RocketSTEM

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SSEP

Orion

Rosetta

SpaceShipOne

Charley Kohlhase

Spaceport America

Deep Space Network

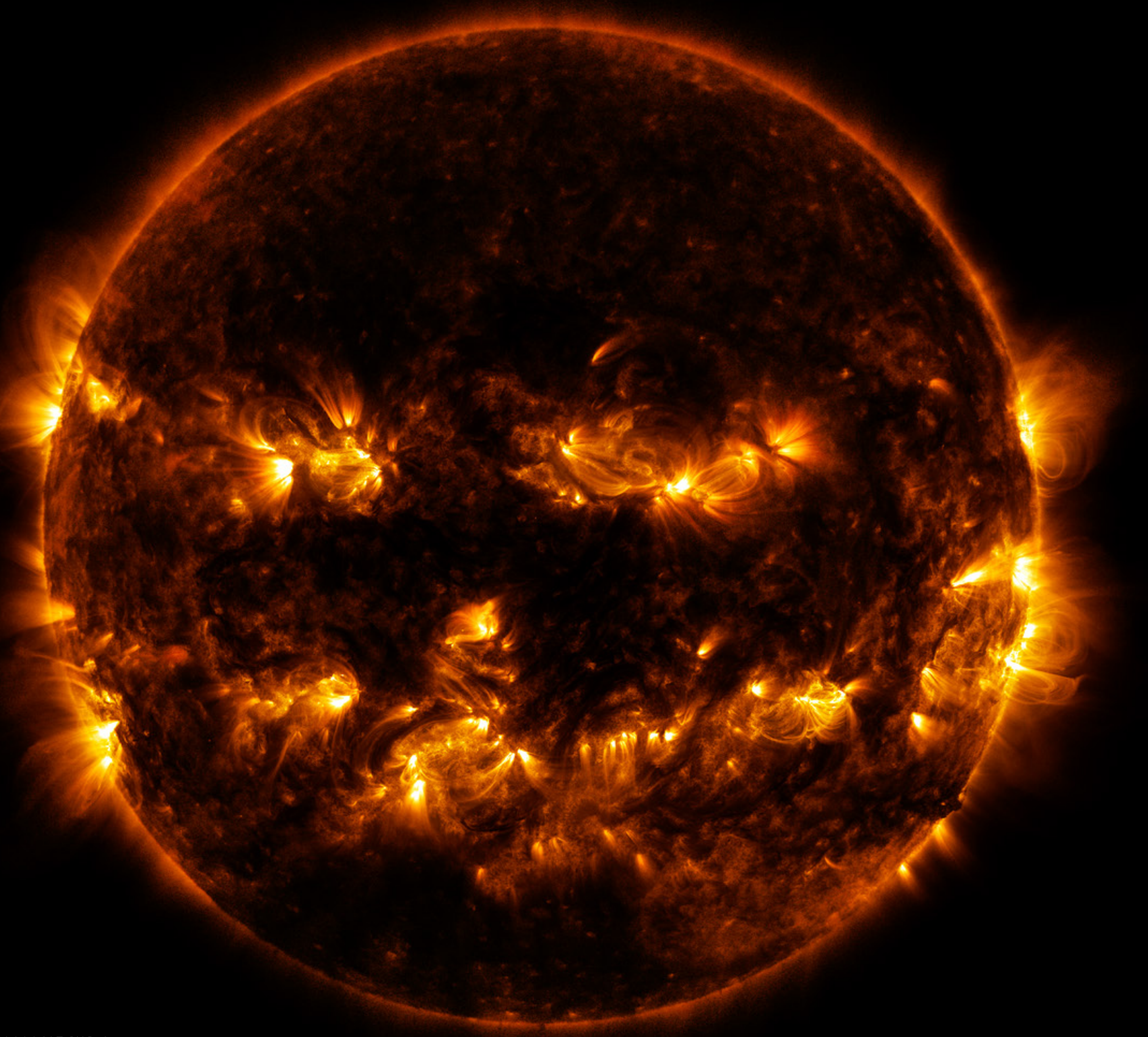
And more!

The fall season has arrived in the Northern Hemisphere, and even the Sun is getting into the Halloween spirit as evidenced by this 'jack-o'-lantern' image captured recently by NASA's Solar Dynamics Observatory. But before you go out trick-or-treating, we've got a number of stories to captivate your curiousity. We highlight the 10th anniversary of SpaceShipOne rocketing into space and claiming the Ansari X Prize. We give you the scoop on Spaceport America in New Mexico from where Virgin Galactic's SpaceShipTwo may soon be launching commercial passengers on trips to space. We tell you all about the Deep Space Network here on Earth that allows us to communicate with the many spacecraft exploring the solar system. And we've got an interview with Charley Kohlhase who was instrumental in the development of many of those planetary probes. We've also loaded this issue of RocketSTEM with articles about Orion's upcoming launch, the Student Spaceflight Experiments Program, the arrival of two new orbiters at Mars, Rosetta's succesful journey to a comet, decisions on NASA's commercial crew program, a beginner's guide to planetary photography, and more.

