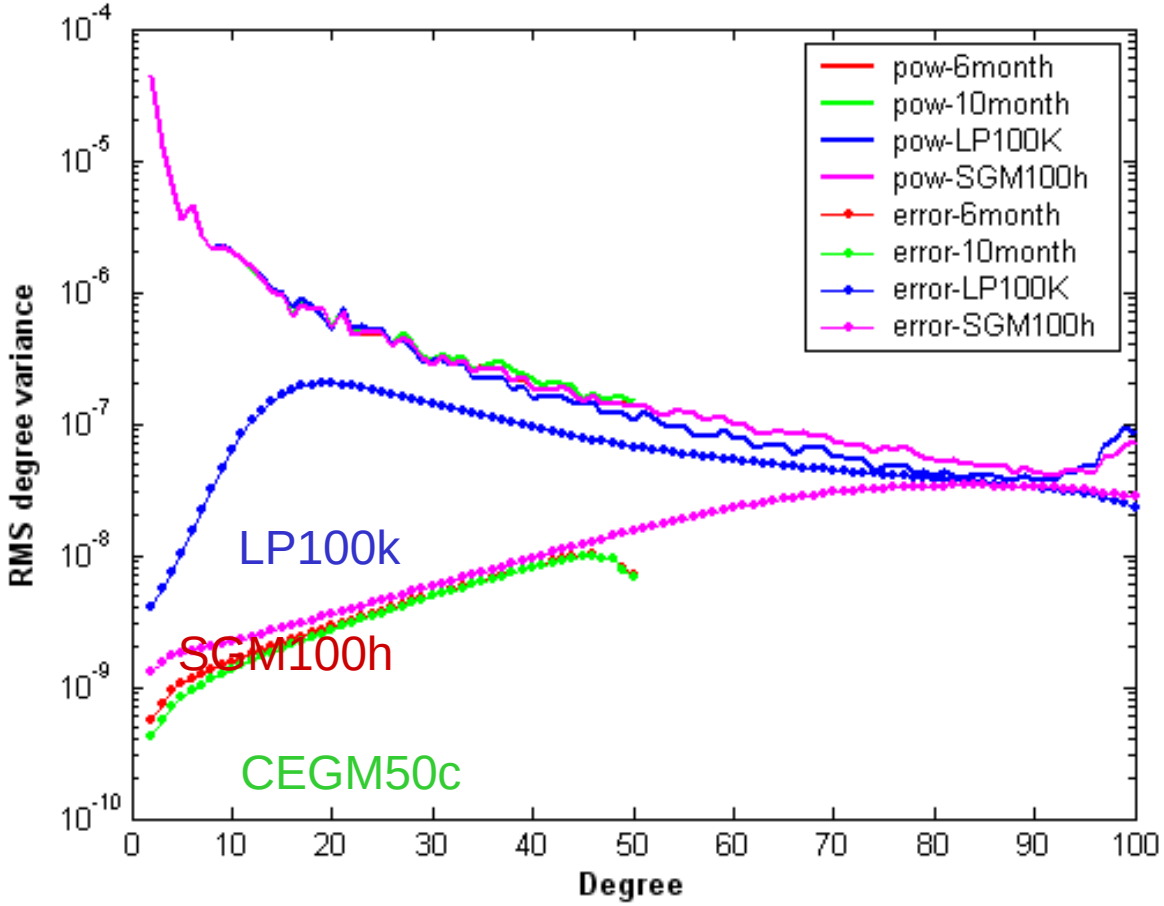
CE-1 Mission

CE-1 Tracking Data Coverage
On CLTM-s01 topography model



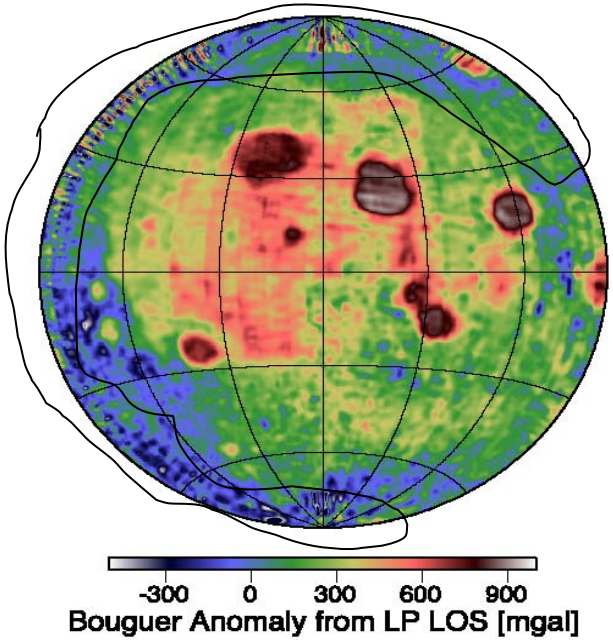
Gravity Error Spectral

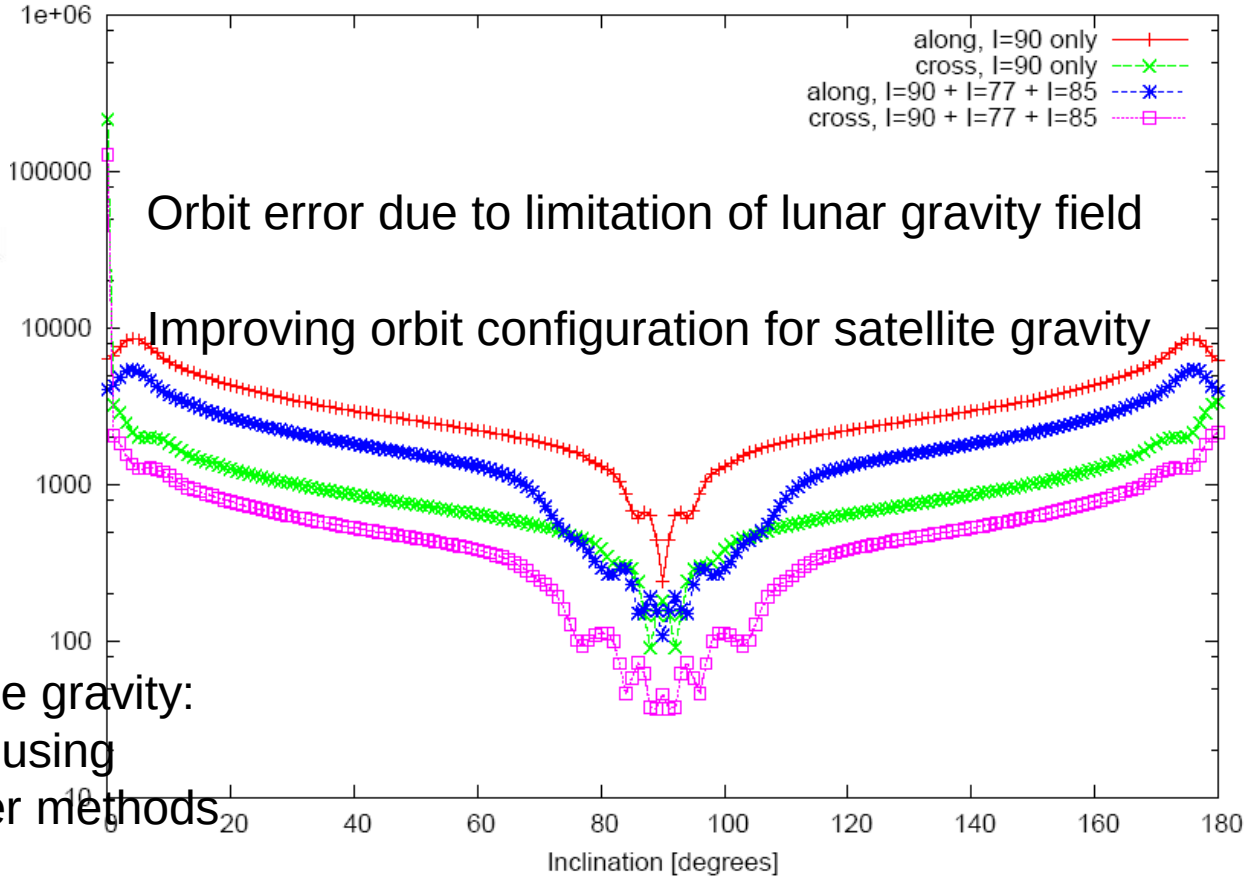
CEGM is 2 times better at low orders/degrees



Improving Lunar Gravity by CE Missions

CE-2 Mission





Orbit error due to limitation of lunar gravity field

