



CAST

Report on Cal/Val Activities

CAST(China Academy of Space Technology)

WGCV Plenary # 39

Berlin

May 6 - 8, 2015

Summary

1 Overview of CAST

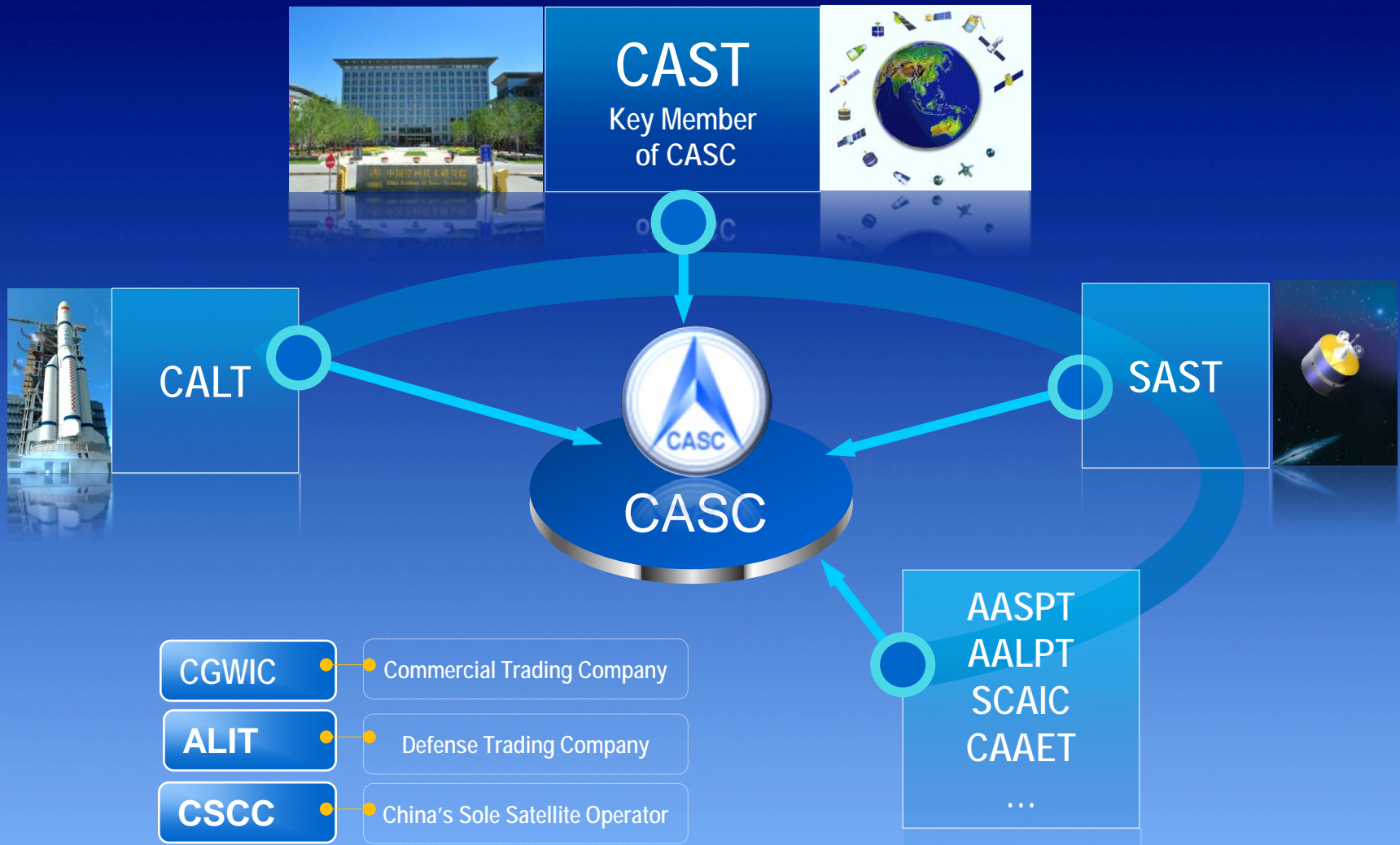
2 Calibration of CAST

3 Latest programs



Overview of CAST

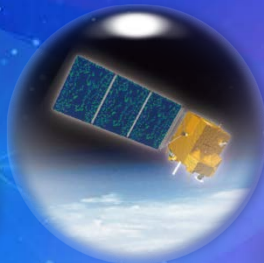
Organization



Core Business



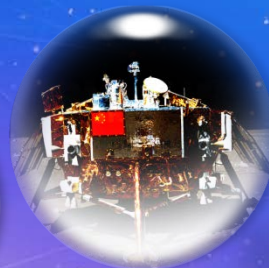
Telecommunications



Remote Sensing



Navigation



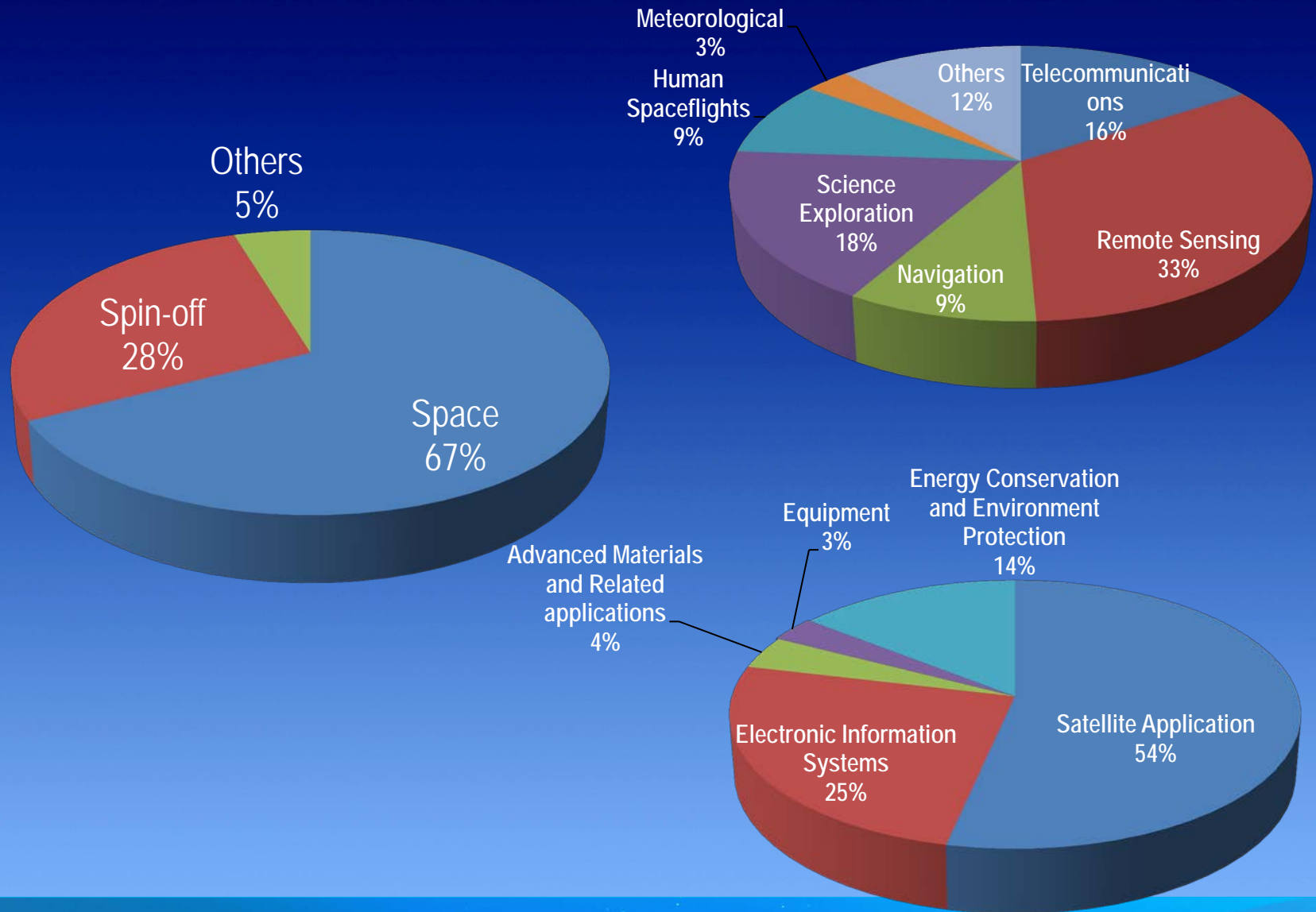
Science Exploration



Manned Spaceflight



Business Breakdown 2014



Management Group



Zhang Hongtai
President & CEO



Li Kaimin
ESVP
HR



Liu Fang
SVP
Telecom & Navi



Yu Houman
SVP
PA



Li Ming
SVP
R&D



Li Zhongbao
SVP
Defense & Spin-off



