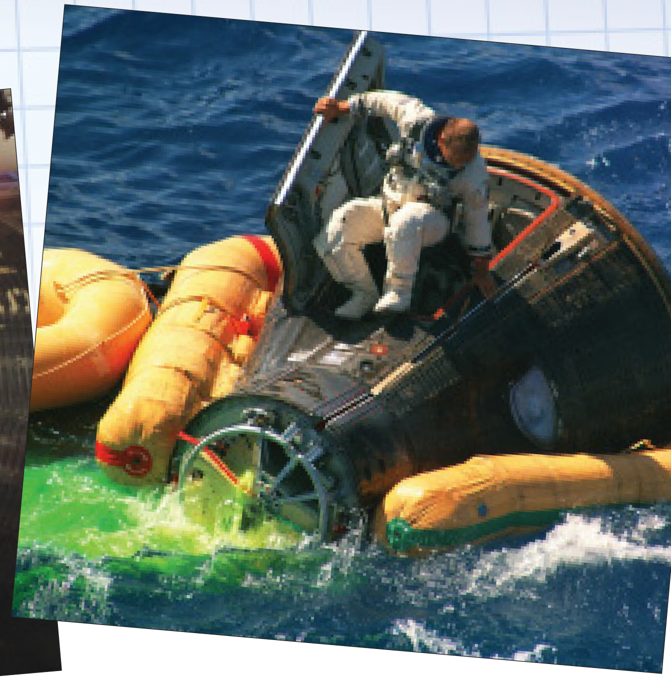


From Mercury to CEV:

by **Frank Sietzen Jr.**
Contributing writer

Sometime this year, most likely in the spring, China will launch Shenzhou 6, its second manned spaceflight. Following the success of its first manned mission, Shenzhou 5, this next flight will carry two Chinese astronauts in a more advanced spacecraft than the one that flew Senior Col. Yang Liwei in October 2003.

The Shenzhou configuration is an adaptation of Russia's veteran Soyuz design. Soyuz is a space capsule whose cargo and payload capabilities are limited. It also requires a retrorocket to brake the machine's descent prior to touchdown.

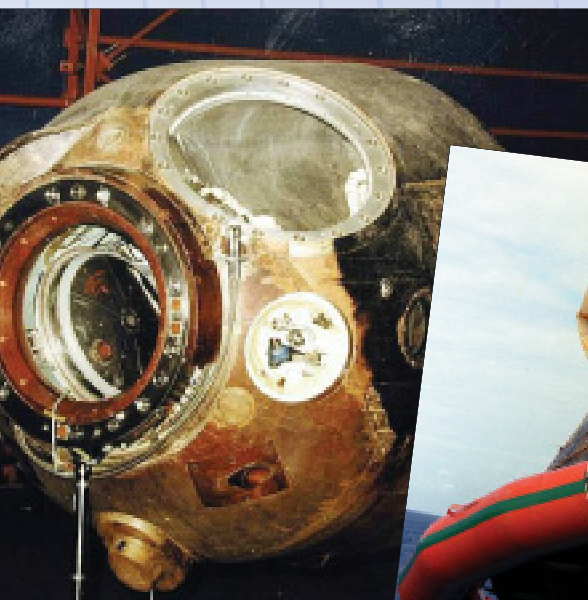
Some U.S. space officials privately scoffed at the Chinese vehicle when it first flew, hinting that it was in essence 30-year-old technology. Shenzhou, whose name means "divine vessel," may well be an upgraded version of an old spacecraft, but the return of the space capsule will probably not be limited to flights in Asian skies. The successor to the space shuttle, the Crew Exploration Vehicle (CEV), will likely be some capsule derivative. And therein lies a tale of space vehicles, past, present, and future.

Origins

In both the U.S. and the former Soviet Union, early manned spacecraft variants were adapted in large measure from the nosecones of ballistic missiles. These warheads were blunt-body shells containing the explosive bomb, but they also ascended atop ballistic missiles such as the Soviet R-7 and the U.S. Thor and Atlas. The external coatings of the U.S. cones allowed for an ablative reentry into the Earth's atmosphere.

