

EXPANDING HUMAN SPACEFLIGHT BEYOND THE EXCLUSIVE GOVERNMENT PROVINCE

Kathryn L. Lueders

National Aeronautics and Space Administration, Kennedy Space Center, Florida, U.S.
kathryn.l.lueders@nasa.gov

ABSTRACT

NASA's Commercial Crew Program (CCP) was formed to facilitate the development of U.S. commercial crew space transportation capabilities with the goal of achieving safe, reliable and cost-effective access to and from low-Earth orbit destinations, including the International Space Station.

There were three additional objectives outlined during Commercial Crew's inception: 1) Develop and implement a strategy that stimulates the U.S. space transportation industry and encourages the availability of space transportation services to NASA and others. 2) Mature the design, development, demonstration and certification of U.S. crew transportation system capabilities. 3) Utilize an alternate business approach by investing in U.S. aerospace industry system design and development.

Commercial Crew currently works to meet all of these objectives. We are on a path to have two NASA-certified end-to-end crew space transportation systems, Boeing's CST-100 and SpaceX's Crew Dragon by 2017. Those two systems will restore the capability to deliver crews to and from the International Space Station back to an American company.

Achievements made during five development and certification phases also have aided in the advancement of multiple subsystems, systems and integrated systems related to low-Earth orbit crew transportation capabilities.

The road has not been easy. In fact, to get to where we are today has taken a delicate balancing act between NASA, its stakeholders and industry. It has required our engineers, technicians, budget analysts, management staff and support teams to be flexible, energetic, open to new ideas, adept at change and most of all committed to this new way of operating.

Through its Commercial Crew Launch America initiative, NASA has ignited the U.S. aerospace industry's desire to once again fly our flag into space and to expand our human presence in low-Earth orbit beyond the exclusive government province.

The program's accomplishments with industry are unprecedented in the human spaceflight realm in terms of cost and schedule -- less than \$6 billion in about eight years.

COMMERCIAL CREW APPROACH

To succeed in meeting all of its objectives, NASA had to take a non-traditional approach with Commercial Crew. The familiar model of government space system development needed to be re-evaluated in order to produce cost-effective systems and open up the potential of space travel to more people than ever before.

The prior approach has its merits -- full government ownership, exclusive intellectual property rights, and control of processes, procedures and trade space. That approach is appropriate for areas of high risk and with high barriers for entry, for things that have never been done before, like travelling to the surface of Mars or developing new technologies, techniques and processes that are capital intensive.

Every spacecraft built for humans, from Mercury to Gemini and Apollo to the space shuttle and the United States section of the International Space Station, was built and operated using the traditional government model. Through that model, NASA devised requirements for a crew transportation system that would carry astronauts into orbit, then the agency oversaw every development aspect of the spacecraft, its support systems and operations plans. An aerospace contractor was then hired to build the system to the design criteria and the standards NASA furnished. NASA personnel were deeply involved in the processing, testing, launching and operation of the system to ensure not only the safety and reliability of the system but also that the government's detailed performance criteria was met. The space agency owned the spacecraft, its launch vehicle and its operating infrastructure. That approach was needed

because human spaceflight was new and the environments for low-Earth orbit and lunar exploration weren't well understood.

Government industry partnerships are appropriate to consider for areas where risks are well understood and considerably lower, and where technologies, techniques and processes also are well defined. Barriers to entry may still remain high, but the government requires the use of capabilities or services, rather than needing to own and operate them. In this approach, the government is able to take on the role of investor, which maximizes competition, encourages partner performance, minimizes administrative overhead and allows both to focus on technical activities.

The government industry partnership concept for NASA dates back to 2006 when the agency was asked to find a way to commercialize cargo transportation to the International Space Station. It successfully transitioned U.S. cargo transportation to two companies, SpaceX and Orbital Sciences, in 2008 through the Commercial Orbital Transportation Services and follow-on Commercial Resupply Services initiatives. Commercial industry also has decades of experience in launching telecommunications and imaging satellites to low-Earth orbit and geosynchronous orbit for government and commercial customers alike.

When NASA decided to support the development of multiple new U.S. human spaceflight capabilities to low-Earth orbit, we initially relied on commercial partners to propose the specifics, ranging from the designs and capabilities to private investment ratio, milestone achievements, success criteria and timelines. Once milestones were outlined and accepted, Commercial Crew and its expert teams worked closely with each company to provide technical support and determine when those milestones were met.

