Independently Developed Systems Engineering of China Aerospace Industry

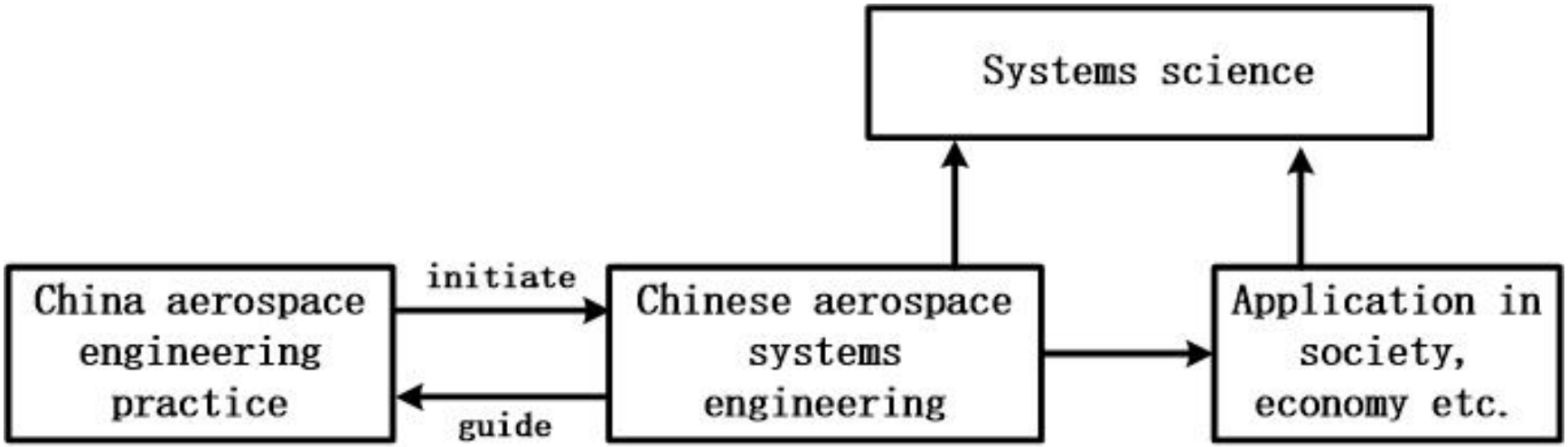
Zheng Xinhua

China Aerospace Academy of Systems Science and Engineering, China

zhengxinhua126@126.com

Preface

- China's aerospace industry is the advocate and successful practitioner of systems engineering, and has developed the Chinese aerospace systems engineering method.
- This method has been applied in social and economy areas and contribute a lot to construct the systems science.



Outline

The Work to Explore China Aerospace SE

Development Process of China Aerospace SE

Main Content of China Aerospace SE

Example of SE Application in China Space Project

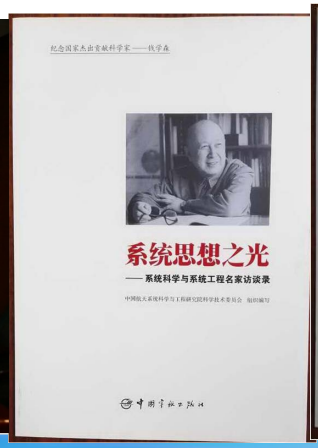
Expansion of China Aerospace SE

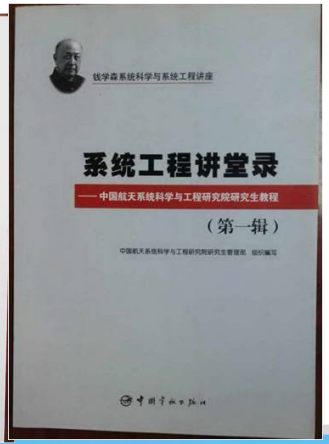
CAASSE

- China Aerospace Academy of Systems Science and Engineering (CAASSE) is the only organization on systems engineering in China aerospace industry, it is combined with Beijing Institute of Information and Control (BIIC) and other units in 2011.
- CAASSE has carried out a lot of work to explore the origin, development process and content of China aerospace SE in recent years.