In the U.S., first the Air Force and then NASA proposed a version that carried a single pilot into LEO, propelled by the Redstone intermediate-range ballistic missile on suborbital tests, and then later into orbit by the Atlas. Larger and heavier winged structures, or designs that produced lift, were generally heavier than their cone-shaped cousins, and their reentry into the atmosphere generated heating on the wings and fuselage of sleek shapes that exceeded the technology of heat shields of the day.

The blunt-body reentry vehicle, coated with a burn-away ablative heat shield, became



Space capsules reemerge

The space capsule, eclipsed for decades by the more complex and costly shuttle, now appears likely to emerge as its successor

the entry-level manned U.S. spacecraft, the Project Mercury capsule. Russia adapted a sphere for its first-generation system, the Vostok. The second generations of both national systems, the Gemini for the U.S. and the Voshkod and Soyuz for the Russians, were extensions of the original vehicle design shapes. In fact, Russia's Voshkod was nothing more than a Vostok with seats for two and three cosmonauts. Gemini was a more advanced flying machine than Mercury, but the semiballistic shape of the Gemini reentry vehicle, coupled with the capability to perform a limited lifting reentry, followed Mercury's lineage.

The Soyuz craft, which began manned flight trials in April 1967, was another semiballistic capsule shape that generated a small amount of lift during its return to Earth. For Apollo, the cone shape was modified and truncated, but also used an ablative heat shield system.

Both Soyuz and Apollo command modules could fly to their intended impact points by using thruster control and a rolling spin to their return paths. Skipping in and out of the atmosphere, the Apollo spacecraft could be "aimed" at specific landing sites where U.S. naval vessels had been deployed extensively. Since the Russians brought Soyuz down on land, no fleets of ships were required.

But although space capsules had simplified shapes, their utility was limited. Their size especially was restricted by the available heavy lifting power of the U.S. and Russian space boosters. As a result, their cargo capacity was sharply less than that of extended long-body designs like lifting bodies or winged shapes, where a payload bay could be installed flanked by wings or canards.

Such designs also allowed for aircraft-like descent and landing, which meant high cargo capacity and the prospect of making such an aircraft shape reusable, if a nonablative heat shield could be devised. That would ultimately be the path taken by the U.S. for the space shuttle, and briefly by the Russians as well with their Buran. But reusable vehicles were first generations, and they turned out to be far more costly to operate and maintain than the simpler but limited space capsule.

Russia never stopped building, or upgrading, its Soyuz vehicles. The U.S. shift to the shuttle architecture brought an end to capsule development, although DOD continued to research lifting body designs.

Shuttle replacement studies begin

By the late 1980s, following the Challenger accident, serious studies began on replacement vehicles for the shuttle fleet. One such potential candidate, derivatives of the McDonnell Douglas DC-X, used an extended cone capsule shape but landed the vehicle base first, using not parachutes but RL-10 rocket engines.

Lockheed's proposed but ill-fated X-33 was a true lifting body shape, but had wings added to its design. Although construction of an X-33 occurred, no test flights were conducted before the program was canceled.

But while U.S. post-shuttle designs came in fits and starts, the veteran Soyuz flew on, becoming the basis for a manned shuttlecraft servicing several generations of Russian space stations. An unmanned version of the Soyuz capsule system, called Progress, was used as a logistic vehicle, carrying food, water, and other equipment, first to the Mir space station, and then to the ISS.

Following the February 2003 space shuttle accident, the Soyuz and Progress systems became the sole means by which crews could be retained on the station while the shuttle fleet was grounded.

China's "divine" path

For China, the manned space development path led to the capsule as well. But when they became serious about human spaceflight, the Chinese—unlike the Russians or the U.S. 40 years earlier—had the experience of other spacefaring nations on which to draw. Thus, aided by the decades-long history of Soyuz and its variants, the Chinese essentially set out to take a proven, flexible design and adapt it for their own purposes. Capsules, unlike some other, more complex spacecraft configurations, could provide this flexibility.

