Holland Innovation Network

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Opportunities in China's Space Program

Summary

Scientific publications and patents reveal China still lacks knowledge in the area of interplanetary flight, and in tracking and telemetry (TT&C) of spaceflight. In a lesser extent it also lacks expertise in hazard monitoring and power generation in space. It needs this knowledge to reach the ambitious goals set in the five years plan of its space agency CNSA. In that plan there is already call for international collaboration on TT&C and monitoring of space debris, offering the clearest opportunities for Dutch companies and research institutes. There are also promises of sharing more launch sites. The China Aerospace Science and Technology Corporation (CASC) and its many subsidiaries, among which the biggest the Chinese Academy of Space Technology (CAST), are the central actors in this plan. The Chinese Academy of Sciences (CAS) and various universities are also expected to contribute in some areas. Space applications are not a focus area of CNSA for international collaboration, but there could be other institutes in China interested in collaboration.

Full message

China has plenty of ambitions in space. The China National Space Administration (CNSA) aims to start operation of the Tiangong-2 space laboratory before 2022, to land a probe on the back side of the Moon in 2018, to launch a probe to orbit Mars in 2020, and to complete its own GPS system. Space has also become one of the eight major focus areas of the Chinese Academy of Sciences (CAS) in its 13th Five Year Development Plan, compromising five of a total of 60 key projects. These projects mostly overlap with CNSA, although there is also an independent plan to build a stratospheric airship for scientific purposes, capable of long flights, to be operated at 20 km height. For a full list of the goals set by the two most important instances, see the appendix.

Not all of this enthusiasm is reflected in public research until now. **With 20% of the world's scientific publications in this area, compared to 31% overall in Engineering, Space has not been a scientific focus.** From 2010-2015, output in terms of publications grew with 5% per year, less than the 6% average for China[1]. Biggest growers were the China Aerospace Science and Technology Corporation (CASC), its subsidiary Chinese Academy of Space Technology (CAST), and the National University of Defense Technology (NUDT), with 22%, 20% and 8% per year respectively. This is a signal that activities in this area are being centralized. Citation impact is below world average. Apart from this, more than 65% of citations to Chinese papers from 2010-2013 came from a publication affiliated to a Chinese research institute, higher than average for China. In turn only 18% of references in Chinese papers were Chinese.

The Chinese exclusion policy of NASA only has limited influence on scientific collaboration with the United States. Still 40% of Chinese international publication are done in collaboration with an American affiliation, a few percentage less than overall. However, the EU-28 does gain a larger share (40% compared to 27% overall), at the cost of the rest of the world. Overall, the area is about as internationalized as average for Engineering, less than other areas like Health and Life Sciences. **The Netherlands is China's 9th biggest partner country.**

Table 1 gives an overview of the biggest universities and research institutes in this area with a number of parameters related to their academic performance. Amounts of successfully filed patents are also

[1] The database Scopus was used for all scientific publication analyses. Papers in the field of Astronautics were identified using the predefined Scopus category Aerospace, from which the journals, conferences and keywords related to Astronautics were manually selected. Biggest keywords were NASA, Spacecraft, Spaceflight, Satellites and Earth. Biggest sources were Proceeding of IAC and SPIE, Advances in Space Research, Advances in Astronautical Sciences, and Astronautica. Unless otherwise stated, all data in this report concerns the period of 2010-2016.

displayed. The biggest filers are all universities, related to CASC or state research institutes. Biggest private filer is Chengdu Linhai (Woodlands) Electronics, which for example built Laos' first satellite in 2015.

Companies	Scientific Publications	Countries per Publication	Citation Impact[2]	Granted Patents	Full Utility Patents (%)
China	21430	1.19	0.82	3176	64%
Beihang University	1761	1.17	0.85	140	97%
Harbin Institute of Technology	1740	1.15	0.82	124	100%
Chinese Academy of Sciences Beijing	1300[3]	1.58	1.36	45	67%
Nat'l Universtiy of Defense Technology	1223	1.08	0.71	13	92%
North Western Polytechnic University	1098	1.08	0.79	63	100%
CAST (Subsidiary of CASC)	928	1.04	0.44	134	90%
Other Institutes Beijing	878	1.25	0.79	14	0%
Beijing Institute of Technology	875	1.07	0.8	39	87%
Tsinghua University	784	1.24	0.77	18	61%
CASC (Other than CAST)	541	1.03	0.46	182	60%
Nanjing University of Aeron. & Astron.	464	1.13	0.86	24	42%

Table 1: Top 10 biggest research institutes and universities based on number of scientific publications produced. Period from 2010-2016. Fully Utility Patents have a lifespan of 20 years, as opposed to Limited Patents also available in China, which last 10 years.