Shang Zhi
SVP
RS



Liu Xudong
CFO

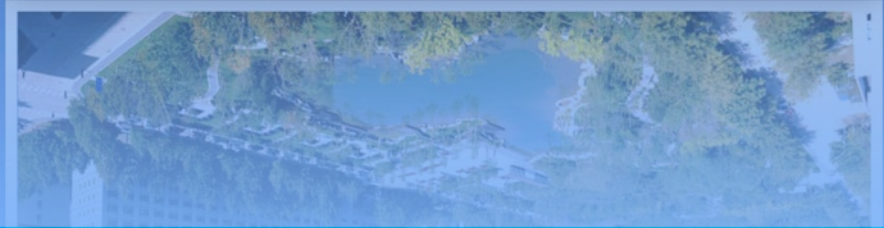


Wang Zhongyang
SVP
CIO

Key Figures

- **24 000 Employees** ✓ Space: 14 000
✓ average age: 34
- **15 subsidiaries in 7 cities**
- **4.55 Billion USD revenue in 2014**

**Key Player in Global
Space Industry**



CAST industrial footprint



15 subsidiaries in 7 cities
3 Representative Offices Abroad

Space Segments

➤ We design, build and deliver end-to-end space systems:

◆ 168 spacecrafts delivered

◆ 88 spacecrafts in orbit

Providing worldwide customers with full range of space to ground solutions



Telecommunications

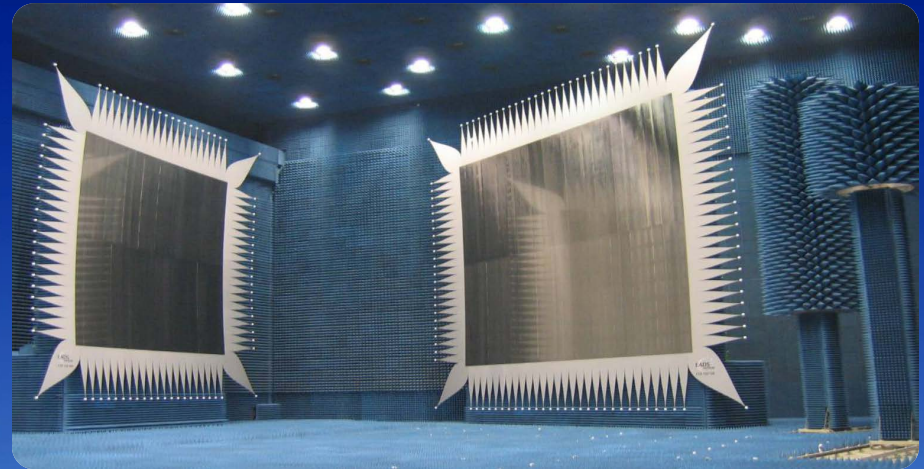
Prime contractor for over 30 telecommunications satellites

