2012 Top S&T Progress in Limelight

By SONG Jianlan (Staff Reporter)

The accurate dockings of China's spacecraft *Shenzhou*-9, which carried the first Chinese woman astronaut and her male colleagues, with the *Tiangong*-1 space laboratory is revealed to top China's most important 10 S&T advances of the year 2012 on January 19, 2013, after a vote by Members of CAS and the Chinese Academy of Engineering. Also on the list are other significant S&T developments in space exploration, including results from the lunar orbiter *Chang'E*-2, and some breakthroughs in basic physics.

This is the 19th time for Members of the two Academies to choose the outstanding S&T achievements of a year to mark China's S&T progress. Now let's follow the academicians to review these achievements, many of which are made by CAS scientists or with their participation, by fields.

Space Exploration and Astronomy

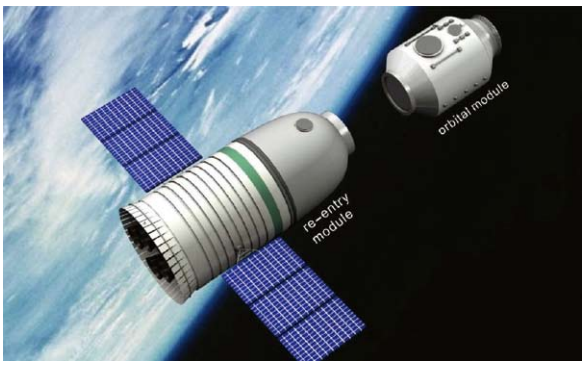
Human curiosity about outer space as well as the subsequent explorations has lightened up the history of science; interestingly the same motivation and efforts have contributed four out of 10 top-notched domestic S&T achievements of 2012: the biggest share compared with other disciplines.

No.1: *Shenzhou*-9's Triumph

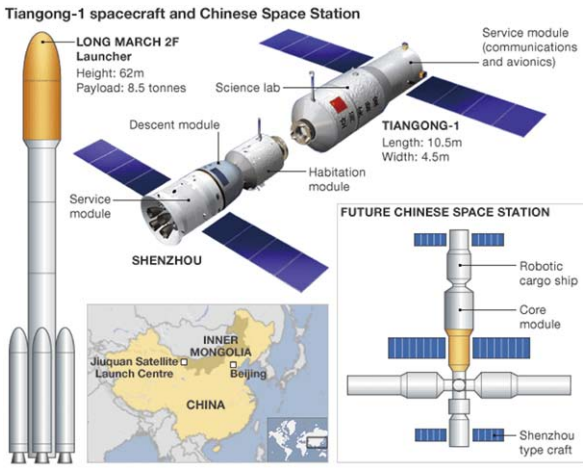
The live broadcasting of the breathtaking dockings and the landing of the capsule carrying the three-astronaut crew, including LIU Yang, the first woman astronaut of China, caught the attention of the world in summer 2012; and now the triumph of this feat in the voting seems to be devoutly wished.

Launched on June 16, 2012, the spaceship *Shenzhou*-9 had been flying for nearly two days when started performing its first docking, an automatic one, with the *Tiangong*-1 on 18 June. Six days later it detached from the space lab and performed a second docking, a manual one. The crew safely returned and landed on June 29 in Inner Mongolia Autonomous Region of China after successfully carrying out the mission. While flying in the space, they also performed a series of scientific experiments as scheduled.

This flight marked a record attempt in many ways for Chinese people. "The *Shenzhou*-9 mission posted a series of firsts: the first manned automatic and manual dockings; the first long-duration spaceflight; and the first crew to live aboard a permanently orbiting module, *Tiangong*-1," Jonathan Amos, BBC Science Correspondent commented on the capsule's successful landing in last June.



The re-entry module of the *Shenzhou*-9 is showed detaching from the orbital module, preparing to return. (Image: Cui Ying, Xinhua)



Toward the first space lab of China: the scheme of "*Shenzhou* Program".