"Space capsules, like cars and airplanes, have certain requisite parts dictated by function and physics," says Joan Johnson-Freese, a lecturer at the Naval War College and author of one of the few books on China's space program. "Models of them differ, with differing capabilities, but the basic design—engines, wheels, needs of propellant, etc., are the same," she explains.

For China, however, there was no space technology base from which to derive a manned design. Attempts in the 1970s to develop a manned spacecraft failed for political reasons. But the country did begin a series of research satellite missions in the 1980s and 1990s using a space capsule design called the FSW. The technologies for heat shield, on-orbit flight controls, reentry, and recovery were perfected during these missions.

But for the larger, piloted capsule, China used a technology development and exchange program with the Soviet Union to improve several elements of its launch and space satellite programs. According to Johnson-Freese's research, the Russians offered Chinese engineers access to the Soyuz design.

"I think the Chinese, in keeping with a long-standing tradition of not reinventing the wheel but learning all they can from others, looked around for a technically capable but not overly challenging design, made improvements to suit their needs and strengths, and updated the technology, making it their own," she says.

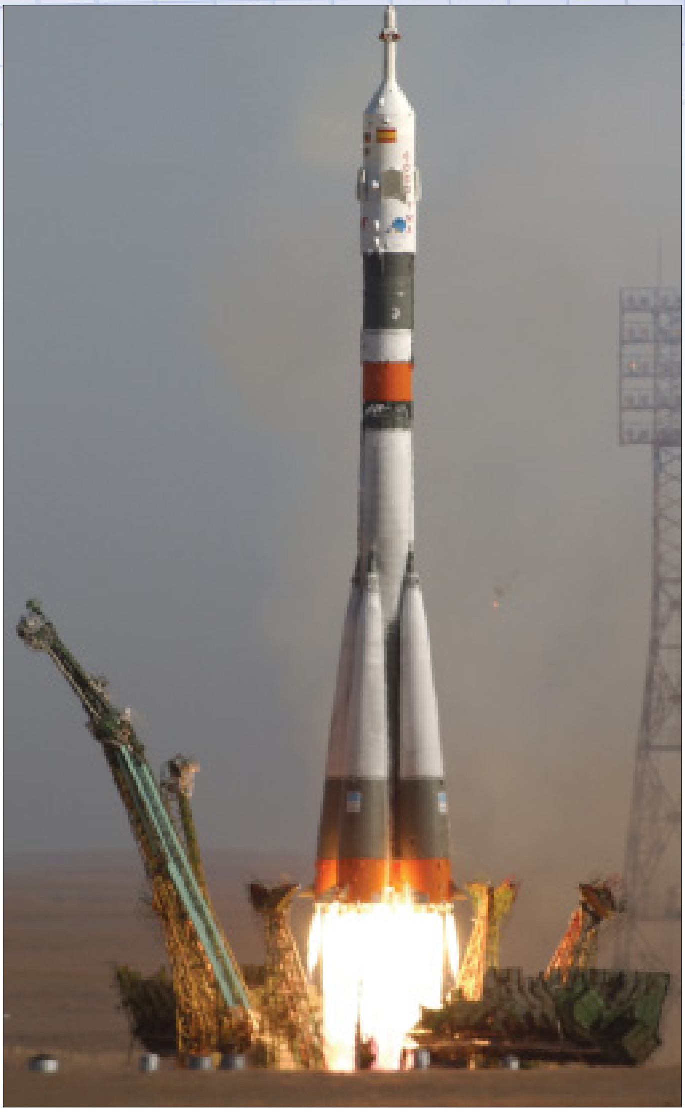
The Chinese Shenzhou spacecraft became the latest in the series of capsule derivatives.

Chinese leaders made no secret of their intention to build a spacecraft unique to their mission objectives—long-duration Earth orbital flight, a mini space station, and use of that experience base to plan lunar missions and more advanced crew-carrying vehicles.

"My understanding of statements made to date was that the Chinese used the modular concept of the Soyuz and precisely duplicated the aerodynamic shape and recovery systems of the reentry capsule," says Mark Wade, editor of the Encyclopedia Astronautica, a Web site that compiles detailed histories of spacecraft and launch vehicles.