Interview SE Specialists

- In 2013, CAASSE carried out a project "Interview SE Specialists", interviewed more than 50 specialists in aerospace, economy and society domain.
- This work shows that:
  - the development of Chinese SE is benefits from the application of China aerospace SE and the leadership of Hsue-Shen Tsien.
  - The Chinese SE has distinct characteristics, and is closely related to China's society, economy and technology.
  - It has been widely used in various fields in China, and has enormous influence.

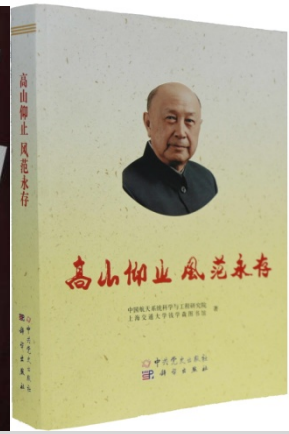




Oral Account Hsue-Shen Tsien Project

- From 2014, CAASSE carried out a project "Oral Account Hsue-Shen Tsien", this project has interviewed more than 70 specialists.
- The interviewees introduced the background for Tsien to found China aerospace SE, the process to improve the approach, the successful applications and the blueprint drawn by Tsien to spread the approach.





Outline

The Work to Explore China Aerospace SE

Development Process of China Aerospace SE

Main Content of China Aerospace SE

Example of SE Application in China Space Project

Expansion of China Aerospace SE

Building SE Under Planned Economy System

- In 1956, China government set up the aerospace organizaiton --- the 5th Academy of Department of Defense.In 1961, the 5th Academy issued “DoD Provisional Regulations for the 5th Academy (draft)", it’s the start of Chinese aerospace systems engineering management.
- In 1962, the flight test of China's first self-developed short-range missile failed. After conscientiously summed up experiences and lessons, the 5th Academy revised the Provisional Regulations. It has 3 core elements:

1) to establish two command line: technical command and administrative command;
2) to establish the system engineering department, scientifically determine the overall scheme on every level, strictly control the configuration state, and ensure the overall system optimization;
3) to establish the planning and coordination management system on research and production work.

Building SE Under Planned Economy System

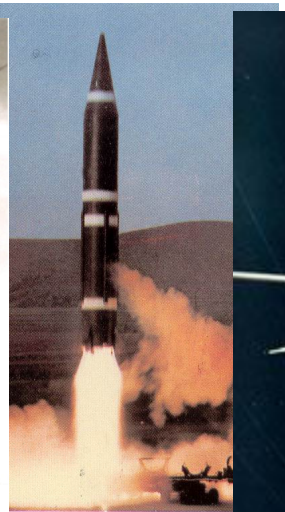
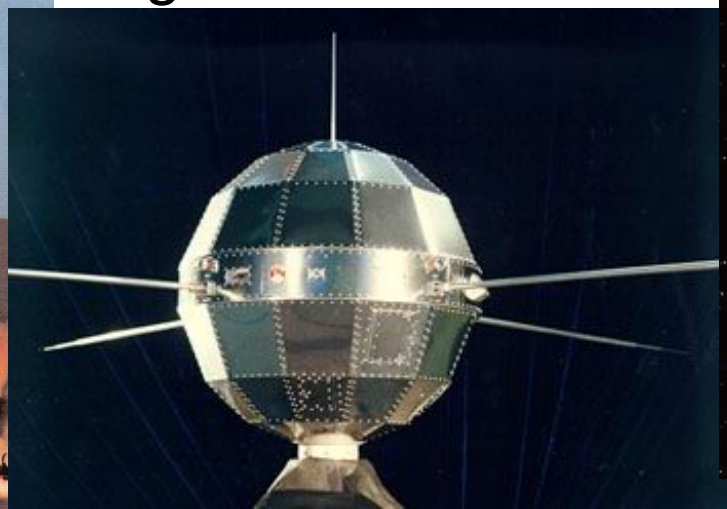
Rudiments of Early Chinese Aerospace SE

Principles:

- Emphasize the system design
- Strictly adhere to the program
- Fully carry out ground tests

