CASC Efforts on Dealing with Space Debris toward Space Long Term Sustainability

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Outline

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1 Overview

2 CASC Efforts of Space Debris Activities

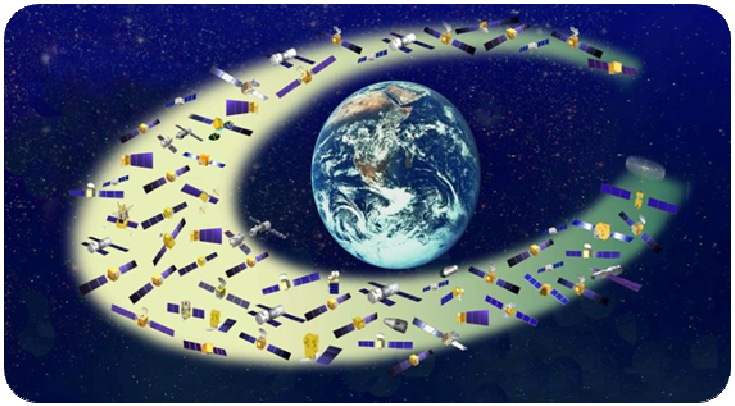
3 Views and Conclusions

CONTENTS

CASC

CASC is the main and the largest state-owned aerospace enterprise in China.

Main fields & Mission：



1. Launchers
2. Human Spaceflight
3. Earth Observation
4. Telecommunications
5. Navigation
6. Space Science and Deep Space Exploration

Manned Space Programs

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The current manned space program in China is composed of 3 phases:

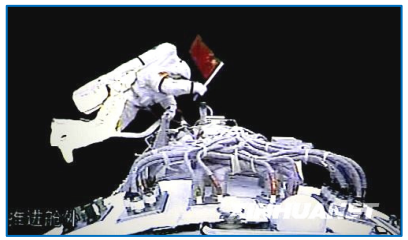
- **Phase 1: Manned space flight**
- **Phase 2:Extravehicular activity, rendezvous & docking**
- **Phase 3: Space Lab and Space station**

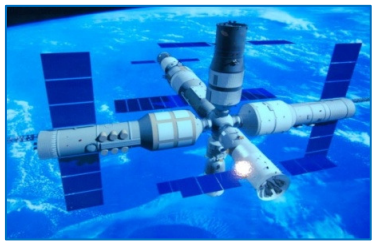
In 2011 and 2012, Tiangong-1 and Shenzhou-8, Shenzhou-9 accomplished first space rendezvous and docking test, laying the foundation for the construction of future space station.

Programs:

Shenzhou - 1
Shenzhou - 2
Shenzhou - 3
Shenzhou - 4
Shenzhou - 5
Shenzhou - 6
Shenzhou - 7
Tiangong - 1
Shenzhou - 8
Shenzhou - 9

Extravehicular activity → Rendezvous & Docking → Space Lab





Earth Observation Satellites

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China has built around 60 Earth Observation satellites, which provide data for weather forecasting, and natural disaster supervisions etc.

Observation satellites

Since 1988, Joint China-Brazil Earth Resources Satellites (CBERS), a family of Earth observation satellites, CBERS 3 (2012) & 4 (2014)…

Meteorological satellites

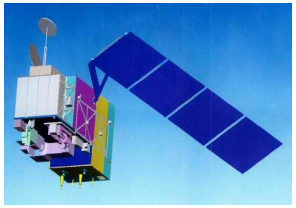
New generation polar orbit weather satellite FY-3 and FY-4, second generation geosynchronous meteorological satellites

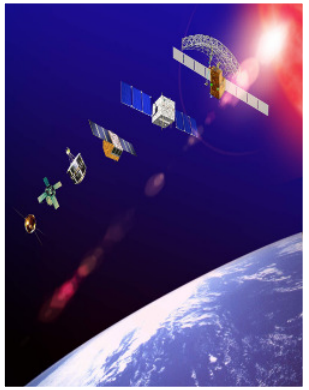
Oceanography

Ocean dynamic environmental HY satellite monitors ocean wind fields, sea levels and temperatures, waves, currents and storms

Environment and disaster monitoring

Huanjing, constellation of satellites, two optical in orbit & a SAR satellite was launched in 2012.