➤ Turnkey Solutions

- Consultation
- Orbit Frequency Coordination Support
- System Design & Integration
- Satellite Manufacture
- Launch and In-orbit Operation Support
- KHTT

➤ Mature DFH platform series for telecommunication, broadcast and customized missions

➤ Reliable and customized payloads



Remote Sensing

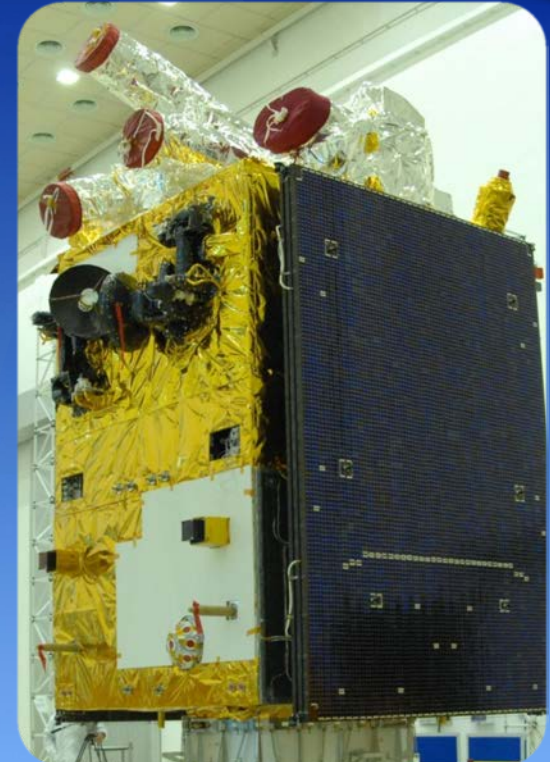
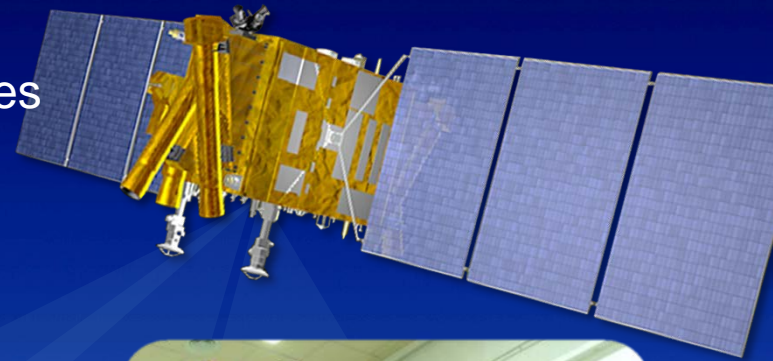
Core Player for over 80 Remote Sensing Satellites

Space to Ground turnkey solutions

Versatile LEO/SSO/GEO satellites and constellations

High performance and innovative bus & payloads

Reliable ground application system



Navigation

Prime constructor of China's Beidou Navigation Satellite System

- The 1st generation: 4 satellites
- The 2nd generation:
 - 16 satellites offers regional services for Asia-Pacific area by 2012.
 - 35 satellites will offer global coverage by 2020.

Beidou navigation satellite applications

- Intelligent transportation
- Disaster Relief
- Emergency Command & Control
- National security
- Precise Timing



Space Science Exploration

A prime in China's Space Science Exploration Missions by delivering over 15 satellites

Prime contractor of China's Lunar & Mars Exploration Program

CAST carries out lunar exploration by three steps.

Orbiting

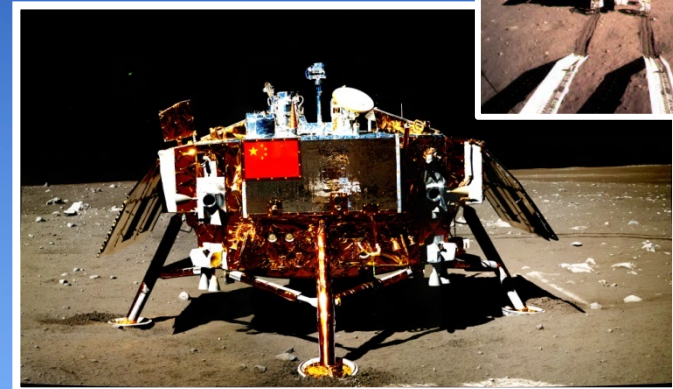
Orbiting around the moon

Landing

Soft-landing on the moon surface

Returning

Sample collection of moon surface and returning to the Earth

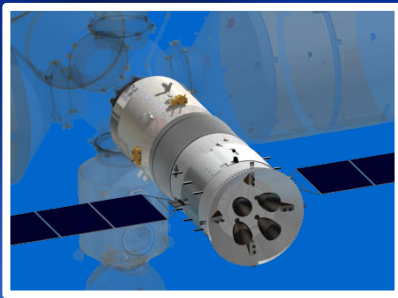


Human Space Flight

Founder of China's Manned Space Program

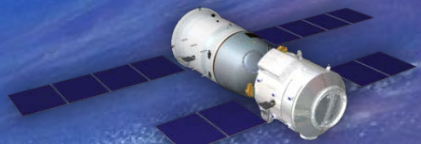
Successfully launched 10 Shenzhou spaceships and 1 Space Lab, will build China's first space station

China's Manned Space Program is implemented by three steps.