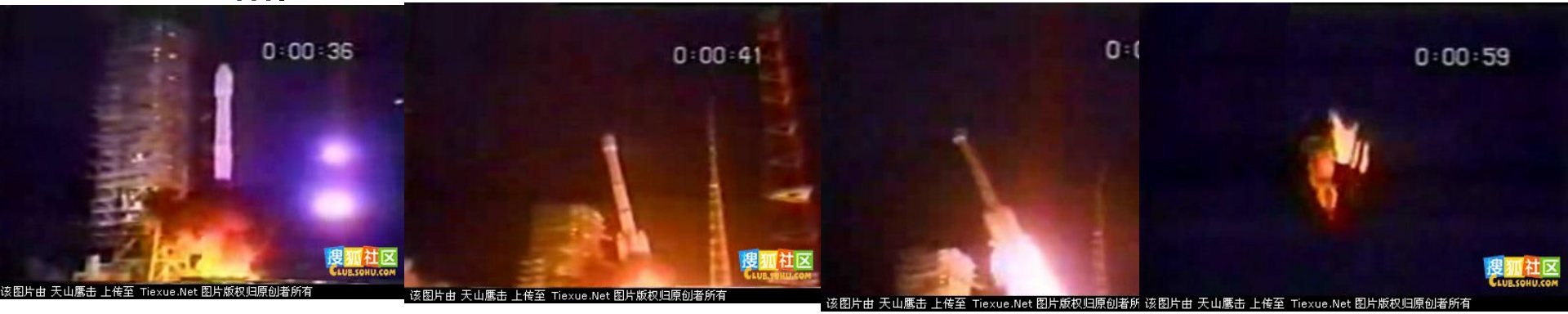
Procedure:

- Explore and research one generation
- Design and prototype one generation
- Finalize and produce one generation


Improving SE under Market Economy System

- In 1978, the Chinese government implemented the "reform and opening--up" policy, the number of state investment aerospace project was significantly decreased
- China’s aerospace faced a large challenge and commit many failures.
  - Feb 15, 1996, CZ-3B launched Intelsat 708 failed;
  - Aug 18, 1996, CZ-3 launched Star VII failed
  - ….



CZ-3B launched Intelsat 708

Improving SE under Market Economy System

Faced with these failures, China's aerospace conscientiously summed up experiences and lessons, then proposed a number of effective measures, including:

- ***technical 5--principle for resolving problem***
  - the fault location is accurate, the fault mechanism is clear, the fault can reoccur, the measures are effective, other similar cases learn the lesson
  - It is accepted as **ISO 18238 <Space Systems – Closed Loop Problem Solving Management>**
- ***managerial 5--principle for resolving problem***
  - the process is clear, the responsibilities are specified, the measures are implemented, persons responsible are punish sternly, the regulations are improved
- ***5—principle for configuration management***
  - demonstrated fully , recognized by all parties, verified by test, approved completely, implemented effectively
- ……

Improving SE under Market Economy System

- China's aerospace promulgated the "*Rules to strengthen the management of scientific research and production work for China Aerospace Corporation (Trial)*" and "*Requirements for strengthening the quality management of space project*" in 1997.

- In 1999, China's aerospace industry is divided into CASC and CASIC.In 2004, CASC promulgated the "*Management regulations for the space project (trial)*". These regulations reflected new systems engineering concepts and methods for space project under the market economy:

- In the subsequent work, CASC carry out fine quality management, including to establish "Quality and Reliability Data Package", to carry out an independent risk assessment and technology readiness assessment.

Outline

The Work to Explore China Aerospace SE

Development Process of China Aerospace SE

Main Content of China Aerospace SE

Example of SE Application in China Space Project

Expansion of China Aerospace SE

Main Content of China Aerospace SE

China aerospace SE has formed a complete system, which is similar to the other famous system engineering standards, but it also has the following characteristics.

1.Emphasis on the System Design and Management

- In China's aerospace industry, each academy sets up a system engineering institute, and each space program sets up a system engineering department.

2. Strictly Following the Development Process

- The stages for China aerospace include demonstration stage, scheme stage, preliminary design stage, detailed design stage, utilization and improvement stage.
- China aerospace set up several review points in the development process and some special reviews (eg. software, configuration changes, reliability and safety, problem solving) before transition.

Main Content of China Aerospace SE

3. Strict Configurations Management

- Lessons learned from the failure of China's aerospace industry, which is "small change cause big error".
- "5—principle for configuration management" (demonstrated fully, recognized by all parties, verified by test, approved completely, implemented effectively).