Buses :

- ***Phoenix Eye***
- ***CAST 2000***
- ***CAST MINI***
- ***…***

Programs:

- ***CBERS 01***
- ***CBERS 02***
- ***CBERS 02B***
- ***ZY-1***
- ***HY-1***
- ***HJ-1A***
- ***HJ-1B***
- ***HJ-1C***
- ***FY-1 A,B,C,D***
- ***FY-2 B,C,D,E***
- ***FY-3 A,B***

…

Telecommunications Satellites

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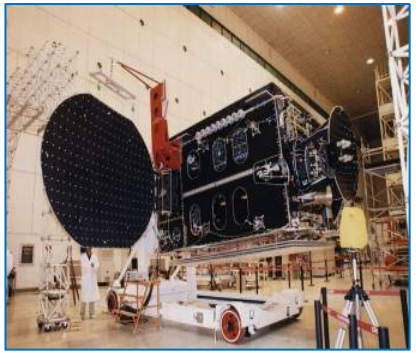
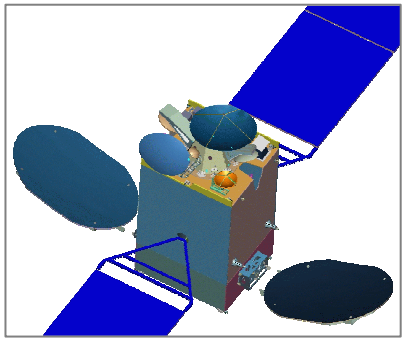
China delivered 25 telecommunications satellites into orbit, providing a total satellite communications system capability, from spacecraft and payload design, manufacture and test to the complete ground control and communications infrastructure, in-orbit operation and services.

Three main buses: DFH-3, DFH-3A,DFH-4, the output power ranges from 2000 w to 10000 w, the service life is from 8 to 15 years.





Programs:

- *Chinasat-5*
- *Chinasat-6*
- *…*
- *Chinasat-22*
- *Sinosat-2*
- *Sinosat-3*
- *VeneSat-1*
- *PakSat-1R*
- *NigComSat-1R*
- *…*

Navigation Satellites

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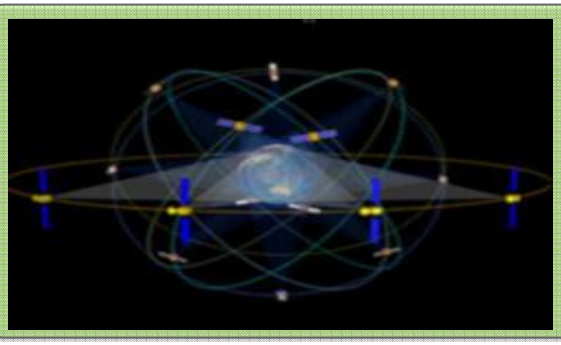
China is building new generation navigation system, implemented a regional Compass navigation system in 2012, which provides navigation and positioning, timing and short-message services will cover the Asia-Pacific region, which consists of 5 GEO, 5IGSO and 4 MEO.

Beidou

Experimental → Regional → International



Beidou, a global satellite navigation system with 35 satellites, offered services in Asia-Pacific region in 2012 & the global system by 2020.

Science and Exploration Satellites

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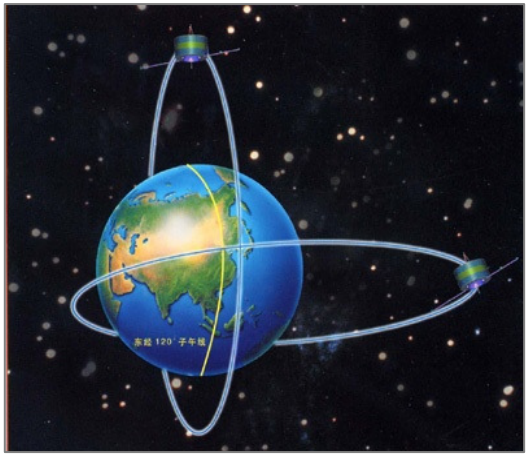
China has developed 15 various science and exploration satellites for exploring the boundless universe. Sun-Earth space exploration, lunar scientific research, microgravity science and space life science are conducted.

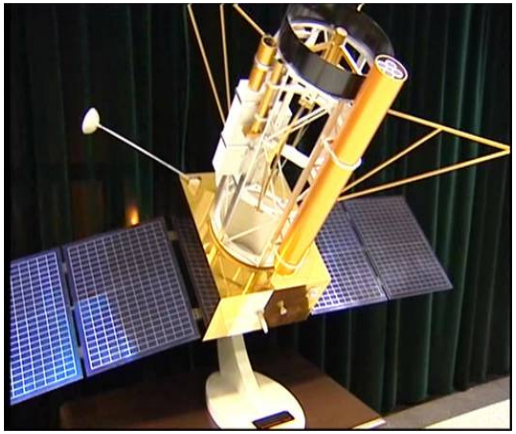
Programs:

- *SJ-1*
- *SJ-2,2A,2B*
- *SJ-4*
- *SJ-5*
- *TC-1,2(Cluster-2)*
- *Chang'e-1,2 (Lunar Mission)*
- *Space Solar Telescope*
- *Kuafu*
- *…*

SJ-5



TC-1,2 (Cluster-2)