Wade looks at the final Shenzhou design and sees in effect a more modern Soyuz that the Russians might produce if they had the technology—and the money. Of the Chinese, Wade says, "Their own experience in spacecraft construction, propulsion, power generation, heat shield materials, and avionics allowed them to find unique and more modern solutions in these areas. This saved them a huge amount of development risk."

What emerged looked a lot like the Soyuz itself.



The Soyuz served as the model for the Chinese as they developed the Shenzhou launch vehicle.

Comparing apples and…apples?

Like the Russian vehicle, the Chinese craft consisted of an orbital module, a reentry vehicle that carried the crew back to Earth, and a service module for propulsion and for performing the retro fire sequence. Also like the Soyuz, the Shenzhou featured deployable solar panels that rode into orbit folded against the vehicle body but deployed in space attached to the service module unit.

But unlike the Russian craft, Shenzhou also sported a second set of solar wings, attached to an enlarged and modified version of the upper forward orbital module. In both the Russian and Chinese spacecraft, the module could be accessed in flight by the astronaut crew (called taikonauts). But unlike Soyuz, the Chinese module could detach from the reentry capsule and remain in orbit for several months, acting as a robotic mini space station, using its solar panels to power instruments and experiments.

The unit was not a reentry vehicle, and on returning would burn up in the atmosphere. The rest of the Shenzhou was also larger than Soyuz. The complete Chinese spacecraft, which like its Vostok, Mercury, Gemini, and Apollo predecessors varied in weight by flight unit, averaged 7,800 kg versus Soyuz's 7,250. According to Wade, the Chinese vehicle was slightly longer at 8.65 m, compared to 7.48 for Soyuz. The crew capsule on the Chinese vehicle was nearly a half-meter wider and a quarter of a meter longer than the Russian ship. The same pattern repeated itself in the orbital and service units as well, with an overall growth of about 13% over the Soyuz spacecraft.

The Soyuz was sized to launch aboard an improved version of the R-7 booster family, sporting new engines and a new upper stage for the Soyuz variant. The Shenzhou was carried into orbit by an improved Long March CZ-2E booster called the 2F, basically a manrated ver-

The Mercury capsule laid the groundwork for all the U.S. capsules to follow.

sion of the 2E satellite launcher. As in the Soyuz design, a solid-fuel launch escape tower sat on top of the booster stack, which when fired would remove the top two parts of the spacecraft, the orbital and reentry modules, which were encased in a launch fairing for the atmospheric ascent.

Shenzhou could carry up to three pilots, but on its maiden manned flight carried a single taikonaut, Col. Yang Liwei of the Chinese air force. The April 1967 maiden flight of Soyuz also carried a single occupant, Russian air force Col. Vladimir Komarov, who perished during Soyuz 1's reentry.

The Chinese craft, according to Johnson-Freese, could remain aloft for as long as three weeks, with the research unit orbital module capable of additional weeks and months alone. Four unmanned test launches had preceded the October 15, 2003, Shenzhou 5 flight. Shenzhou 1 was launched November 19, 1999, on a 14-orbit test flight. The second test came on January 9, 2001, carrying a monkey, a dog, and a rabbit, according to Wade. The flight tested Shenzhou's environmental control system and life support capability for the first time. It also loaded the capsule with 64 scientific payloads during the week-long flight, which ended with a successful return to Earth.

Shenzhou 3 was launched on March 25, 2002, on a 6.78-day flight with a dummy astronaut in the crew cabin couch. The fourth and final test launch came on December 29, 2002, on a test flight of nearly the same duration as that of Shenzhou 3. But both it and the third flight allowed the orbital modules to remain in space for months before the orbit was permitted to decay and the units to be destroyed during reentry.