Improving orbit configuration for satellite gravity

Improving poor lunar edge-side gravity: through face-on orbit tracking using VLBI(DOD) and 3-way Doppler methods

Flying lunar orbit at frozen orbits of various inclination

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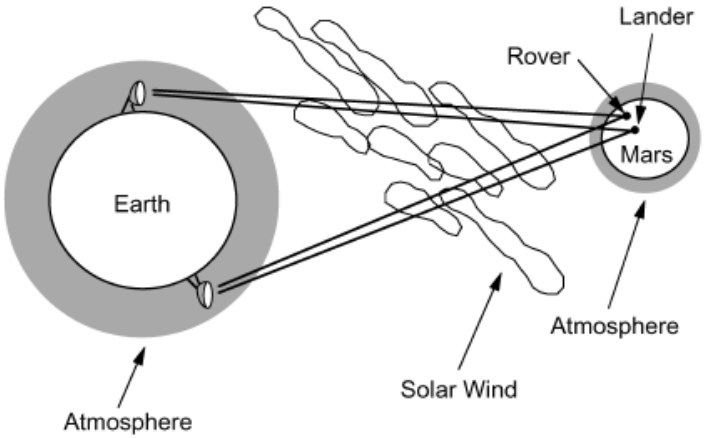
Near Future & Future Methods