China successfully performed the first unmanned in-orbit docking a year before, with *Shenzhou*-9's sister, the *Shenzhou*-8 and *Tiangong*-1 successfully joining hands in the space.

The dockings by *Shenzhou*-8 and *Shenzhou*-9 are part of China's efforts to build its own space station, represented by its *Shenzhou* Program. According to the schedule of the Program, the next planned mission will be performed by *Shenzhou*-10 in 2013.

CAS as a contributor to the Program received a congratulation letter from State senior leaders after *Shenzhou*-9's spaceflight completed.

No.4: *Chang'E*-2's Results

Another achievement in the field of space science also scores well, taking the fourth place: the release of the high-resolution image of the whole Moon based on data sent back by *Chang'E*-2, a lunar orbiter under the framework of the lunar exploration plan *Chang'E* Program of China. Announced by the State Administration of Science, Technology and Industry of National Defense on February 6, 2012, it marked the only image so far obtained by human beings of a resolution better than 7 meters covering 100% of lunar area.

The ongoing *Chang'E* Program, which is composed of three stages of explorations each featuring a lunar probe named after *Chang'E*, the Goddess living on the Moon according to Chinese mythology, was set up and designed according to suggestions proposed by CAS Member Prof. OUYANG Ziyuan from the CAS Institute of Geochemistry (IGCAS) based in Guiyang, Yunnan Province of China. OUYANG now serves as the Principal Scientist of the Program. *Chang'E*-3, a lunar lander and rover, will be sent to the Moon in 2013 as scheduled.

Since the implementation of the *Chang'E* Program, CAS institutions including IGCAS and the National Astronomical Observatories, CAS have played critical roles in securing safety of the navigation and flights of *Chang'E* serial orbiters by providing reliable data support and accurate calculation of orbits. Also, CAS is responsible for the design of the payload aboard the orbiters and involved onboard scientific experiments.

No.7: New Generation of Heavy-lift Rocket Engine

Another top-notched achievement, a new generation of heavy-lift rocket engine capable of carrying 120 tons of loads, will thrust China a further step forward on its journey to deep space. This marks the first high-pressure combustion cycle rocket engine that China has independently developed and owns the intellectual property rights. The new engine has a lot of advantages including high performance, high reliability, zero toxicity and zero pollution. This success made China the second country in the world to master the key technologies for this type of rocket engine that uses liquid oxygen and kerosene as propellants, only next to Russia.

No.10: Biggest Radiation Telescope of Asia

The winner of the 10th place, the biggest-so-far radiation telescope of Asia located in the Sheshan Mountain Station of the Shanghai Astronomical Observatory, CAS will also fuel new power for China's ability to explore the space.

Completed on October 28, 2012, this 65-meter-aperture omnibearing telescope covers eight wave bands ranging from 21 cm to 7 mm, and is hence capable of centimeter- and millimeter-levels of radiation observations. This 70 meters tall, 2,700-ton giant telescope is equipped with a modified Cassegrain antenna, which can flexibly tune both laterally and vertically to lock on the target celestial body or space vehicle with accuracy better than three second of arc. Its overall performance ranks the fourth in the world.

Deep Water Exploration

No. 2: *Jiaolong*'s New Diving Record

The second place on the top list is reaped by Jiaolong, a manned diving submersible named after the water dragon from Chinese mythology. Forming an interesting contrast with the Shenzhou Program, this project is aimed to breakthrough the depth below rather than the height above sea level: it targets at the deepest part of the seabed. Jiaolong successfully delved down to a depth of 7,020 meters below sea level on the morning of June 24, 2012, updating its own record of 5,188 meters from test dives a year before and culminated the research project by meeting

The deep-diving submersible "*Jiaolong*". (Photo: By courtesy of COMRA)

its all preset goals. The success of Jiaolong implies that China has obtained the ability to send people to up to 99.8% of this planet's seabed and perform underwater explorations or other tasks.