Manned Space Flight

STEP 1



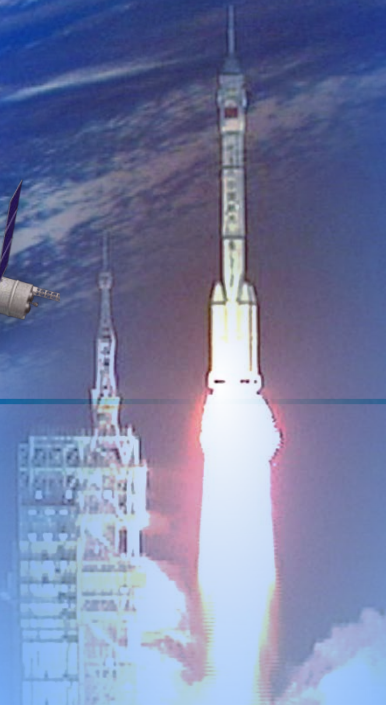
EVA, rendezvous & docking

STEP 2



70-ton Space station

STEP 3



Launches 2014/2015

2014

Remote Sensing

(14 in total)

SJ-06/07/08

GF-2

YG-20A/B/C

YG-21

YG-24

YG-25A/B/C

CBERS-04

Science

Chang'e-5 test module

...



Expected in 2015

Telecommunications

(3 in total)

APSTAR-9

Laosat -1

Remote Sensing

(9 in total)

GF-4

Navigation

(2 in total)

Pico & Nano

(8 in total)

...

Global Partners of CAST





Introduction of CAST's Calibration activities



Calibration of CAST



- Dunhuang
- Yili
- Baotou
- Hami
- Huailai
- Heihe
- Songshan
- ...

**Calibration
Validation**

- GF-1 (Pan/MS)
- GF-2 (Pan/MS)
- ZY1-02C/04C (Pan/MS)
- ZY3 (Pan/MS)
- HJ-1A/1B/1C (Pan/MS)
- SJ-9 (Pan/MS)
- HY1B (Pan/MS)
- FY-3 (HSI)
- GF-5 (Pan/MS/HSI)
-

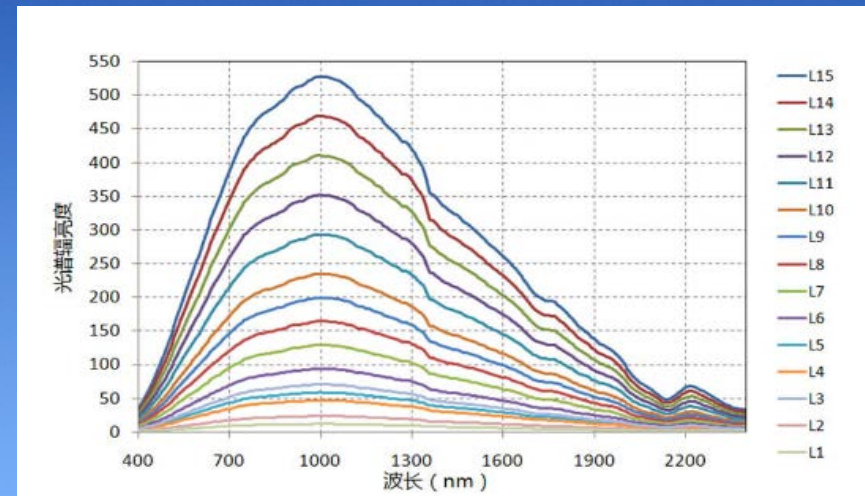
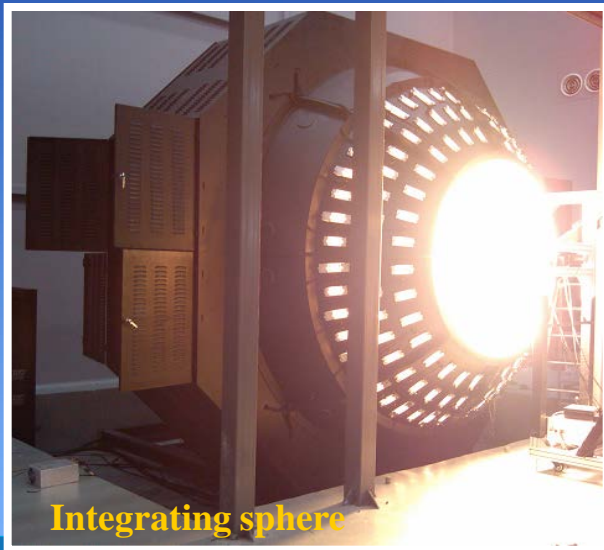
- Establishing various cal & val sites in China and abroad
- Providing consistent sensor calibration service including Pan, MS and HIS
- Calibration service for clients can be included in turn-key solutions by CAST



Pre-launch radiometric calibration

Integrating sphere system:

- Uniformity: >99% Angle: >30°
- Diameter: 4m
- Calibrated sensor's diameter: 1.6m(suit for China's largest camera)
- Levels: 32



Pre-launch radiometric calibration

- Integrating sphere with large diameter($D=4m$)
- Collimator with long focus($f=50m$)
- Blackbody with large diameter
- Repeatable test, including thermal vacuum test, vibration test.....