Space Solar Telescope

Lunar Exploration

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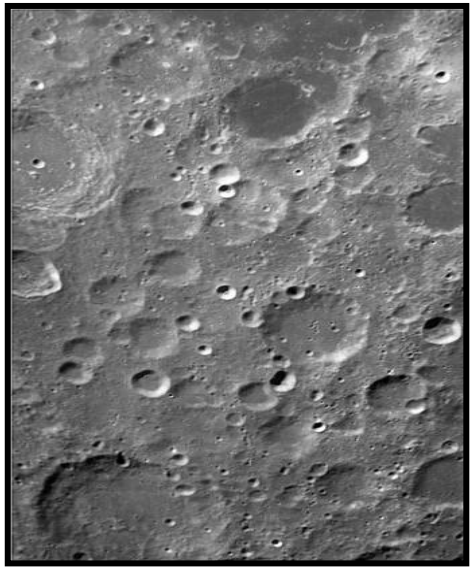
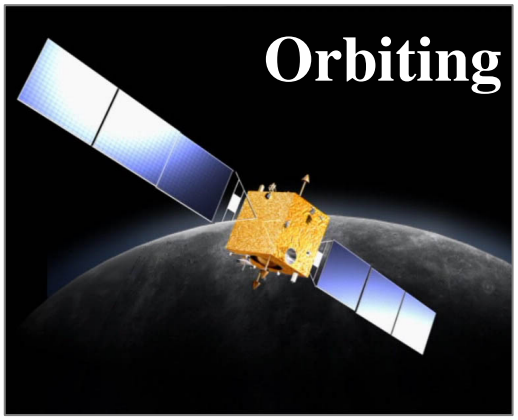
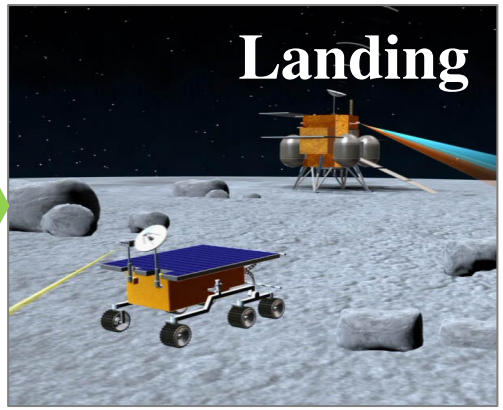
- First step: Orbiting, 2007
- Second step: Landing, 2013
- Third step: Sample Returning, 2017

1st lunar surface photo by Chang'e-1







What's in Space Today?

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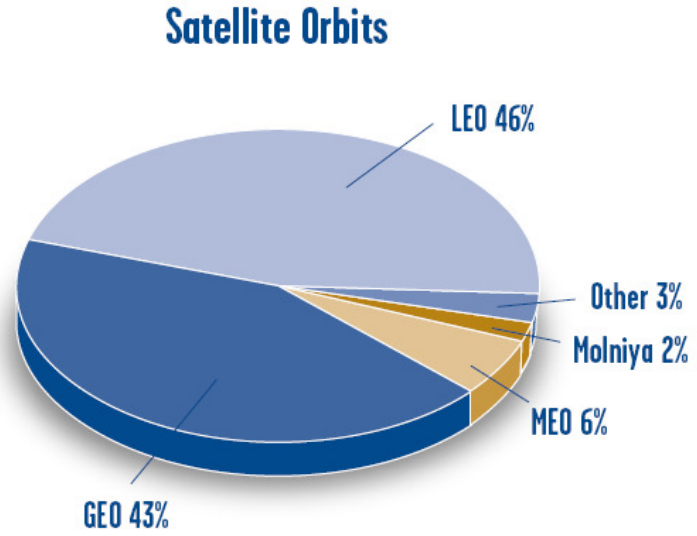
- More than 5000 satellites launched since 1957 till end of 2012.
- More than 200 times on-orbit break-up.
- Currently only 1000 operational satellites.
- Most of the space objects are unfounctional.

- 3 areas of space contain 95% of operational satellites:
  - Low earth orbit (LEO): 300-2,000 km altitude
  - Semi-synchronous (MEO): 20,000 km altitude
    - Navigation satellites (eg, GPS)
  - Geosynchronous (GEO): 36,000 km altitude
    - Communication/broadcast satellites