CAS institutions including the Shenyang Institute of Automation (SIA) and the Institute of Acoustics (IOA) contributed to the ten-year-long project by developing the underwater acoustic system and the controlling system, under the organization and leadership of the China Ocean Mineral Resources Research and Development Association (COMRA). The onboard equipment developed by CAS played a key role in securing safety of the diving and underwater navigation. CAS scientists also personally participated in the strategy making, decision making and technology support for the diving operations, and even personally attended some pilot dives.

Basic Physics

Two major breakthroughs in basic physics are elected into the top 10 list: the expanded multipartite quantum entanglement and the successful observation of a new transformation of neutrino oscillation.

No.8: Breakthrough in Multipartite Quantum Entanglement

Elected the eighth greatest by the Academicians is the successful generation of entanglement states linking eight photons demonstrated by a research group led by Prof. PAN Jianwei from the Shanghai branch of the National Laboratory for Physical Sciences at Microscale and the Department of Modern Physics under the University of Science and Technology of China (USTC), CAS.

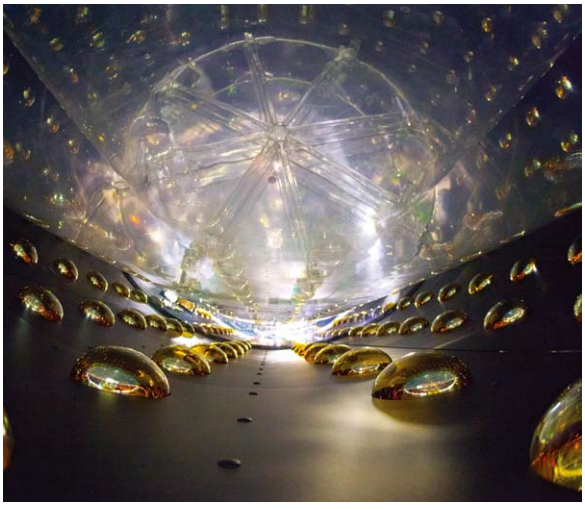
PAN is well known for his earlier successes in producing and maintaining entanglement states of three photon pairs and other achievements in quantum encryption and communication. This time his team successfully created in their new experiment an eight-photon Schrodinger cat state, using new ultra-bright sources of entangled photon pairs, an eight-photon interferometer and post-selection detection. Described as the "spooky action at a distance" by Albert Einstein, quantum entanglement is believed by physicists to be promising in communication, as the entangled quantum particles will remain identical in polarization and this makes it possible to obtain the information stored on either particle by measuring the other. The expanded quantum entanglement was published online in the *Nature Photonics* on February 12, 2012.

Later on the 22nd of the same month they published in *Nature* the result from another experiment of theirs, in which they succeeded in demonstrating topological error correction with an eight-photon cluster state. Their work is thought to have proven the viability of topological error correction for fault-tolerant quantum information processing and will find future application in quantum communication.

Only less than half a year later, on August 8 PAN's team published online again in *Nature* a further breakthrough, the successful demonstration of quantum teleportation and entanglement distribution of six photons over 100 km free space channels. For the first time ever human beings succeeded in hundred-kilometer-level quantum teleportation and entanglement distribution, taking a large step forward on the way to practical quantum communication.

No.9: New Type of Neutrino Oscillation Detected in Daya Bay Experiment

The ninth place goes to a breakthrough in particle physics of worldwide influence, the successful observation of a new type of neutrino oscillation by an international team at Daya Bay of southern China led by scientists from



Innards of a cylindrical antineutrino detector in Daya Bay experiment: the transparent acrylic vessels at the center, one nested in another, are both seen perching in a stainless-steel container. The highly sensitive photomultiplier tubes lining on the wall of the detector can amplify and record the telltale flashes emitted from antineutrino interactions. The detectors at the site helped the international team there catch the most elusive type of neutrino oscillation, marking a great breakthrough in basic physics. (Image: By courtesy of Roy Kaltschmidt, Lawrence Berkeley National Laboratory.)

the CAS Institute of High Energy Physics.