A SPACE CAPSULE COMPARISON

	Crew	Manned flights	Launch vehicle	Length	Diameter	Weight
VOSTOK	1	1961-1963	R-7	4.3 m	2.42 m	4.7 tons
VOSHKOD	2-3	1964, 1965	R-7	5 m	2.42 m	5.3 tons
SOYUZ	1-3	1967-present	R-7 variant	7.4 m (Not including launch escape system)	2.7 m	6.9 tons
MERCURY	1	1961-1963	Redstone, Atlas	3.34 m (Not including launch escape system)	1.89 m	1,935 kg (At launch, typically)
GEMINI	2			5.736 m	3.048 m	3,400 kg on orbit
APOLLO	3	1968-1975	Saturn I, IB, Saturn V	10.1 m (Not including launch escape system)	3.91 m	29.6 tons
SHENZHOU	1-?	2003-present	CZ-2F	8.65 m	2.8 m	7,800 kg
CREW EXPLORATION VEHICLE	Four for Earth and lunar missions; possibly six for manned Mars Capable of both Earth orbit and manned interplanetary flight	2014	Crew Transportation System (CTS)	?	?	?

Sources: *History of Manned Spaceflight*; *Encyclopedia Astronautica*; CEV Statement of Work, Level 0 Requirements.
Note: Each spacecraft flight unit varied in weight and capability. Soyuz variants differ widely.

Chinese state newspapers and media have indicated the Shenzhou 6 mission will carry two taikonauts into orbit for several days. Planning is also under way, according to Chinese officials, for upcoming space walks. The Shenzhou orbital module features a large hatch that could be used for this purpose.

The capsule's possible future

The manned space capsule, then, is alive and well in a new generation. Russia, however, has indicated it will replace Soyuz with a lifting-body capsule design called Klipper, which will need a new and more powerful booster. Although a Klipper mock-up has been shown, actual development of test articles or flight vehicles has been hampered by chronic funding shortages in Russia's manned space program, which can barely produce Soyuz and Progress vehicles for use in the International Space Station program today.

An earlier version of Soyuz, called Zond, was once intended for manned lunar flight but was abandoned when the Soviet Union canceled its lunar program and moved to use the Earth-orbital Soyuz variant to support space stations. China might well take the Shenzhou from orbital flight to the Moon, with history repeating itself, this time perhaps to make China the second nation to send humans beyond Earth orbit. If so, it will likely be the space capsule that carries them to these new destinations.

This may also be the case with the newest U.S. spacecraft, the Crew Exploration Vehicle. Although the published requirements for the CEV do not dictate mold lines or vehicle shapes, a capsule design is considered by many a front runner. This space capsule, unlike any that preceded it, is set to carry waste management systems more closely akin to the shuttle's, with a galley and a crew health maintenance system related to the station's.

Early architectures for Project Constellation suggest an Earth orbit rendezvous scenario in which the CEV docks to an Earth departure stage, which in turn has docked to a lunar surface access module, the craft that actually would take astronauts to the Moon's surface. "You don't need wings to land on the Moon," says NASA Associate Administrator for Space Science Ed Weiler. These spacecraft would appear to have more in common with their Apollo predecessors than the one-size-fits-all large payload bay used by the space shuttle fleet and its payloads for more than three decades.

Will this resurgence of the capsule configuration yield a new lunar space race?

"Certainly, any competition that might accrue will come when the Chinese demonstrate greater capabilities than Shenzhou," says Roger Launius, chair, Division of Space History at the Smithsonian National Air and Space Museum, itself home to a few U.S. and Russian space capsules.

Each manned Gemini flight carried a crew of two; hence its name.

"I suspect at some point before the Chinese go to the Moon and replace our flag at Tranquillity Base with their own, Americans would begin to get excited," Launius jokes. "But I'd like to think that rather than competing, the various spacefaring nations would cooperate to undertake activities for the good of all," he adds.

Shenzhou, Soyuz, and now possibly the CEV will provide the basis for such advanced human spaceflight dreams. It was a technology many in the U.S. thought old and obsolete, replaced by the winged capability of the shuttle.

The shuttles have served the nation well in an era of different spaceflight objectives, payloads, and missions. Now seems to be the time for a blast from the past—a simpler and more limited spacecraft that may spark a resurgence in human missions beyond Earth orbit.