Main Content of China Aerospace SE

4. Paying High Attention to Quality Management

- quality first
- organization in charge of the quality system, project in charge of the quality specification, professional institutions in charge of professional technology
- start from the source, control along with the whole process, zero defect management, fight for succeed at one time

Main Content of China Aerospace SE

5. Paying High Attention to Risk Management

- China attaches great importance to the success of products and missions. In the limited conditions, strengthen risk management, strengthen the ground test for space product, to find and eliminate all kinds of factors that may cause failure.
- Independent risk assessment for key tasks is performed.

Main Content of China Aerospace SE

6. Support SE with Information System

- Application of SE in the management work, such as Gantt and PERT/CPM, in 1960s.
- Developed software tools and information system to realize the corresponding SE in 1980s.
- Several SE management information systems, such as AVIDM, AVPLAN, AVTDM, AVMPM, are widely used in China aerospace organizations, and spread to other industries.

Outline

The Work to Explore China Aerospace SE

Development Process of China Aerospace SE

Main Content of China Aerospace SE

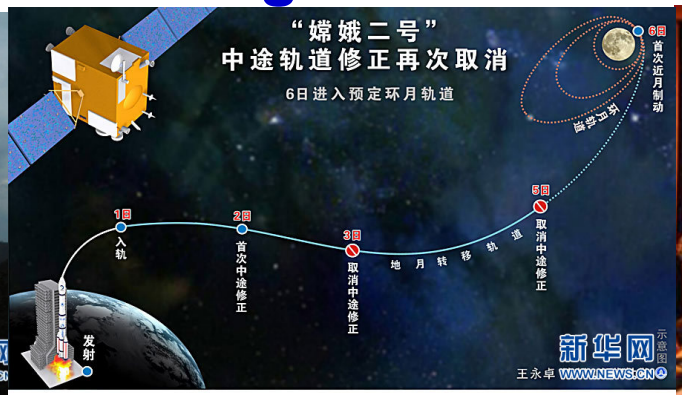
Example of SE Application in China Space Project

Expansion of China Aerospace SE

Example of SE Application: CE-2

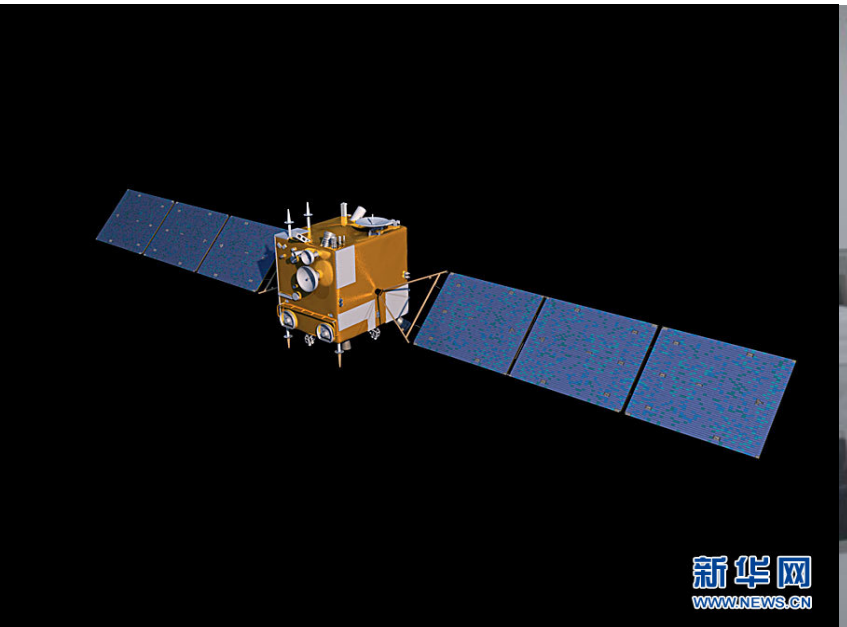
- There are hundreds of CSCI and programmable logic devices in the CE-2 project
- Software has strict requirements on intelligence, real-time, safety and reliability
- Competition mechanism and international communication is encouraged

In order to ensure the smooth progress of software development and to assure software quality, systems engineering methods are applied in the software development and management in CE-2 project.