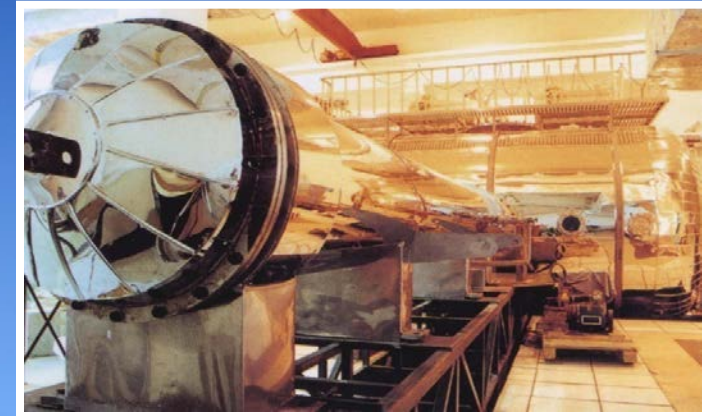
Advanced Instruments
Innovative Methods



Higher precision



Blackbody



Collimator

Pre-launch geometric calibration



- Accuracy of 2D revolving table: 1" for Horizon and 2" for pitch
- Photoelectric goniometer: 0.02"
- Sub-pixel center position: 1/14pixel
- 1:5000 mapping cameras
- Camera: f:20m D:1m

Interior orientations testing instrument

Higher precision

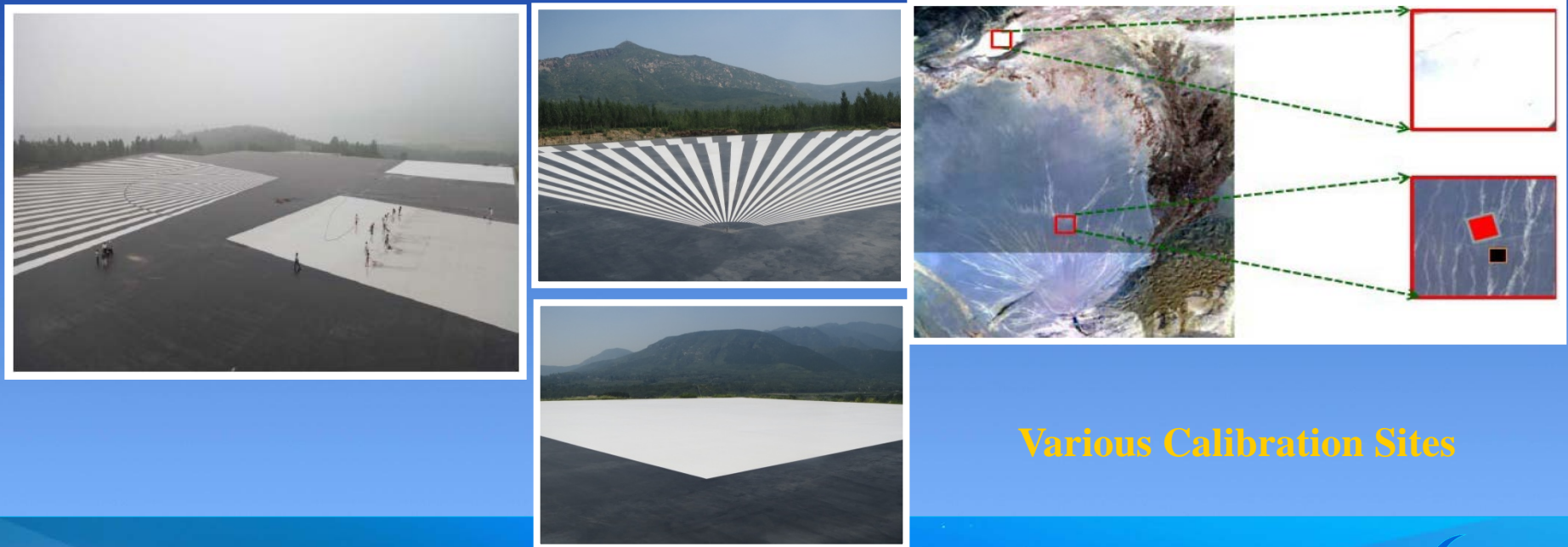


ZY-3

In-orbit radiometric calibration



- **statistical methods and pre-launch data to improve the accuracy of relative radiometric calibration**
- **Multiple bar-pattern with different reflectivity to improve the accuracy of absolute radiometric calibration**
- **Various calibration sites**



Various Calibration Sites

In-orbit geometric calibration

□ Calibration method:

- a step-by-step calibration model
- Interior Calibration + Exterior Calibration

□ Geometric calibration parameter:

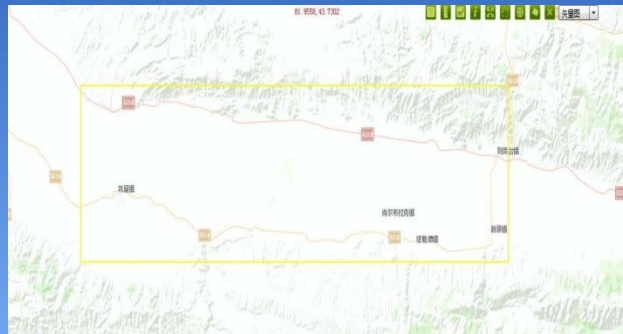
- Exterior orientation elements
- Interior orientation elements in every imaging CCD array
- Each linear array geometrical relationship in camera
- Camera geometrical relationship in satellite platform