Neutrinos are among the 12 elementary particles composing the material world. While travelling at a speed close to light, the three flavors of them, electron, muon and tau neutrinos as well as their corresponding antineutrinos mix together and transform from one to another — the so-called oscillation. This phenomenon, however, is very hard to detect as neutrinos have very light mass and seldom interact with materials. Nuclear reactors produce massive amount of neutrinos and antineutrinos and hence provide good opportunities for research on related physics issues. Previous experiments and research managed to find two types of them but the third one remained too elusive to detect.

A major goal of the Daya Bay experiment is to measure the value of neutrino mixing angle θ_{13}, a basic physics parameter describing the size of the third mode of neutrino oscillation. The international collaboration observed tens of thousands of interactions of electron antineutrinos using six massive detectors adjacent to the powerful nuclear reactors located at the Daya Bay affiliated to a nuclear power plant. On March 8, 2012 the Daya Bay team announced their discovery that the neutrino mixing angle θ_{13}, expressed as $Sin^2 2\ \theta_{13}$, is equal to 0.092 plus or minus 0.017.

The new data will lay a step stone towards further work on neutrino oscillation, including the observation of another parameter describing this phenomenon, the charge-parity phase.

The team also obtained the amplitude of the newly detected oscillation with the best accuracy of the world and predicted the possibility of its occurrence.

Two other experiments are currently measuring reactor neutrino oscillation and may eventually confirm the results from Daya Bay. This work is believed to have furthered human understandings of the basic properties of neutrino and was thought highly by the international community of high energy physics. It was also elected into the top 10 greatest scientific breakthroughs of the world by *Science* magazine.

Medical Research

No. 6: Vaccine against Hepatitis E

The sixth place of the list is won by the first vaccine against hepatitis E in the world, which was a recombinant vaccine based on *E. coli* developed by Xiamen University in cooperation with the Yangshengtang Pharmaceutical and has passed necessary examinations to be ratified the production approval number for national first-class new drugs. This marked an important breakthrough in the worldwide battle against and the control of hepatitis E. The research group at Xiamen University made a series of original discoveries in recognition and structural characterization of protective antigens, as well as ensemble mechanisms of virus particles, and established a system of technologies based on these discoveries. They published 26 academic papers in international peer-review journals including *Lancet*.

Technology

Elected into the top 10 are also two important technological breakthroughs, namely the successful solution of three hard technical problems that plagued the construction of the first high-speed railway in alpine areas (No.3), and the first petascale high-performance computer system of China solely based on domestically made CPU chips: Sunway (Shenwei) BlueLight MPP supercomputer system (No.5).

December 1 of 2012 witnessed the opening of the high-speed railway connecting Dalian and Harbin cities in northeastern China, an alpine region. This 921 km railway marked the first high-speed one built and running in alpine areas of the world. With infrastructure designed and built for a speed of 350 km/h, it allows trains to travel on it at a speed of 200 km/h in winter and 300 km/h in summer. To secure safe operation of the railway, engineers managed to overcome three bottlenecks: frost heaving of the roadbed, melting ice on the contacting nets and the thawing snow on the turnouts.

The Sunway BlueLight MPP supercomputer system is built with 8,704 ShenWei SW 1600 microprocessors, a third generation CPUs developed by the Jiangnan Computing Research Lab in Wuxi, China. The whole system is capable of operating at a peak performance of 1.07016 petaflops and a sustained performance of 795.9 tflops. It passed the appraisal by an expert panel organized by the Chinese Ministry of Science and Technology on September 11, 2012, a milestone marking China the third in the world to be able to build a petascale supercomputer on its own, only next to USA and Japan.

Based on this supercomputer system, a supercomputing center was set up in Ji'nan City, Shandong Province to provide computation services to the public.