Space Debris Population

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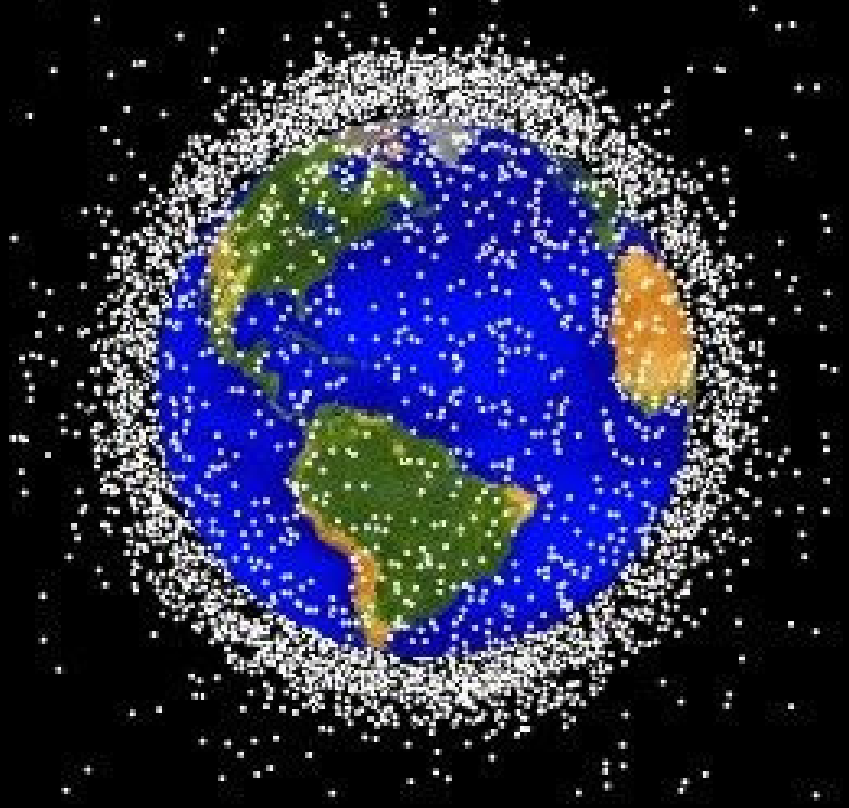
- size > 10 cm
  – detectable
  13,120
- size 1-10 cm
  – non-detectable
  more than 300,000
- size < 1 cm
  – non-detectable
  Millions objects,

Average impact V=10 km/s



Space debris distribution in Low Earth Orbit

Categories & Risk of Debris

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Physical Size	Comments	Potential Risk to Satellites
> 10 cm	-Can be tracked -No effective shielding	Complete destruction
1-10 cm	-Larger objects in this range may be tracked -No effective shielding	Severe damage or complete destruction
< 1cm	-Cannot be tracked -Effective shielding exists	Damage

CONTENTS

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1 Overview

2 CASC Efforts of Space Debris Activities

3 Conclusions and Comments

Space Debris Related Activities in History

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- From 1957 until 1985 there was very few civilian concern about space debris and it was not an open subject.
- Following an Ariane launch to GTO there was complain about space debris from USA in 1986. a few scientist, awareness of the problem was made.
- 1991: First IAA Symposium on Space Debris at the International Astronautical Congress.
- 1991:The Inter-Agency Space Debris Coordination Committee founded.
- 1993:China National Space Administration (CNSA) joined IADC.

Related Key Events *in China*

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- 1993: installation of Chinese National Space Debris Office and Chinese Space Debris Advisory Group of experts, coordination of space debris research activities in China.
- 1999: formation of Chinese National expert committee of Space Debris research.
- 2000:started special budget for Chinese Space Debris research.
- since 1999: always actively participated in the IADC activities; Presented status report on space debris activities of China at IADC annual Meeting. already implementing practical steps on space debris mitigation on a voluntary basis within its own national mechanisms.
- 2001: first Chinese Conference on Space Debris was held .The conference was opened and was held every two year. The one and only journal of space debris research in the world issued.
- 2006: China National Industry Standard "Requirements on Space Debris Mitigation"） implemented.