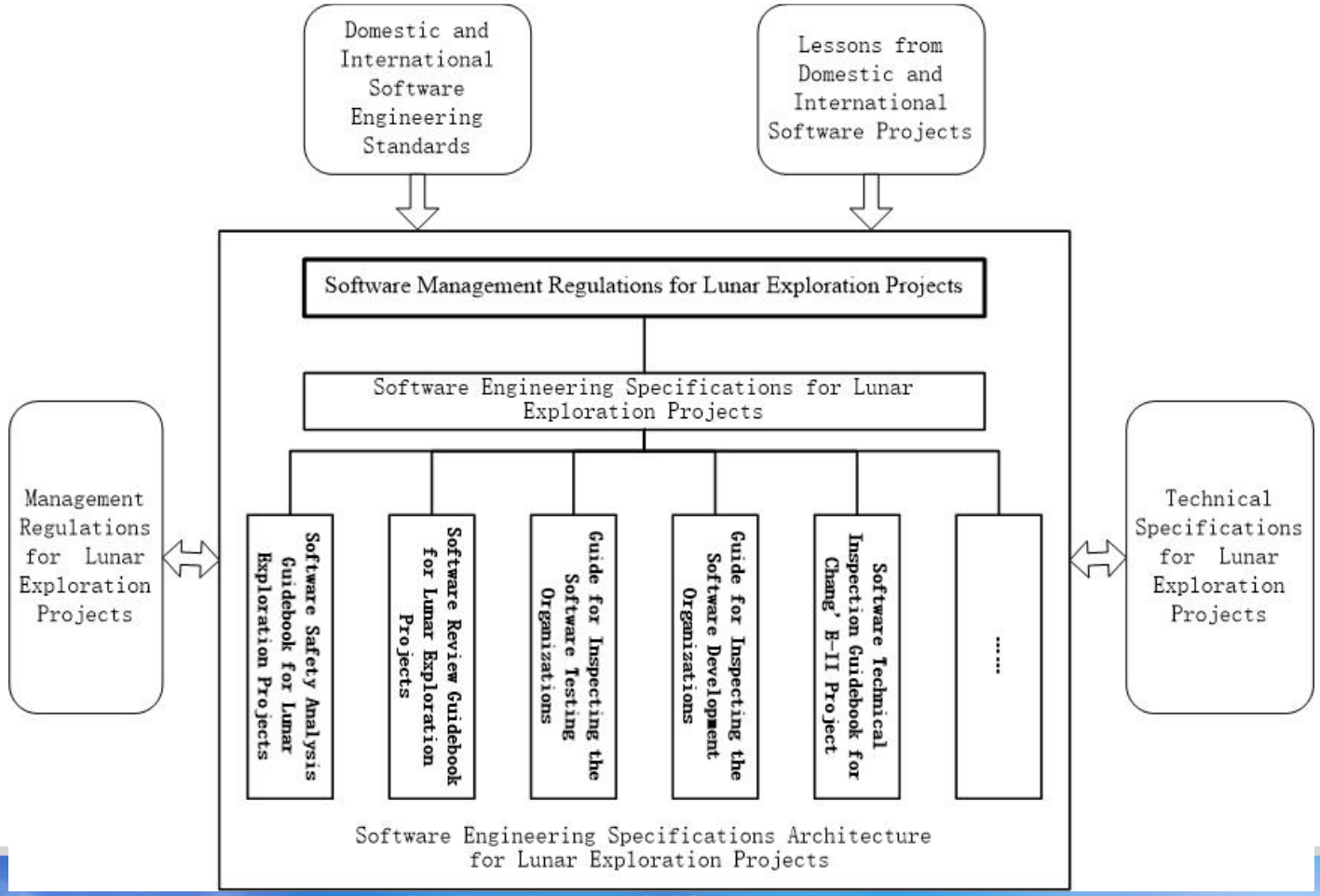
Example of SE Application: CE-2

1. Carrying out spacecraft information system design and software system design.
   - integrated electronic system
   - Software system design
   - software technology selection