In terms of scientific impact, universities all perform similarly. Beijing institutes of CAS catch the eye with high impact and high internationality. Institutes with a clear focus on this area are the National Astronomical Observatories and the Center for Space Science and Applied Research, although many other also participate.

China Aerospace Science and Technology Corporation (CASC) is the main contractor for the Chinese space program. It employs over 170,000 people, has assets worth 40 billion EUR and is wholly state-owned. The company supervises a long and somewhat confusing list of subsidiary research institutes and production companies. The only competitor of CASC is the China Aerospace Science and Industry Corporation (CASIC), although it is bigger in terms of assets, it focuses more on missiles, and does not show up as a relevant player in Astronautics by patents or scientific publications.

The biggest subsidiary of CASC is the Chinese Academy of Space Technology (CAST) in Beijing, which in itself again controls a dozen subsidiaries, some of which have their own subsidiaries. In terms of research and patents, the most important one of these is Beijing Institute of Control Engineering and the Beijing Institute of Spacecraft System Engineering. Other important subsidiaries of CASC outside CAST are the Shanghai Satellite Engineering Institute, the Shanghai Aerospace System Engineering Institute and the China Academy of Launch Vehicle Technology. It is important to note that these institutes are sometimes competing rather than collaborating.

The low citation score and internationality of research at CASC and CAST are striking. There are also no patents filed abroad. **If CASC wants to realize the ambitions set by the space agency CNSA, it might benefit from more international research collaboration. This could offer opportunities for Dutch research institutes or companies.**

Beijing also has many other small institutes active in this field, not directly affiliated to CASC, which further muddy the picture. Many of these are directly affiliated to ministries or the State Council, like the China Astronaut Research and Training Center, State Oceanic Administration, China Earthquake Administration. Others are directly affiliated to the army, like various Aerospace or Satellite Control Centers.

[2] Parameters used in the "mean normalized citation score", the number of citations per paper normalized by the world average per year. A score of 1.00 means cited exactly average for the world, less means cited less. Only English language articles and reviews were used for this.

[3] Estimate. Some papers of CAS are not affiliated to an institute, and therefore they have been classified to the Beijing branch using the ratio of all CAS papers in Beijing in the known affiliations.

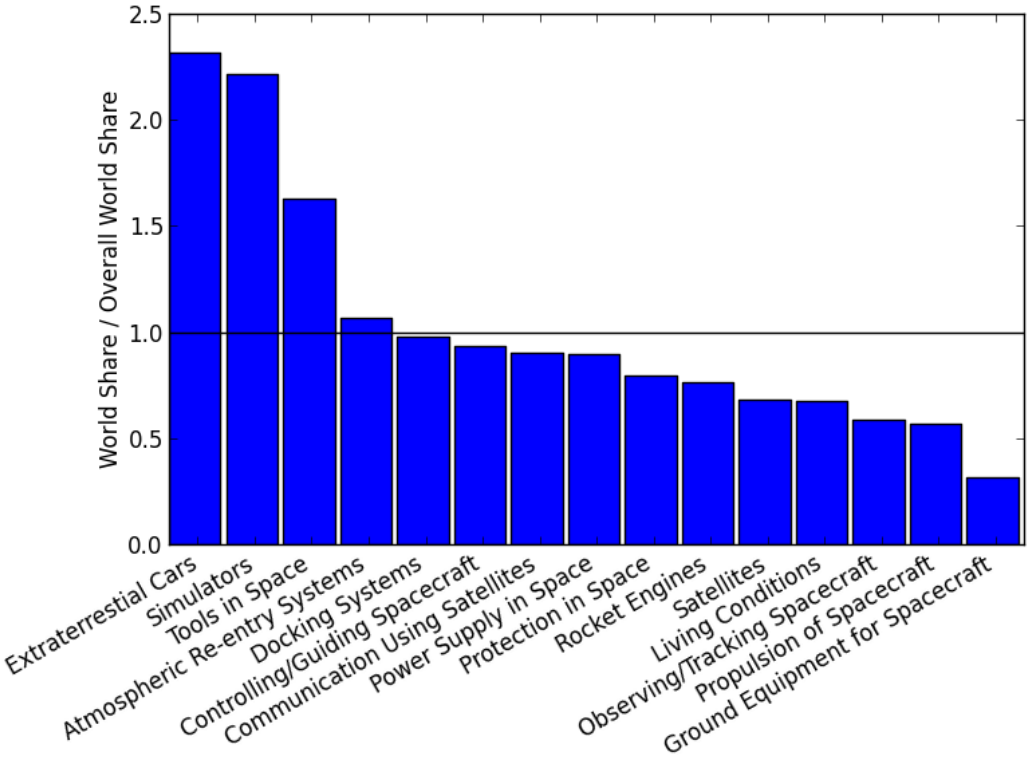

Figure 1: Distribution of patents within the space patent category (B64G, H04B7/185, F02K 9). Patents in the left are overrepresented in China. Five categories were omitted because they were too vague in scope (e.g. other parts) or too small (e.g. Space Suits). Categories have been simplified a bit from the official name.