Calibration period: 3 months
Accuracy: sub-pixel



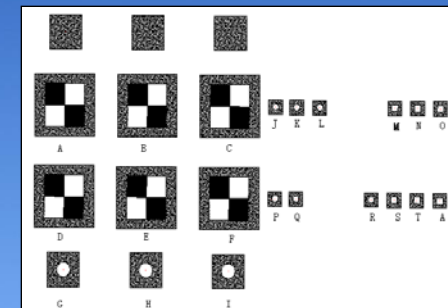
Songshan cal site

- 50km × 40 km



Yili cal site

- 120km × 30 km



Bar-pattern target



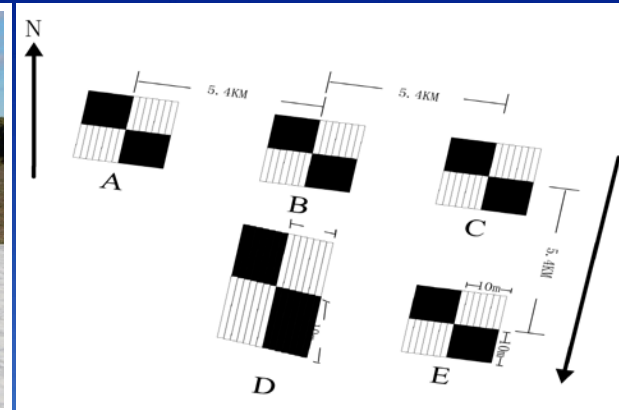
Latest Cal/Val activities of CAST



ZY-3 satellite

In-orbit calibration (with CSIRO)

- ❑ Stereometric mapping: EO mode + Surveying mode
- ❑ Assess for the stability of intersection angle
- ❑ Bar-pattern targets with 2400m² coverage
- ❑ Accuracy of relative radiometric calibration: ~1%
- ❑ Accuracy of absolute radiometric calibration: <7%



various targets

GF-2 satellite

• Pre-launch calibration

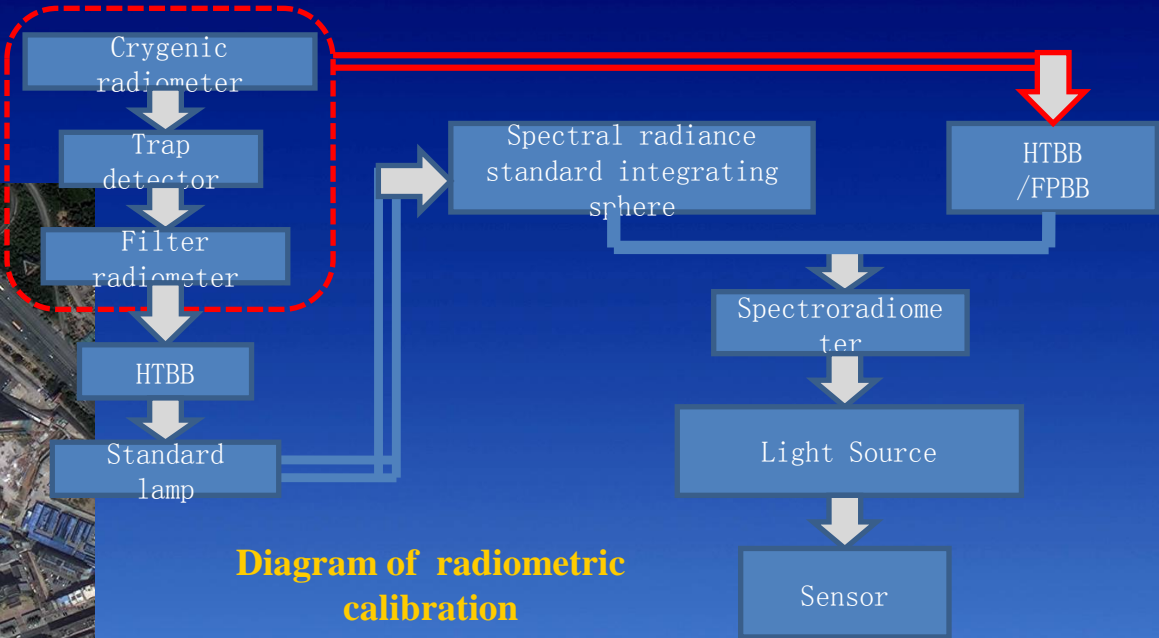
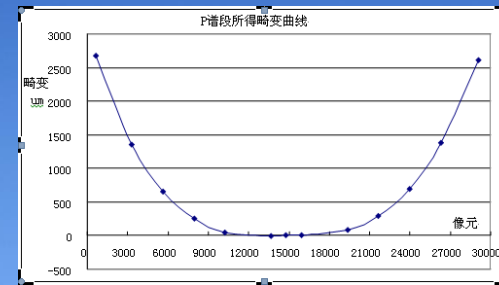
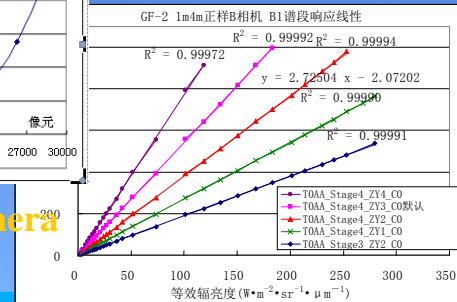