- Chinese Deep Space Network (S/X/Ka band)
- Total Phase Count and Differencing;
- Inverse VLBI;
- GNSS-lunar mission SST Tracking;
- Relay S/Cs (L2/L3, L4/L5) Tracking & Communication, or Relay S/Cs (lunar GNSS)
- Space VLBI for Deep Space Tracking



SBI for lander & orbiter

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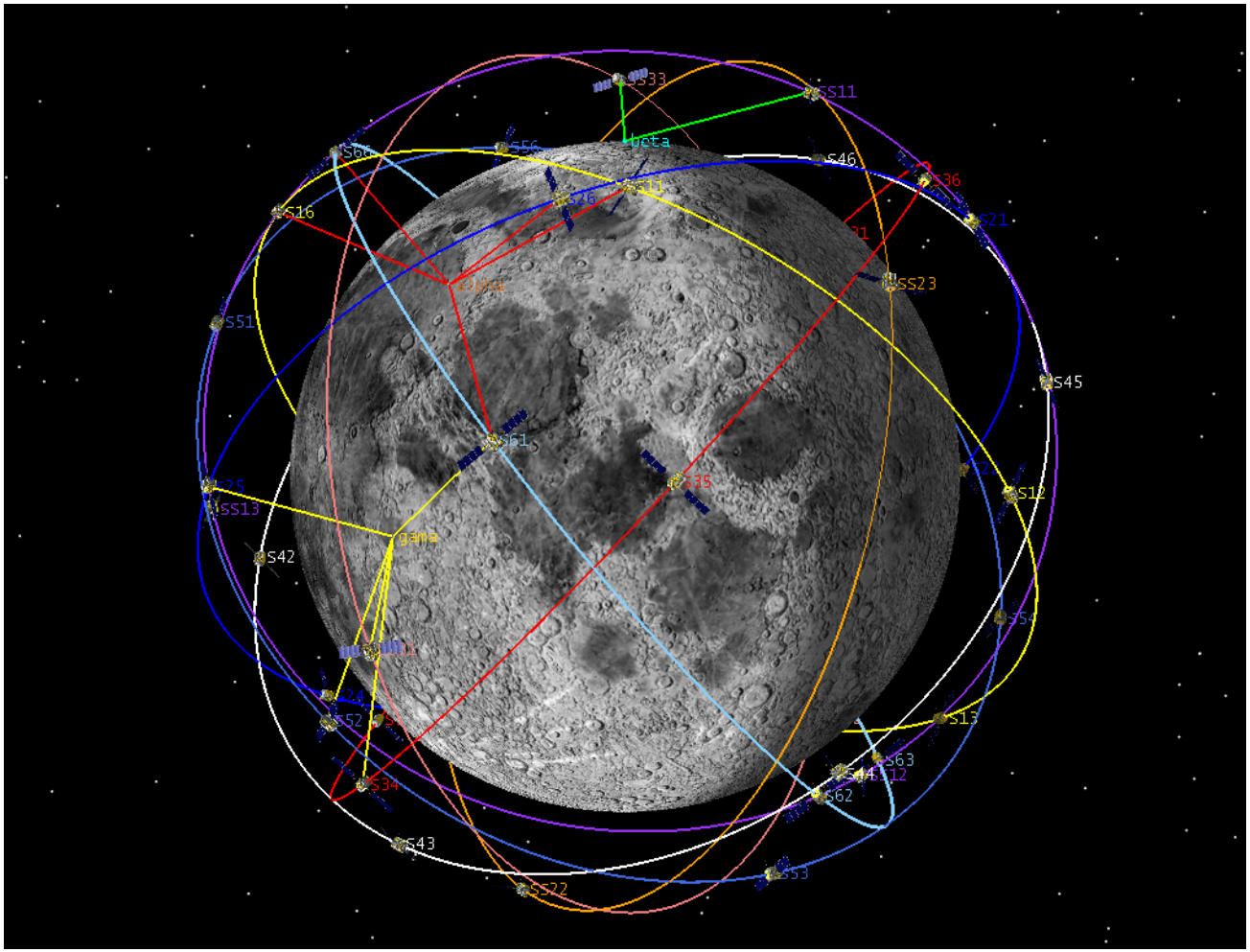
Long-term Stable Orbits

3D constellations



Extremely Long Baseline Interferometric (ELBI) Deep Space Navigation System

航天器

从航天器发出的无线电波提取载波/副载波点频信号

从航天器发出的无线电波提取载波/副载波点频信号

- Tracking by 2-3 baselines
- One space tracking station can processing 9nformation
- DDOR is required some time
- Space baselines are monitored from ground

Solution of Tracking Stations' Global Coverage Problem

Thank You

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