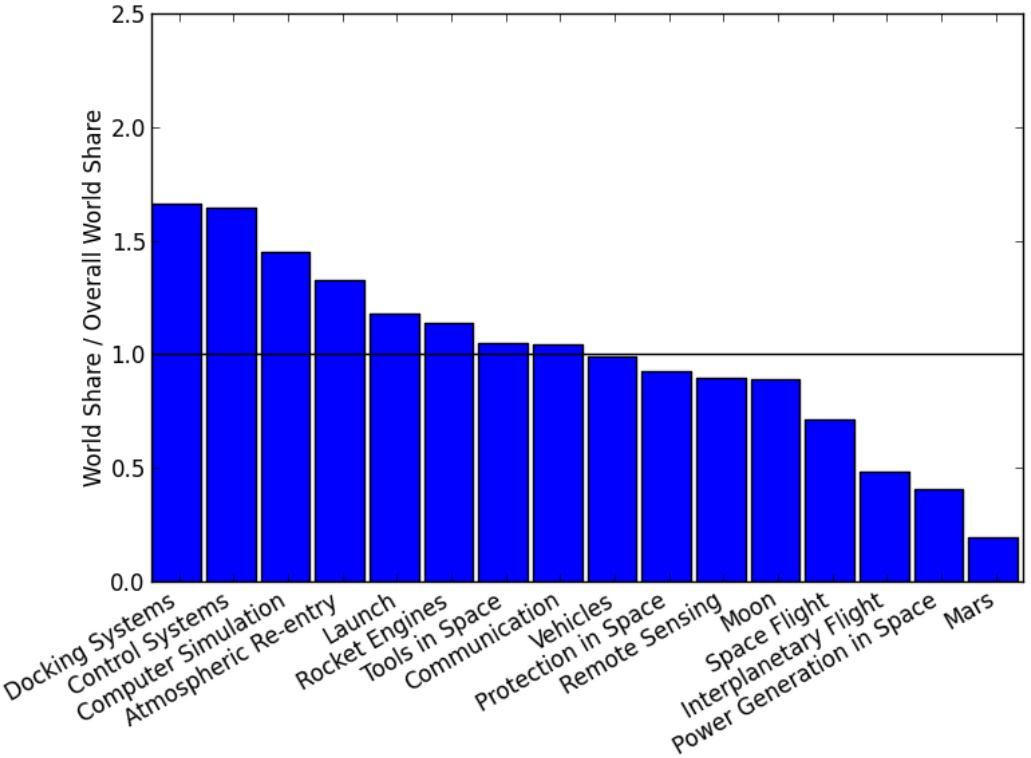

Figure 2: Frequency of categories of author provided keywords within the Chinese Astronautic publications. Groups of keywords related to topics on the left are overrepresented in China compared to the rest of the world.

Figure 1 and 2 give an overview of which scientific areas are overrepresented in patents and scientific publications. **Simulation, docking and atmospheric re-entry have clearly had a big focus in China. However, the country has little experience with interplanetary flight**. There might prove to be a big demand here for international cooperation to reach the ambitious goals of sending an orbiter to Mars.

Sino-Dutch collaboration in space has already proven to be fruitful. A Memorandum of Understanding (MoU) was signed in 2015 between the Netherlands Space Office (NSO) and CNSA. This MoU for example paved the way for a Dutch instrument to be included in the Chang'e 4 mission. Furthermore, TNO founded a joint laboratory with Beijing Institute of Space Mechanics and Electricity (BISME), a smaller subsidiary of CASC, on space optical instruments. Furthermore they organize an annual TNO-BISME conference. China's ambitions in space are big, but scientific publications show it still lacks expertise. This makes it likely there will be more opportunities in the future for Dutch companies and research institutes to expand or start collaboration with China in space.

However, it could be hard to identify the right partners in China. In the appendix, the goals until 2021 set by CNSA and CAS are displayed. Especially on Telemetry, Tracking and Control there is a call for international relationship by CNSA. Furthermore, there is an aim to "explore and advance the building of space launch sites that are open to cooperation and sharing", and a plan for data-sharing on space debris and space climate. The Netherlands is strong in space applications, but there is no call for international collaboration here by CNSA. This does not necessarily mean there is no need in China, but perhaps different institutes need to be approached. IA China is planning to make a mapping of relevant institutes in the near future.