This new approach is all about balance – determining the minimum agency needs to carry out its critical missions while enabling that capability to provide an opportunity to promote new industries and markets. Interested companies were free to design the transportation systems they thought were best. They were encouraged to apply their most efficient and effective manufacturing and business operating techniques throughout the process. The partnership approach allowed NASA engineers insight into each company's development process while the agency's technical expertise and resources were accessible to NASA's industry partners.

As a final phase, NASA always knew it would need to enter into contracts to ensure companies were meeting the agency's pre-determined set of safety and mission performance requirements and to buy services. The ability to provide formal feedback and acceptance, or rejection, of partner products was a critical part of the path to certification and International Space Station crew transportation flights.

DEVELOPMENT AND CERTIFICATION PHASES

While Commercial Crew followed the path initially set by commercial cargo, the transportation of crew was different and more challenging than cargo, so Commercial Crew followed a multi-layered strategy. We invested resources, both dollars and expertise, in industry to develop human transportation subsystems, systems, and integrated systems. Those then became the building blocks for systems that will transport crew in the coming years.

Commercial Crew Development Round 1

As NASA retired the space shuttle, the ability of private industry to take on the task of providing routine access to space was of vital importance. In 2010, NASA invested a total of nearly \$50 million of the American Recovery and Reinvestment Act (ARRA) funds for CCDev1 to stimulate efforts within the private sector to aid in the development and demonstration of safe, reliable and cost-effective crew transportation capabilities. It included the development and maturation of subsystems, such as a spacecraft, launch vehicle, launch abort systems, environmental control and life support system, launch vehicle emergency detection systems and more. The CCDev1 partners were Blue Origin, \$3.7 million; Boeing, \$18 million; Paragon Space Development Corporation, \$1.4 million; Sierra Nevada Corporation, \$20 million; and United Launch Alliance, \$6.7 million

Commercial Crew Development Round 2

Commercial Crew Development Round 2 (CCDev2) kicked off in April 2011 when NASA awarded a total of nearly \$270 million to four companies to aid in further development and demonstration of safe, reliable and cost-effective transportation capabilities. The agency also signed unfunded Space Act Agreements to establish a framework of collaboration with additional aerospace companies. As part of those agreements, NASA reviewed and provided expert feedback on overall concepts and designs, systems requirements, launch vehicle compatibility, testing and integration plans, and operational and facilities plans. The CCDev2 partners were Alliant Techsystems Inc., unfunded; Blue Origin, \$22 million; Boeing, \$112.9 million; Excalibur Almaz Inc., unfunded; Sierra Nevada Corporation, \$105.6 million; SpaceX, \$75 million; and United Launch Alliance, unfunded.

Commercial Crew Integrated Capability

The Commercial Crew Integrated Capability (CCiCap) continued the development of three fully integrated systems. The Space Act Agreements called for industry partners to develop crew transportation capabilities and to perform tests to verify, validate and mature integrated designs. The CCiCap partners were Boeing, \$460 million; Sierra Nevada Corporation, \$212.5 million; and SpaceX, \$440 million.

NASA later funded an additional \$20 million to Boeing, \$20 million to SpaceX and \$15 million to Sierra Nevada Corporation by exercising optional, pre-negotiated milestones, which were part of their original Space Act Agreements, to accelerate development. NASA continues to work with both SpaceX and Sierra Nevada Corporation to finalize their SAA milestones.

Certification Products Contract

To support the goal of achieving safe, reliable and cost-effective access to and from the International Space Station for the agency, NASA awarded contracts intended to permit the certification of commercial crew transportation systems to carry NASA astronauts.

Throughout the Certification Products Contract (CPC), the first phase of a two-phase certification plan, companies worked with NASA to discuss and develop data products to implement the agency's flight safety and performance requirements. This included implementation across all aspects of the space system, including the spacecraft, launch vehicle, and ground and mission operations.

Under the contracts, certification plans were developed toward achieving safe, crewed missions to the space station. It included data that will result in developing engineering standards, tests and analyses of crew transportation system designs. The CPC contractors were Boeing, \$9.993 million; Sierra Nevada Corporation, \$10 million; and SpaceX, \$9.589 million.

These contracts enabled NASA to a) get feedback on our requirements and approaches, and b) allow the commercial aerospace industry to fully understand the government's requirements and how to comply with them. In addition, NASA solicited feedback on our requirements through several requests for information and touch-points.