Diagram of radiometric calibration

- ❑ Launch date: 2014.8
- ❑ GSD: 0.8 m @ 631.5km
- ❑ SWATH: 45 km
- ❑ 1 Pan and 4 MS bands covered 450nm-900nm
- ❑ Accuracy of relative radiometric calibration: <1%



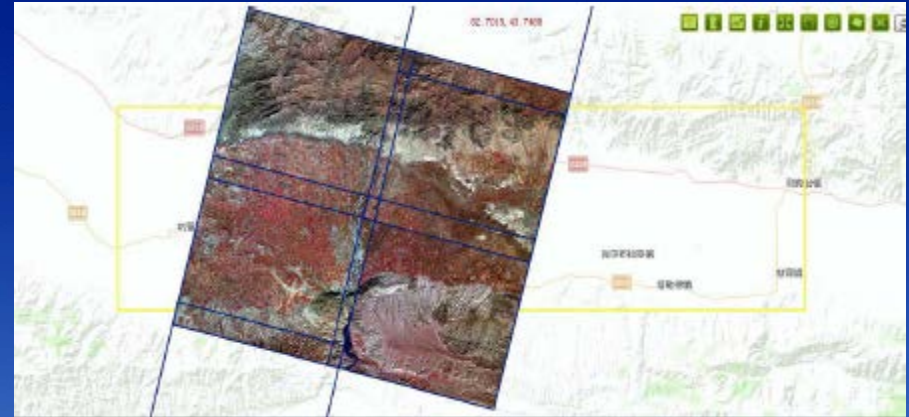
Aberration of GF2 A-camera @Pan band



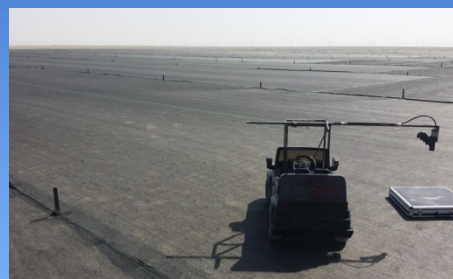
Linearity of GF2 B-camera @B1 band
China Academy of Space Technology

GF-2 satellite

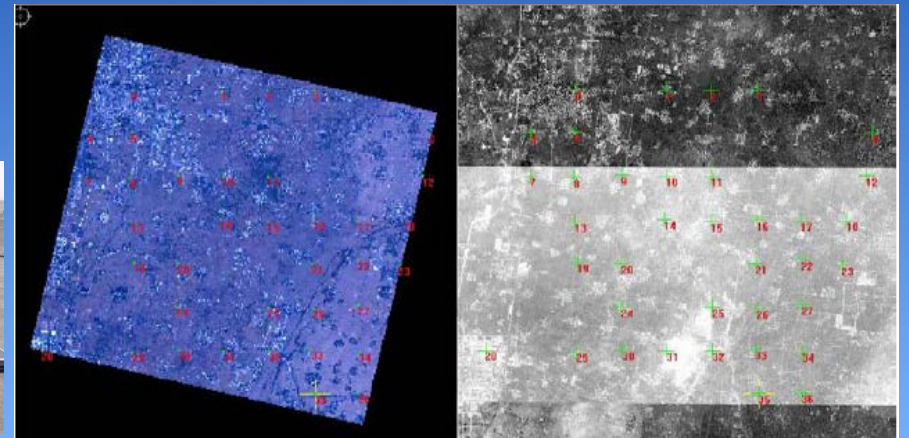
- **In-orbit calibration**
 - ❑ Accuracy of relative radiometric calibration: <1%
 - ❑ Accuracy of absolute radiometric calibration: <7%
 - ❑ Accuracy of internal geometric calibration:
 - Along track 1.3m
 - Across track 0.7m



Coverage of cal site



Cal site



MSS image and control points

GF-4 satellite

- 1st GEO high resolution satellite in China
- GSD:50m
- Swath: 500km-500km
- Bands: 1 Pan +4 Ms+ 1 Infrared
- Launch date: 2015

Pre-launch calibration has been completed. The in orbit test and calibration will be finished in 2016.

GF-5 satellite

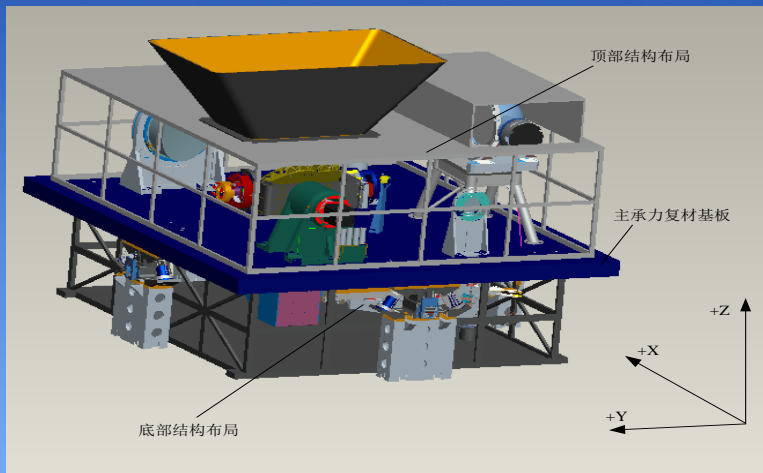
➤ Hyperspectral Sensor Calibration (with TNO of Netherlands)