Space Debris Research Project in China

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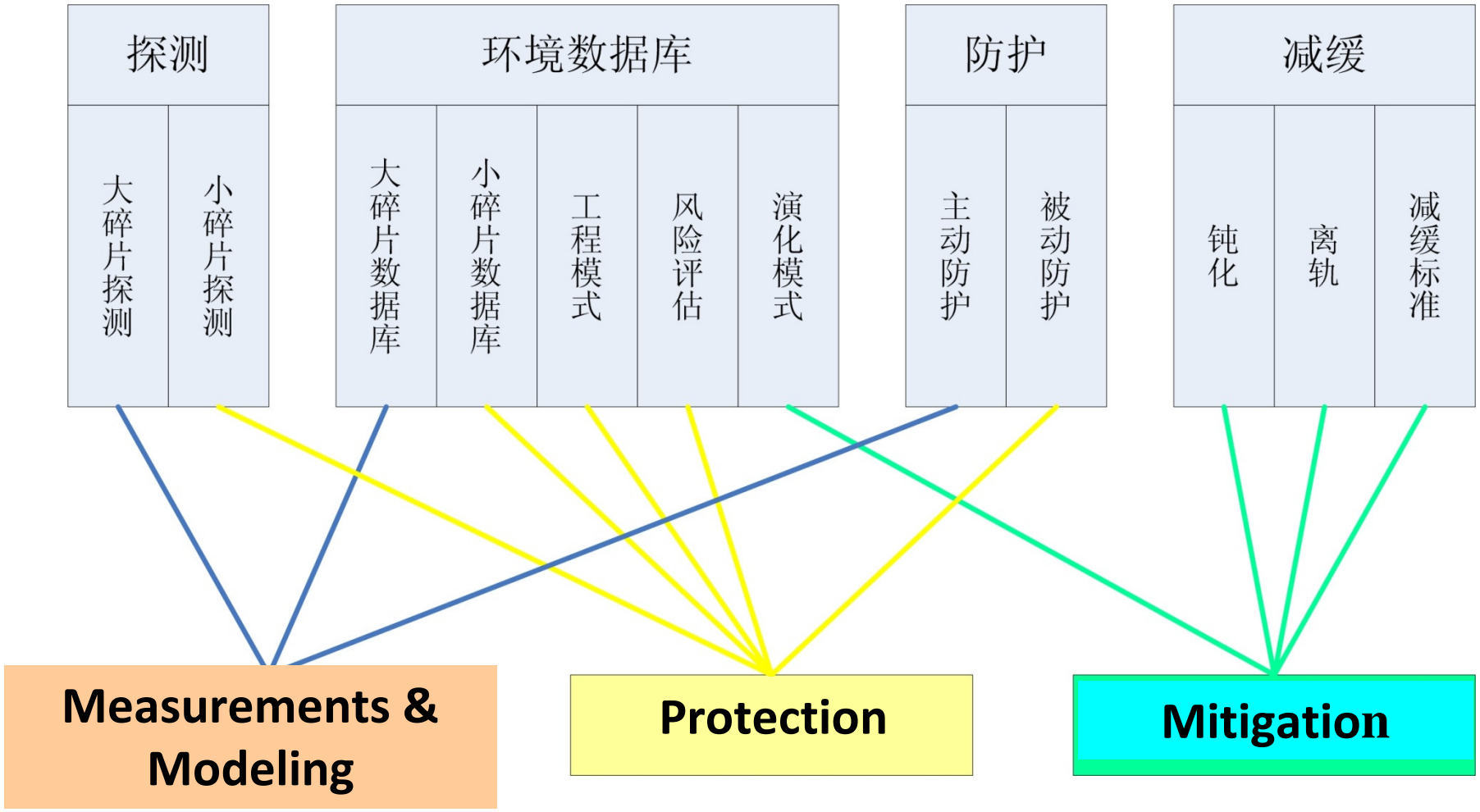

Highlights -- Measures

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CASC together with China National Astronomical Observatories, CAS, participated worldwide measurement campaigns for Low Earth and Geostationary environment :

- Radar for LEO
- Optical for GEO

Campaign results are used to

- calibrate debris environment models
- compare sensor performances
- identify debris populations below the detection limit of operational surveillance systems

Highlights -- Modeling & Risk Analysis

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CASC together with China National Astronomical Observatories, CAS, works on characterisation and modelling of meteoroids and space debris around the Earth. Including :

- short and long-term evolution
- collision prediction and risk assessment
- development of models which characterize explosions or collisions in space
- uncontrolled re-entry
- Analysis of the Space Debris Mitigation Measures

Analysis of the Space Debris Mitigation Measures

- Comparing the Effects of Different Mitigation Measures to Future Space Environment
- Propose a Method for Evaluating the Mitigation Measures

Analysis of the Cost-benefit of Space Debris Mitigation Measures

- Comparing the Cost-benefits of Different Mitigation Measures

- Present a Model for Calculation the Cost-benefit of Space Debris Mitigation Measures

Highlights -- Mitigation techniques

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(1) Mitigation techniques of the Launch vehicle including:

- Launch vehicle equipment passivation,
- Solid retro-rocket fairing and other operational debris controlling,
- the active de-orbit of orbital stages,
- the correlative standards

(2) Mitigation technology of Spacecraft including:

- spacecraft passivation;
- spacecraft passive de-orbit ;
- Design and practice of lifetime 25 years limit of LEO space system,
- active removing of spacecraft and orbital stages that have reached the end of their mission operations in protected regions;
- Accurate measure and depletion technique of the residual propellants;
- Controlling techniques of discharging batteries, relieving pressure vessels, Self-destruct systems, terminated flywheels and momentum wheels during the disposal phase;
- Safety Assessment for Re-entry of space debris,
- the correlative standards

Mitigation technology research

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- **2006: China National Industry standards "Requirements for Orbital Debris Mitigation （QJ3221-2005), put into effect.**

  All China flight projects are now required to provide debris assessments and end-of-mission planning as a normal part of the project development.

- **2010: The integrated system of space debris mitigation design of China.**

  To minimize or eliminate generation of debris in every steps of space activities, during planning, design, orbit operation, end of mission of spacecraft and launch vehicles.

  Also can be used for learning and training tool.