Commercial Crew Transportation Capability

Commercial Crew Transportation Capability (CCtCap) is the second phase of a two-phase certification plan for commercially built and operated integrated crew transportation systems. Two FAR-based, firm fixed-price contracts were awarded to two companies in September 2014 following an open competition. Through its certification efforts, NASA will ensure the selected commercial transportation systems meet the agency's safety and performance requirements for transporting NASA crew to the International Space Station. The CCtCap contractors are Boeing, \$4.2 billion; and SpaceX, \$2.6 billion.

BALANCING SAFETY AND INNOVATION

This new approach allowed us to review NASA's human spaceflight safety standards and pare them down to the essentials that help ensure safety, while leaving room for industry innovation. NASA tried to balance giving up some control with the benefit of having new safe and cost-effective systems that can return our crew members to the International Space Station. To have an efficient marketplace, the government cast a wide net for companies so as to further benefit NASA by spurring several design concepts and approaches toward low-Earth orbit human spaceflight transportation. These new ideas expand on the systems that NASA has built.

The government chose to dictate minimal requirements while allowing for a certain amount of "meets the intent" proposals for alternate standards and methods. This gave industry an opportunity to apply their commercial practices to best meet our requirements and allowed for innovative technologies, techniques and processes. It also enabled the use of existing aerospace capabilities.

NASA also balanced its needs with the needs of industry in the CCtCap contract. NASA used a firm, fixed-price contract so that both industry and NASA have incentives to keep the goal of safe transportation also a cost effective one. Yet, the contract also provided commercial incentives as NASA is certifying a crew transportation capability and buying a service rather than the traditional strategy of buying a vehicle. This allows industry to keep their intellectual property rights, and further use their systems for future commercial and national opportunities beyond just Commercial Crew missions.

In addition, NASA continues to leverage the investment the nation has made in spaceflight missions by openly sharing its expertise with industry. This capitalizes on 50 years of human spaceflight experience paid for by the American taxpayer. Commercial Crew has facilitated the transfer of thousands of documents related to

engineering, safety, and operations to industry partners throughout all of the development and certification phases. Critical examples of where industry is stair-stepping off of what NASA has learned from are Apollo's entry guidance, aero-thermal reports and up-righting system for landings; the space shuttle's main engines, thermal protection system certification plan and orbiter window drawings; and Orion's parachute system. This knowledge transfer of technical information, produced with taxpayer funds, multiplies the benefit of those dollars to lower the cost of crew transportation systems.

REAPING THE REWARDS

The United States has a storied past of acting as a catalyst for commercial markets, from communications and the Wide World Web to rail and air transportation. Each of these successful commercialization ventures began with a significant investment in technology and infrastructure from the government. Once matured and available, the government encouraged entrepreneurs to take over the market by relinquishing its role as supplier to become a customer. Industry then flourished with niche markets resulting in competition and spurring innovation to enhance services and reduce costs.

NASA's past and present human spaceflight programs – from Project Mercury through the International Space Station Program – have laid the groundwork for us, over 50 years carefully teaching us valuable lessons and helping us understand the unforgiving environment of space and what it takes to get there, and live there, safely. The investment the nation has made has lowered the barriers for entry to low-Earth orbit and enabled the transition to commercial operations.

The human spaceflight industry is now in the same position the aviation industry was in 100 years ago. People didn't necessarily appreciate the capability of commercial airplanes 100 years ago -- how to transition from flying airmail to transporting hundreds of paying passengers on flights, thousands of them a day. In the same way, the Commercial Crew Program is facilitating that transition now by investing in industry, and procuring certified crew transportation capabilities.

NASA will be flying to the station on two new human transportation systems in the near future. Through this activity, NASA is facilitating new industrial capabilities that are then available as platforms for further innovation and commercial opportunities in low-Earth orbit. Now industry needs to further leverage their emerging capabilities and demonstrate their inherent ingenuity and see new possibilities. These new commercial opportunities could then open up new capabilities that NASA can use to meet their objectives in earth science and micro gravity research.

For NASA to accomplish its mission for space exploration, it cannot continue to solely maintain human presence in low-Earth orbit alone. The capability that industry is investing in and plans to maintain a commercial low-Earth orbit presence will be critical for NASA to continue to learn within that domain while the agency focuses on pushing our learning into deep space, to the moon, an asteroid and on to Mars. The work Commercial Crew is doing is an important building block toward that future.