Appendix

Structure of Chinese Space Program

As a result of 50 years of expansion, intertwinement with the People's Liberation Army (PLA), and an overall complexity of the Chinese government system, the activities for the Chinese space program are scattered across a maze of governmental and semi-governmental organizations. The China National Space Administration is the most clearly defined supervisor. It is in itself supervised by the State Administration on Science, Technology and Industry for National Defense, which is part of one of China's most important ministries, the Ministry of Industry and Information Technology (MIIT). It does however not have formal authority over the Chinese Academy of Sciences (CAS), which has the authority of a separate ministry. The large overlap between the 13th five year plan of CAS and CNSA suggests there is coordination going on between the two. The PLA comes in with joint responsibility over CASIC, and the China Satellite Launch and Tracking Control General (CLTC), responsible for the launch and tracking sites.

Unlike NASA, CNSA does little more than supervising the space program. It's two important subsidiaries are the China Aerospace Science and Technology Corporation (CASC) and the China Aerospace Science and Industry Corporation (CASIC), which is jointly supervised by the PLA, and focuses more on missiles and satellite components. The most important subsidiaries of CASC are the Chinese Academy of Space Technology CAST (often called the Beijing Branch of CASC), Shanghai Academy of Spaceflight Technology SAST (often called the Shanghai Branch of CASC), and the China Academy of Launch Vehicle Technology (CALT).

More information:

- General overview relevant government bodies space: http://www.springer.com/cda/content/document/cda_downloaddocument/9783319194721-c1.pdf
- CASC structure: http://english.spacechina.com/n16421/n17138/n17242/c127153/content.html
- CAST Structure: https://web.archive.org/web/20080429003232/http://www.cast.cn/CastEn/Class.asp?ClassID=71

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13th Five Year Plan CNSA and CAS

CNSA released an English language white paper on its strategy December 27th 2016, listing ten major project. CAS released a Chinese language strategy in reaction to the central 13th five year plan of the Chinese government. In the area of space, they list five projects, which partly overlap with one or more of CNSA's projects. In general, the program of CNSA is more comprehensive.

CNSA	CAS
Space Transport System: - Improve medium-lift launch vehicles. - Start project to develop heavy-lift launch vehicle.	*No activities*
Space Infrastructure: Improve satellite infrastructure for: - Remote Sensing. - Communication. - Navigation (Beidou-2), 35 satellites by 2020.	Beidou Global Positioning System: - Build Beidou-2 navigation system in 2020. - Satellites need to be smaller, more leightweight and smarter.
Manned Spaceflight: - Connect Tianzhou-1 to space station Tiangong-2. - Start operations of Tiangong-2.	Manned Space Station and Laboratory Applications: Start use of Tiangong-2. Lay foundation for scientific uses of Tiangong 2: - Cold atomic clock. - Detect polarization of gamma rays. - Satellite quantum key communication experiment.
Deep-space Exploration: - Soft landing and return of Chang'e 5 on Moon at end of 2017. - Soft landing of Chang'e 4 on back side of the Moon, including in situ laboratory, radio telescope. - Launch the first Mars probe by 2020 to carry out orbiting and roving explorations.	The Moon and first Explorations of Mars: - Chang'e 4&5 to the Moon - Bring back samples from back of Moon - Construct Telescope at back of Moon - Research of Martian atmosphere and surface.
Experiments on New Space Technologies Using four new satellites: - Shijian 17, 18 & 19. - Global carbon dioxide monitoring satellite. - Experiments on key technologies for new electric propulsion, laser communications and new-generation communications satellites. - Build in-orbit servicing and maintenance systems for spacecraft.	Partly overlap with Space Science Pilot Project (see lower panel).

Space Launch Sites - Improve reliability and IT application - Advance building of space sites open for sharing.	*No activities*
Space Telemetry, Tracking and Command - Enhance TT&C systems, build and operate a second generation relay satellite system. - Intensify international collaboration. - Form a new TT&C service pattern marked by openness and sharing.	*No activities*
Applications of Space - Remote sensing for industrial applications. - Urban planning. - Public services (communication, telemedicine, wearables).	*No activities*
Space science - Satellite to detect high-energy electrons and gamma rays. - Experiments on board Shijian-10, Chang'e, Tianzhou-1 and Tiangong-2. - Quantum entanglement, teleportation experiment satellites.	Space Science Pilot Project: Launch 3-6 satellites to do research on: - Geosphere coupling law. - Gravitational waves. - Climate change, water cycle. - Relationship between solar outer layer and magnetic eruptions.
Space environment monitoring - Improve space debris database and data-sharing model - Improve monitoring facilities - Enhance spacecraft protection capabilities.	*No activities*
No activities	Stratospheric Airship: - Design and develop airship for scientific experiments. - Capable of long flight at 20,000 m altitude.

CNSA: http://www.spaceref.com/news/viewsr.html?pid=49722
CAS: http://www.cas.cn/yw/201609/t20160902_4573584.shtml