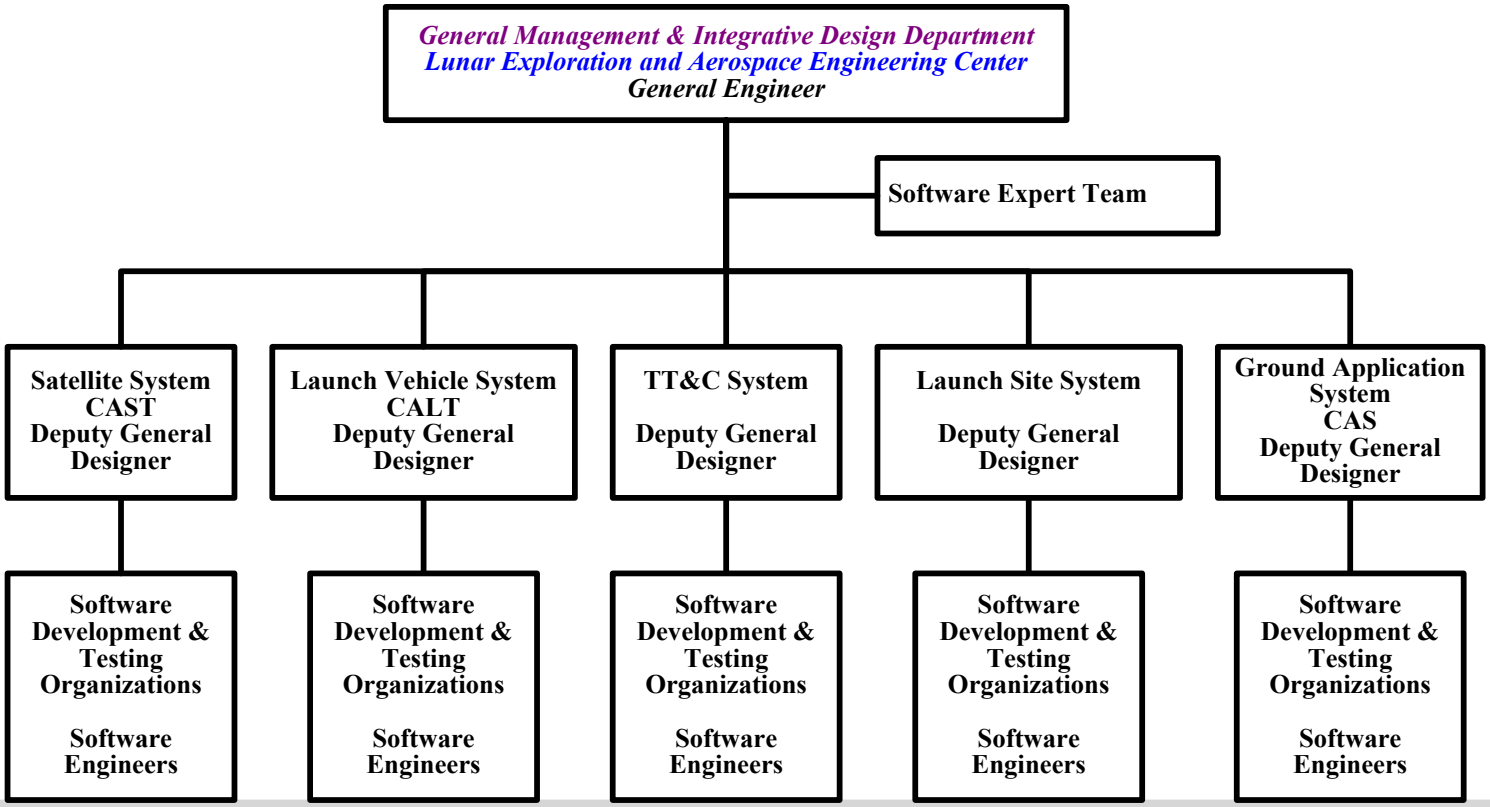
Example of SE Application: CE-2

2. Developing the software engineering specifications system



Example of SE Application: CE-2

3. Establishing software organization system with clear responsibilities at all levels.



Example of SE Application: CE-2

4. Processing the software engineering management orderly and coordinately.

- early stage: propaganda and training
- middle stage: review, inspection and check
- later stage: special analysis and verifications, such as interrupt protection, interrupt nesting analysis, avoiding access conflict to global variables, etc

Example of SE Application: CE-2

5. Carrying out software special inspection

- **Focus on new software and FPGA**
- **Verify the treatments:**
  - empty interrupt protection,
  - interrupt nesting analysis,
  - avoiding access conflict to global variables
  - watch-dog reset
  - IP verification…

SE contributed a lot to ensure the success of software work in CE-2 project.