- **2010: preliminary Safety Assessment for Re-entry of space Debris of China.**

- **2011, 8 items relevant standards of space debris mitigation have been finished to research and compile, and these documents are under to be approved.**

Space Debris Mitigation Standards in China

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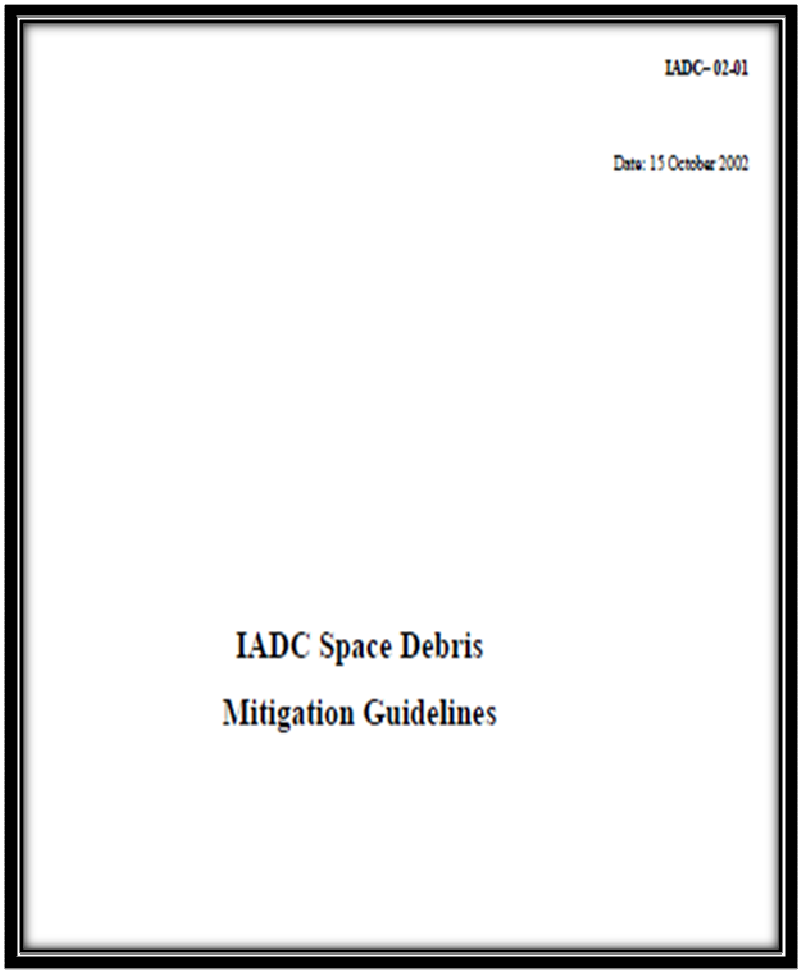
1. China National Industry standard QJ3221-2005 Requirements for Orbital Debris Mitigation (put into effect in 2006)
2. KJSP-T-1-01 Rules of Spacecraft Passivation Desgin (under approved)
3. KJSP-T-1-02 Requirements of GEO Spacecraft Treatment and Implement after Task (under approved)
4. KJSP-T-1-03 Requirements of LEO Spacecraft Treatment and Implement after Task (under approved)
5. KJSP-T-1-04 Control Requirements and Desgin Rules for Operational Debris of Spacecraft (under approved)
6. KJSP-T-1-05 Residual Propellant Measuring and Estimating of Spacecraft (under approved)
7. KJSP-T-1-06 Procedure Requirements and Risk Assessment of Reentry of Spacecraft (under approved)
8. KJSP-M-1-01 Management Requirements for Orbital Debris Mitigation of Spacecraft (under approved)

The China National industry Standard ---- «Requirements for Space Debris Mitigation » put into effect in 2006. The requirements of the Standard were in line with the UN Space Debris Mitigation Guidelines and IADC Space Debris Mitigation Guidelines.



Highlights -- Mitigation Practice

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1 Venting of residual propellants

● Up to now , Most of the launch vehicle took measures relevant to Debris Mitigation, the orbital stage of rockets completed the passivation operation, depleted thoroughly all the residual propellant after the separated of the satellite and the rocket, to eliminate the potential breakup on the orbit.

⇧ CZ-2D	Nov, 5, 2008
⇧ CZ-2D	Dec, 1, 2008
⇧ CZ-4B	May,27, 2008
⇧ CZ-4B	Oct,25, 2008
⇧ CZ-4B	Dec,15, 2008
⇧ CZ-2C	Sep,6, 2008
⇧ CZ-2F	Sep,25, 2008

● CZ-4B/C launched 4 times in 2010 and brought 7 satellites into the scheduled Orbital, , depleted thoroughly all the residual propellant after the separated of the satellite and the rocket.

2 De-orbit of upper stage

LV	Launch Date	De-orbit Effect
CZ-2C	Sep,9, 2008	660km→242km
CZ-2D	Nov,5, 2008	780km→306km
CZ-2D	Dec,1, 2008	640km→Direct Reentry

● CZ-2D launched 3 times in 2010 and actively took the de-orbit disposal after the successfully separated of the satellite and the rocket.

3 Mitigation operations of the satellites :

In order to protect the geosynchronous region, 3 China satellites :

Xinnuo-2(GEO),

FY-2A,

FY-2B

actively took the de-orbit disposal at the end of mission successively.

