1974 Canada accepted NASA's invitation to take part in the Space Shuttle program by building the Shuttle Remote Manipulator System (Canadarm), which has flown on Shuttle flights and moved satellites, payloads, and astronauts. At the invitation of NASA, Canada established an astronaut program in 1983, and on 5 October 1984 Marc Garneau became the first Canadian in space when he lifted off onboard the Space Shuttle *Challenger*. After Garneau, Roberta Bondar, Steven MacLean, Chris Hadfield, Robert Thirsk, Bjarni Tryggvason, Dafydd "Dave" Williams, and Julie Payette became Canadian astronauts. Hadfield was the only Canadian to visit the *Mir* space station (1995) and the first to walk in space (2001). In 1985 Canada agreed to take part in what eventually became the *International Space Station* (*ISS*), for which it built the mobile servicing system that included a robot arm, a base system, and a manipulator system.

On 1 March 1989 the Canadian Space Agency (CSA) began operations with its headquarters in St. Hubert, Quebec, cooperating closely with NASA and the European Space Agency (ESA). Canadian cooperation with Europe began in the 1970s, when Canada took part in the European Symphonie communications satellite program. Canada signed a formal cooperation agreement with ESA in 1978, making Canada the only non-European country to be a cooperating member of ESA. In 1995 *Radarsat 1*, Canada's first remote sensing satellite, was launched. In 2003 Canada launched two scientific satellites: *MOST* (*Microvariability and Oscillations of Stars*, an astronomy research satellite carrying a small telescope) and *SCISAT* (investigating Earth's ozone depletion problem). While as of 2007 no satellites had been launched from Canadian soil, the Black Brant sounding rocket was developed in Canada, and sounding rockets were launched from Churchill, Manitoba, for many years.

Canadian experiments have flown on board spacecraft from many nations, including a Canadian ultraviolet imager for auroral research flown on the Swedish *Viking* satellite in 1986 and a thermal plasma analyzer experiment to examine Mars's atmosphere on the Japanese *Nozomi* spacecraft that was launched to Mars in 1998.

Chris Gainor

See also: European Space Agency, International Space Station, MacDonald Dettwiler Corporation, Space Shuttle

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China

China began development of its modern space program in the 1950s, led by American-trained Qian Xuesen (Tsien Hsue-Shen). Qian, with approximately 100 other Chinese scientists, was expelled from the United States in 1955 during the

McCarthy era. Initially through the civilian Chinese Academy of Sciences (CAS), Chinese scientists and engineers worked on updated German V-2 rockets, the R-1 and R-2, given by the Soviet Union and on the development of satellites. Between 1960, when the Soviet Union severed relations with China, and the late 1990s, when collaboration with Russia on human spaceflight began, Chinese space efforts were primarily indigenous. International politics and the self-imposed isolation of the 1966–76 Cultural Revolution (the growth of the program slowed as scientists and engineers were persecuted and/or worked as laborers) left China working independently. China later built a comprehensive, albeit austere, space program.

The Chinese military has played a significant role in Chinese space activities since the mid-1960s. While much of the policy-setting process has remained opaque, the State Council and, until it was merged into the newly created State Administration for Science, Technology and Industry for National Defence (SASTIND) in 2008, the Commission for Science, Technology, and Industry for National Defense (COSTND), as well as the Central Military Commission (CMC) have been considered key players, with implementation left to various parts of the military or the military-industrial complex. For example, by 2008 the head of the General Armaments Department of the CMC, responsible for armaments for the People's Liberation Army, was also the commander of the human spaceflight program. Military involvement in the organizational structure allowed for political control in addition to maximizing resources and talents working on space research and application with utility to the civil and military sectors.

Nevertheless, at the start of the twenty-first century, the Chinese government recognized that some bifurcation of efforts was necessary to increase space engagement with other countries. External organizations were understandably reluctant to work with the Chinese military on space activities. As a result, the Chinese government made bureaucratic changes to separate civilian and commercial programs from military programs. That split continued into the twenty-first century, though the Chinese military continued to provide a variety of services, such as security at launch sites. A multitude of Chinese organizations have worked on space activities, with structures and practices often confusing to Westerners. Since its establishment in 1999, China Aerospace Science and Technology Corporation (CASC), which has also been responsible for other national defense and aerospace endeavors, has managed China's space program. CASC was formed from part of the China Aerospace Corporation, a large state-owned enterprise under direct supervision of the State Council, as part of a concerted government effort to make its industries more competitive (the other portion became China Aerospace Machinery and Electronics Corporation). When dealing externally, CASC has continued to manage most programs, but under the name of the China National Space Administration.