Outline

The Work to Explore China Aerospace SE

Development Process of China Aerospace SE

Main Content of China Aerospace SE

Example of SE Application in China Space Project

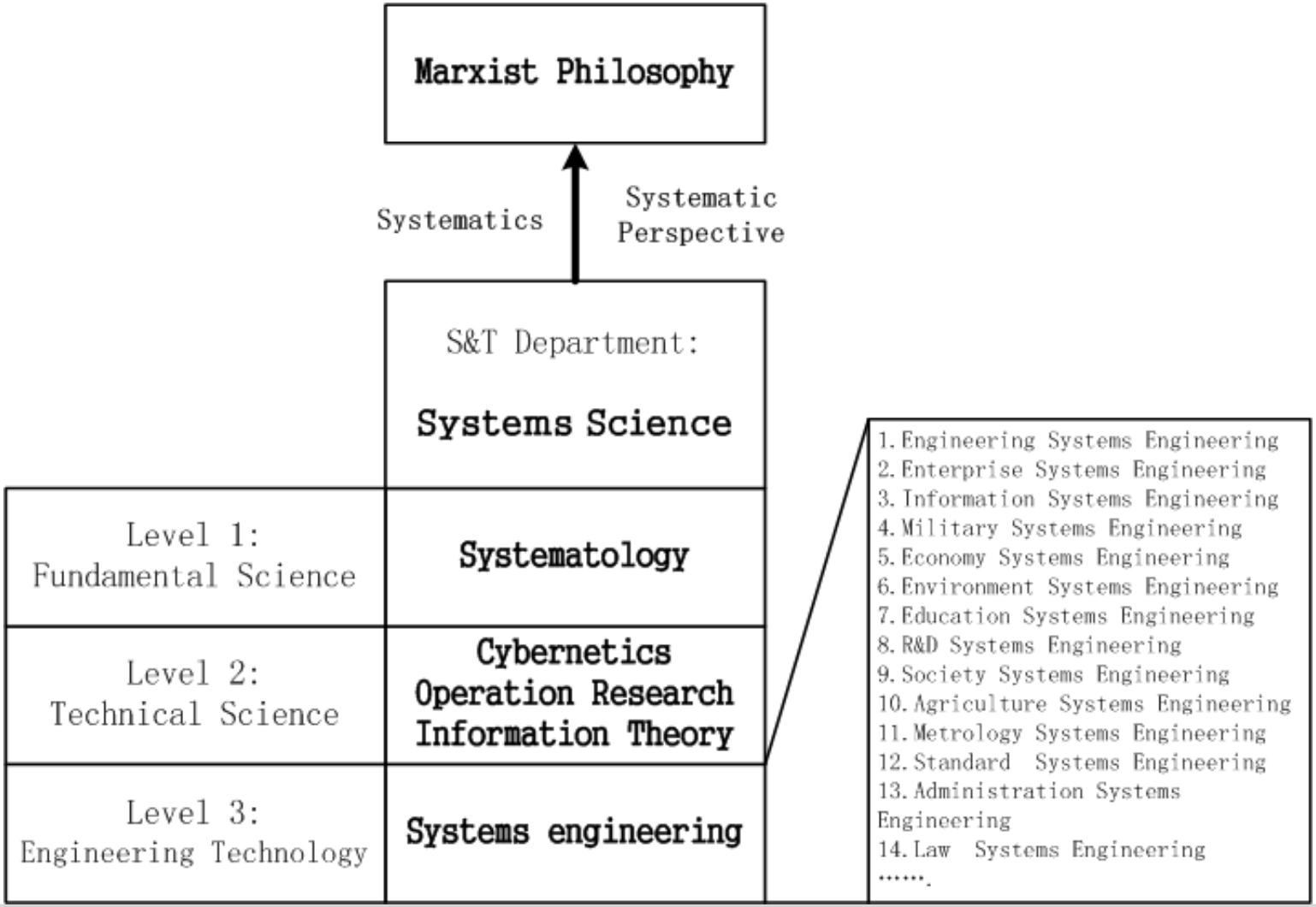
Expansion of China Aerospace SE

Expansion of China Aerospace SE

- In 1978, Qian published *"Organization and Management Technique – Systems Engineering*", the milestone of the development of systems engineering in China.
- In 1982, China set up a professional institute on system engineering - Beijing Institute of Information and Control (BIIC).
- In 1986, Qian organized "systems science seminar" in BIIC, and discussed the system theory weekly.
- In the meantime, China's aerospace promoted and used PERT, review etc. and carry out dynamic management base on computer.