Highlights -- Protection

CASC

Hypervelocity Impact Testing Facilities in China Academy of Space Technology (CAST)

Caliber： Φ18

- **Launch Speed： 2-7km/s**
- **Projectile: aluminium alloy spheres and cylinders, 1-15mm in diameter, 0.0015-5g.**

Highlights -- Protection

CASC

Hypervelocity Impact Testing Facilities in China Academy of Space Technology (CAST)

- Laser energy: 20J, pulse
- Launch Speed: 1-10km/s
- Flyer: metal foil,0.5-3mm in diameter, 3-25 μ s in thickness.

Highlights -- Protection

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We completed "Space Debris Protection Design Manual" which provides a standard framework to assess meteoroid and orbital debris impact risk to spacecraft and designed relative shield.

The whole family of space debris hypervelocity impact research in BISEE, CASC

Highlights -- Protection

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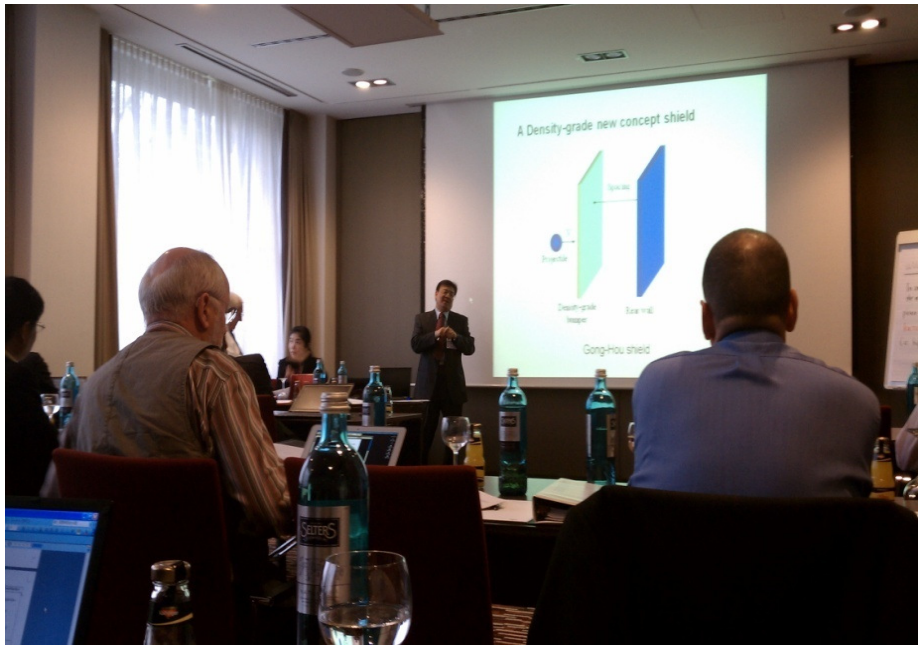
Hypervelocity Impact Testing Facility Cross Calibration between CNSA and NASA



Dr. Zizheng Gong and Dr. Eric L. Christiansen from NASA-JSC addressed the Hypervelocity Impact Testing facility cross calibration results at the 29th IADC Meeting.

Highlights -- Protection

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BUMPER: NASA, JAXA
ESABASE/DEBRIS: ESA
COLLO, BUFFER, PSC: ROSCOSMOS
MDPANTO: DLR
SHIELD: BNSC
MODAOST: CAST

Impact Risk Assessment Codes

Table 1 Calibration results for the cube

		BUMPER	ESAB./ Debris	MDPANTO	COLLO	SHIELD	MODAOST
NASA 2000	d > 0.1 mm	2.131E+01	n.a.	2.139E+01			2.143E+01
	d > 1.0 cm	2.876E-06	n.a.	2.872E-06			2.873E-06
	p > 1.0 mm	3.528E-01	n.a.	3.360E-01			3.368E-01
	single	1.714E+00	n.a.	1.642E+00			1.639E+00
	double	2.373E-05	n.a.	2.257E-05			2.303E-05
Meteoroid	d > 0.1 mm	2.221E+01	2.12E+01	2.164E+01			2.164E+01
	d > 1.0 cm	1.398E-06	1.30E-06	1.360E-06			1.362E-06
	p > 1.0 mm	1.013E-01	8.30E-02	9.064E-02			8.812E-02
	single	6.804E-01	6.00E-01	6.204E-01			6.018E-01
	double	1.354E-05	1.20E-05	1.142E-05			1.142E-05

Highlights -- Protection

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- Conducted the space debris impact risk assessment and designed the appropriate protection shield for China‘s first space lab module Tiangong-1.

Conferences on Space Debris in China

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Conference on Space Debris, held every two year.

2001: Haerbin
2003: Shanghai
2005: Beijing
2007: Nianjing
2009: Yantai
2011: Chengdu

2013: Xiamen

Chinese Journal of space debris research

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The one and only journal of space debris research in the world.