CASC has controlled more than 130 organizations, including five large research academies, the Chinese Academy of Launch Vehicle Technology, the Chinese Academy of Space Technology, the Shanghai Academy of Space Flight Technology, the Chinese Academy of Space Electronic Technology, and the Academy of Space Chemical Propulsion Technology; two large research and manufacturing bases, the Sichuan Space Industry Corporation and Xi'an Space Science and Technology

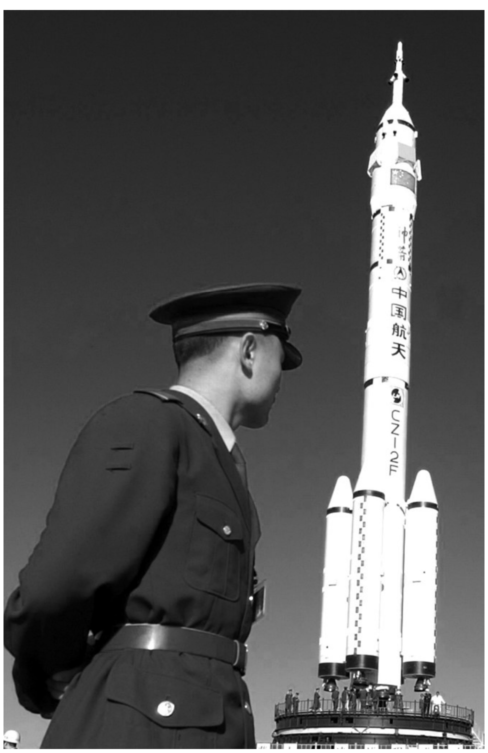
Industry Corporation; a number of factories and research institutes under the direct supervision of the headquarters; and companies in which it has had various levels of ownership. CASC had 100,000 employees as of 2008. All foreign space launch orders have been handled by CASC's international cooperation platform and launch-marketing company, China Great Wall Industry Corporation (CGWIC), established in 1980. Since CGWIC first offered commercial launches in 1985, it has conducted more than two dozen international commercial launches of more than 30 satellites and six piggyback payloads. In 2004, in a sign of diversifying commercial capabilities, CGWIC contracted with international customers to deliver communications in-orbit satellites based on the newly developed Dong Fang Hong (DFH)-4 satellite bus.

China has three areas of publicly acknowledged space activity: launch vehicles, satellites, and spacecraft; defense systems; and satellite applications. China's first satellite was a DFH communications satellite. *DFH 1*, launched in 1970, broadcast the song "The East Is Red." Since then, China has developed and launched dozens of military, civilian, and dual-use satellites of various types and sizes; including Feng Yun meteorological satellites, remote-sensing satellites (e.g., Fanhui Shi Weixing [FSW] recoverable satellites, Feng Yun weather satellites, and Yaogan disaster relief/military satellites), Shijian scientific experimental satellites, and Beidou navigation satellites. The FSW satellites deserve particular note as they clearly illustrated the dual-use nature of space technology developed and employed in China. Although FSW satellites were originally developed for military reconnaissance purposes and first launched in 1974, the technology was adapted for use in Earth resource observation and crystal and protein growth experiments in the late 1980s.

China developed the Chang Zheng (CZ)/Long March (LM) series of launch vehicles. The LM vehicles were derived from earlier CZ military counterparts, not an unusual practice (U.S. civilian workhorse vehicles Delta, Atlas, and Titan were originally military vehicles). The spacecraft used in China's human spaceflight program, for example, was the CZ 2F. China has used three launch sites: Xichang in Sichuan Province (all geosynchronous satellite launches), Jiuquan in the Inner Mongolia Autonomous Region (Chang Zheng 2F), and Taiyuan in Shanxi Province (polar-orbiting spacecraft); a fourth, Wenchang on Hainan Island at only 19 degrees North, is scheduled to be completed in 2013. The Chinese have significantly increased their heavy-lift launch capability. In the mid-1980s China began offering commercial launch services using the LM series. That effort resulted in the beginning of bifurcation efforts to separate its program into civil and military sectors, with the military oversight less visible. A series of launch accidents in the mid-1990s and subsequent demands by Western insurance companies for accident reports caused political issues for China. Allegations of technology theft by China were made in the United States in connection with the launches and the accident reports.