These activities made China's aerospace become the core of researching and spreading systems engineering method.

Expansion of China Aerospace SE



Expansion of China Aerospace SE

- In 1980, Systems Engineering Society of China (SESC) was established in Beijing.

- With the help of Mr. Qian, SESC and others experts, systems engineering method is widely used in Chinese society and economy areas, eg. Three Gorges Project, many great oil and petrochemical project and the development of China's railway network…

Expansion of China Aerospace SE

- BIIC kept studying on China‘s major decisions on the reform, opening--up and modernization, and support the Chinese government a lot on decision support work:
  - In 1980s, the quantitative research on China‘s population developing process
  - 1983-1985, *Comprehensive study on fiscal subsidies, prices and wages*
  - From 1986, *Study on Three Gorges Project’s comprehensive benefits*
  - From 1993, AIDS’s socio-economic impacts
- In 2011, BIIC and other units combined as China Aerospace Academy of Systems Science and Engineering (CAASSE).
- After it is formed, CAASSE propose the “Improving Theory” to guide the different branches of systems engineering techniques in China, edit the *"History of Systems Engineering Thoughts”,* and also carried out technology/management/staff maturity assessment, economic and social complex systems modeling and simulation ….


Song Jian

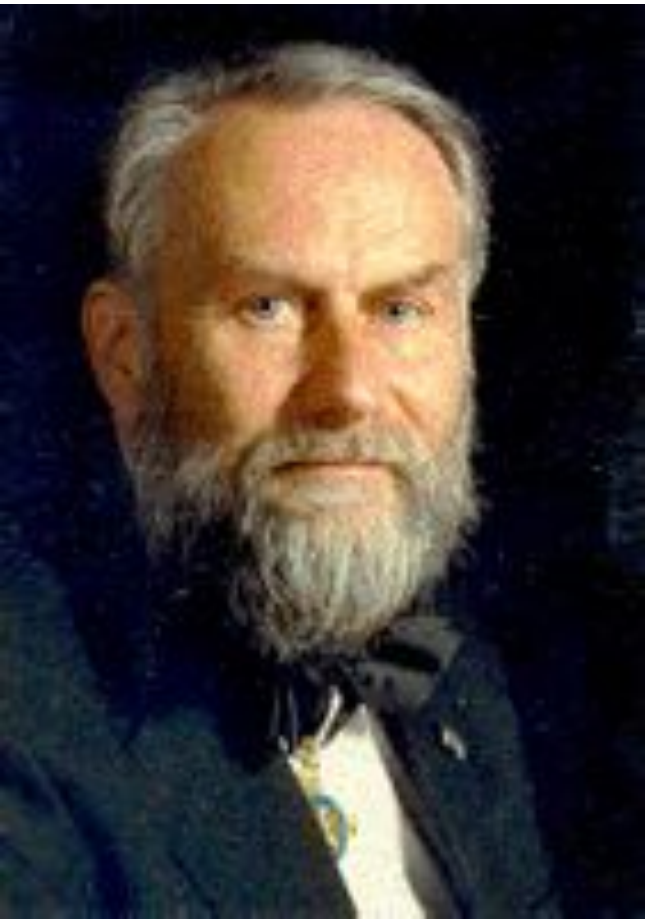
Yu Jingyuan


Guo Baozhu


Wang Kunsheng

Xue Huifeng

Conclusion



Hermann Haken

In 1986, H.Haken said:

"Systems science and systems engineering is on the essential position on the contemporary Chinese science, I have been aware of it when I visited China. During my visit, the Chinese way of thinking and solving problem has repeatedly impressed me. I am sure this way of thinking will spread throughout the world."

Conclusion

- China’s aerospace is the representative of Chinese high-tech industry, it integrates many China's advanced science & technology and management methods, explored and summarized the aerospace systems engineering method at first.
- With the integrated development of Chinese military and civil aerospace industry, China’s aerospace is continuously enriching systems engineering contents and methods, these methods are extending to Chinese society and economy and more areas, and will produce great results.

Thanks for your attention!