It's quarterly. Published since January, 2001.

Other Space debris related publications

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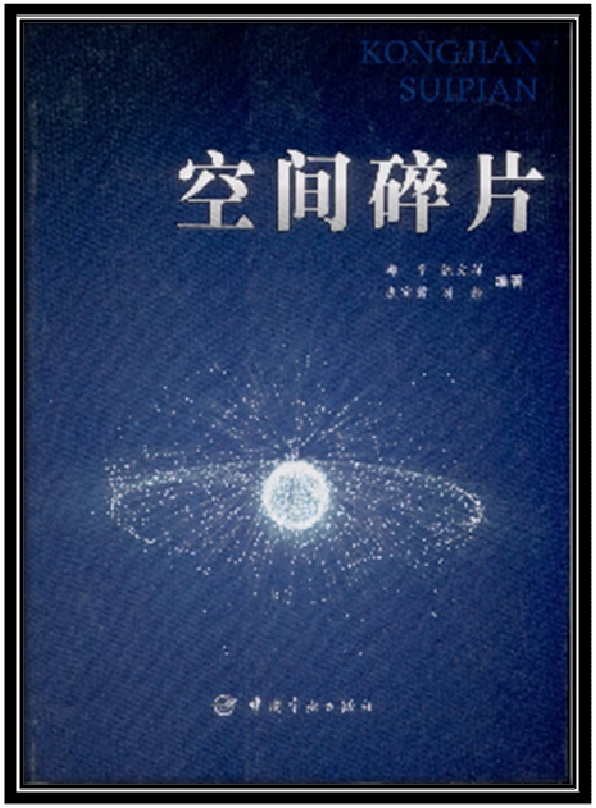

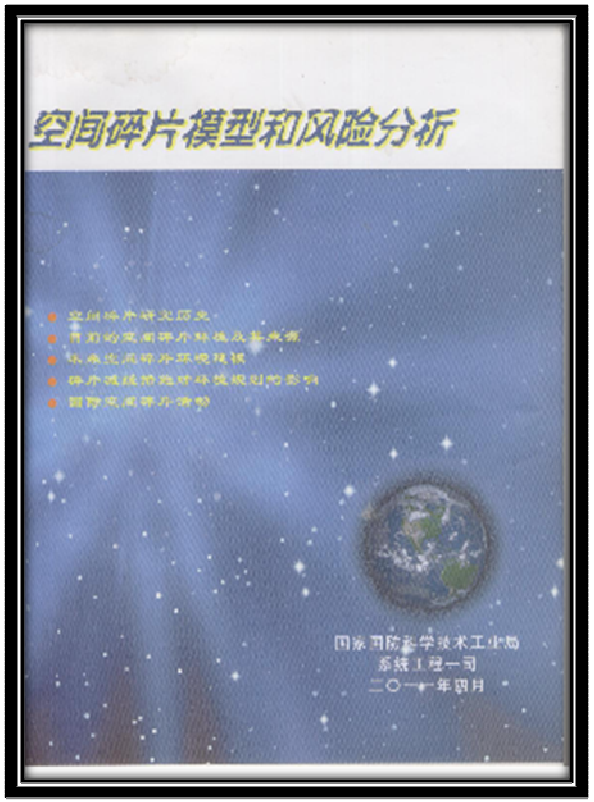

Beijing International Topical Conference on Space Sustainability

- Beijing Orbital Debris Mitigation Workshop
  October 18-19, 2010
- Beijing Space Sustainability Conference
  October 13-14, 2011
- Be ijing Space Sustainability Conference
  November 8-9,2012

This is a productive conference.
I proposed that the conference should be a regular annual conference in Beijing.

Beijing Space Sustainability Conference

Beijing Orbital Debris Mitigation Workshop, October 18-19, 2010

Beijing Space Sustainability Conference

Beijing Space Sustainability Conference October 13-14, 2011

CONTENTS

CASC

1 Overview

2 CASC Efforts of Space Debris Activities

3 Views and Conclusions

Views & Conclusions

CASC

- The space debris is a real concern and is of much importance regarding the long-term sustainability of outer space activities.

The UN Guidelines should be universally respected and implemented.

- Mitigation and Active Remove on-orbit are wise approaches pursuing long-term sustainability of outer space activities. The keynote of dealing with space debris is changing from protection against space impact to mitigation, then to active removal, and to the end of clean space. Intergovernmental and multinational and effective collaborations are needed in this regard.

Comments & Conclusions

CASC

- CASC has been making relentless effort to protect space environment and is already implementing practical measures on space debris mitigation on a voluntary basis within its own national mechanisms, also taking into account the UN Space Debris Mitigation Guidelines and IADC Space Debris Mitigation Guidelines, and had made its own contributions in this field.
- CASC encourages its institutes to promote exchanges and cooperation in various dimensions regarding space debris and long-term sustainability of outer space activities.

Thanks for your attention!