□ Collaboration

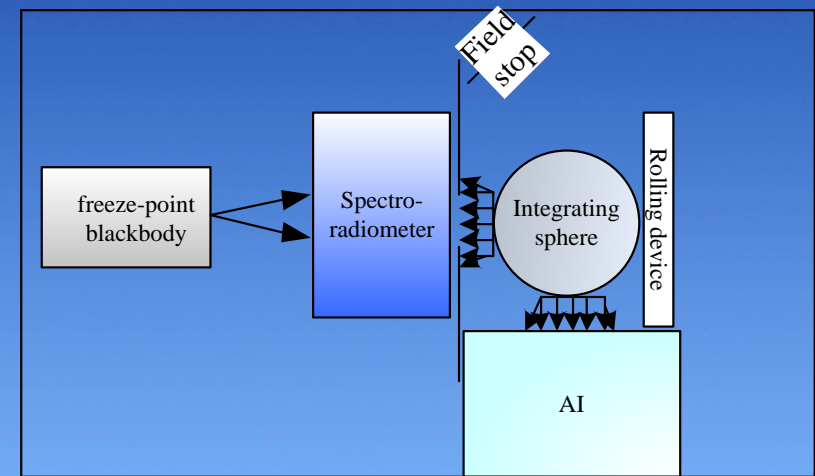
- Space Optical Instruments Joint Laboratory
- atmospheric detection, deep space exploration.....

□ Hyperspectral Sensor

- The error of the spectral calibration : $<0.005\text{nm}$
- Launch date: 2016



Hyperspectral sensor for atmosphere detection

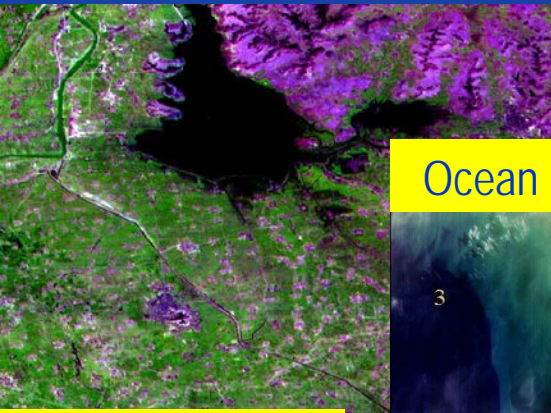


Absolute Radiometric Calibration Configuration

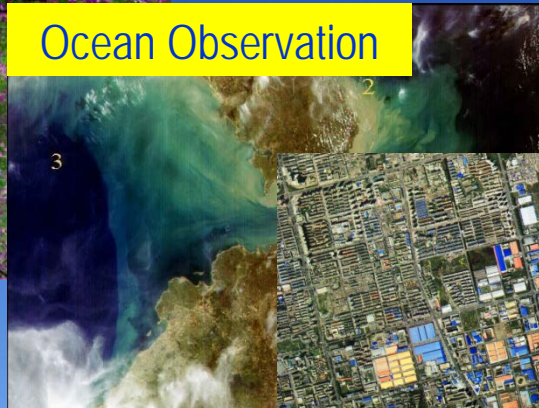
Future Plan

- More optical remote sensors
- More challenges
- More expectations
- More collaboration

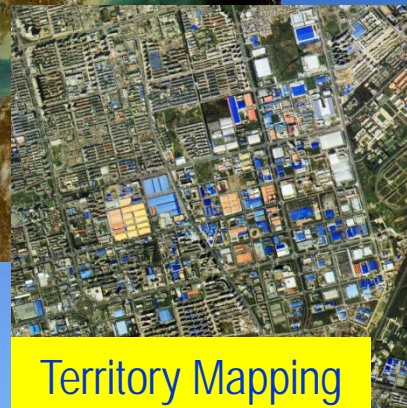
- Land Observation
- Ocean Observation
- Territory Mapping
- Disaster/Environment Monitoring
- Atmosphere Detection
- Deep Space Exploration
- Scientific Experiment
-



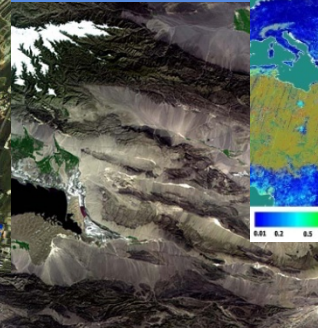
Land Observation



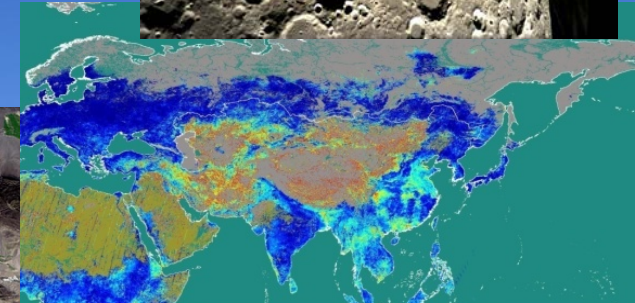
Ocean Observation



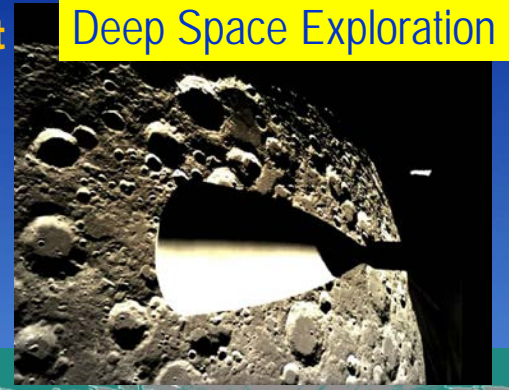
Territory Mapping



Disaster/Environment Monitoring



Atmosphere Detection



Deep Space Exploration

LET'S WORK TOGETHER
CREATING A BETTER FUTURE