While commercial launch opportunities decreased in the late 1990s, China continued to seek cooperative opportunities with other countries. Under the China-Brazil Earth Resources Satellite (CBERS) program, for example, China launched three jointly developed satellites, with more planned. Again, the dual-use nature of the technology raised considerable speculation about the military potential of the satellite technology for high-resolution military reconnaissance. Additionally, having been limited in its access to the European Union (EU)'s Galileo, its future alternative to the U.S. Global Positioning System (GPS), China began developing its own positioning system based on Beidou satellites. An initial four-satellite Beidou-1 navigation constellation deployed in 2007 offered basic positioning over China and its immediate periphery; a 35-satellite Beidou-2/Compass system will provide improved regional coverage by 2011 and global coverage by 2015–20; three satellites have been launched as of 2010.

China's second human spaceflight effort was Project 921. Because the capsule that carried taikonauts into orbit atop the CZ 2F was known as Shenzhou (divine or heavenly ship), human spaceflight missions have been designated as Shenzhou missions. An earlier human spaceflight program was started in the 1970s but was halted in 1980 due to lack of funds, technological barriers, and a pragmatic decision to prioritize applications satellites. By 2003, 14 taikonauts had been selected, drawn from the elite ranks of military fighter pilots. Two taikonauts (Wu Jie and Li Qinglong) trained in Russia and became instructors for those later trained at a facility north of Beijing. While the Shenzhou capsule was reportedly able to carry three taikonauts, the first launch on 15 October 2003 took only one taikonaut, Yang Liwei, into space for a 21-hour, 16-orbit trip, making China the third country to develop human spaceflight capability. *Shenzhou 6* launched on 12 October 2005 with two taikonauts, Fei Junlong and Nei Haisheng, for a five-day flight. During their stay in orbit, they were able to change into lighter, more comfortable space suits, for ease of movement while conducting experiments and living in space. During this flight, for the first time, the



Chinese soldier stands guard near the China National Space Administration's Shenzhou 6 *space vehicle. The rocket launched in October 2005, carrying two taikonauts, China's second human spaceflight mission. (Courtesy AP/Wide World Photos)* taikonauts were able to enter the orbital module. *Shenzhou 7*, launched on 25 September 2008, included the first extravehicular activity by taikonauts. *Shenzhou 8* is planned for 2011.

Shenzhou 6 completed phase one of step one of the officially approved three-step human spaceflight program—step one to demonstrate technical capabilities (with phase one testing life support and crew capabilities, and phase two, beginning with *Shenzhou 7*, focusing on docking maneuvers and related activities, including extravehicular activities or space walks); step two to develop a small space laboratory, likely from Shenzhou modules; and step three to develop a larger space station, which would also require development of a new Long March 5 heavy-lift launcher.

China has announced ambitious plans for robotic lunar and Mars exploration. In addition, although China has expressed interest in *International Space Station* (*ISS*) participation, the United States, which has held a veto within the *ISS* partnership, by 2010 had not extended or approved an invitation. Chinese prospects to participate in *ISS* were not helped by the January 2007 test of an antisatellite weapon, which destroyed a Feng Yun weather satellite and created many thousands of pieces of space debris. Chinese space activities have avoided space spectaculars in favor of incremental progress in a broad range of programs designed to meet key national objectives at affordable cost.

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See also: Long March, Russian Launch Vehicles, Shenzhou

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Europe

Europe's space program has been primarily driven by economic and technical considerations, as opposed to the military and political factors that drove the space efforts of the superpowers: the United States and the Soviet Union/Russia. After World War II, Europe consisted of medium-sized and small nations, most of which did not have the money, technical resources, or industrial capability to go to space. Competing with the superpowers was not practical. One of the results was a drive among Western European nations for economic integration, particularly through the Common Market, which led to the European Union. Integration was also fruitful in high technology efforts, such as nuclear research and power generation and, in the 1960s, in space. For many of these nations, the only way to secure a presence in space was to pool resources and build transnational collaborative structures. In Western Europe, this