Once again we are pleased to announce that a limited number of high-quality printed copies are available for this issue. If interested, please visit www.rocketstem.org/purchase. While there, also consider signing up to be notified should we begin offering an annual print subscription for the 2015 calendar year.

Since founding RocketSTEM two years ago, we've stated that each issue of the magazine will be FREE to read online. As a non-profit organization that is a mission we intend to never stray from, however, that is not to say that funding such a publication is not costly. If you would like to help us continue our mission, please consider making a donation to RocketSTEM via our website at www.rocketstem.org/donate.

We hope you enjoy this magazine, and will continue to be inquisitive about the universe we all inhabit.



Credit: NASA/GSFC/SDO

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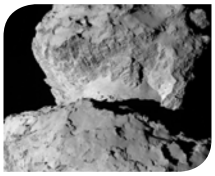

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RocketSTEM Media Foundation, Inc.
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email: ***info@rocketstem.org***

The Australian complex is located 40 kilometers (25 miles) southwest of Canberra near the Tidbinbilla Nature Reserve. Credit: NASA/JPL-Caltech deep space network:

Finding the signal for 50 years

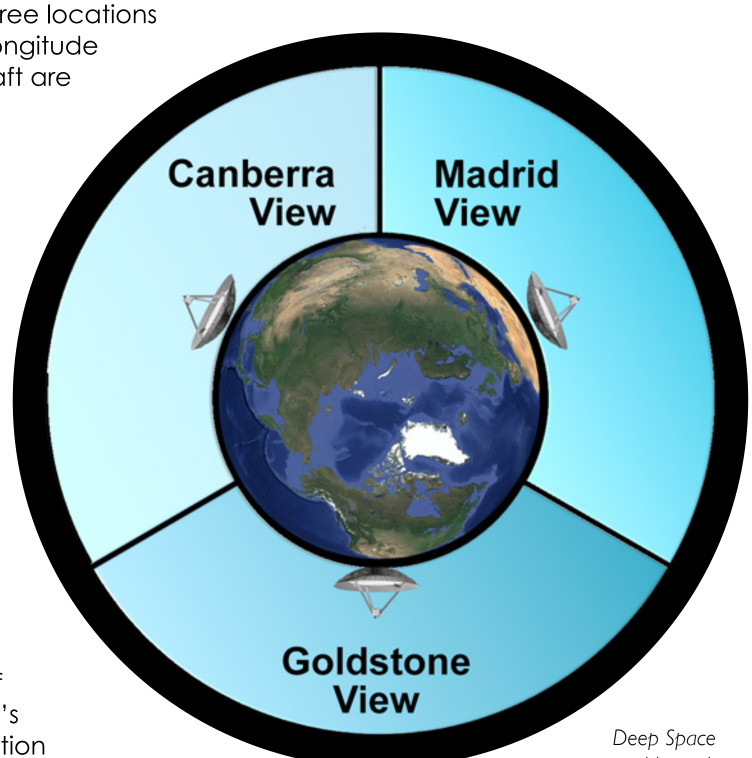
By Tony Rice

Robotic missions exploring our solar system have wowed the world with their discoveries and especially the images they return. But even the most sophisticated spacecraft is useless until the science and engineering it gathers makes it back to Earth. NASA's one of a kind collection of massive dishes around the world makes that possible.

The NASA Deep Space Network (DSN) is an international network of communications complexes supporting interplanetary spacecraft missions and doing a bit of science on its own. The network is made up of huge antennae located at three locations separated by approximately 120° longitude around the Earth ensuring spacecraft are visible to at least one at all times.

Goldstone located in California's Mojave Desert halfway between JPL in Pasadena and Las Vegas; at Robledo near Madrid, Spain; and at Tidbinbilla near Canberra, Australia. The complexes stay synchronized within microseconds of each other via atomic clocks.

During its first year of operation, the DSN communicated with just three spacecraft. Since then it has played a central role in each of NASA's high-profile exploration missions, including early Pioneer probes, the Mariner missions of the 1960s and 1970s, Viking and Voyager, Galileo, Cassini- Huygens, as well as each of the Mars rover missions. Today Earth's only global spacecraft communication network communicates with 30+ spacecraft including those from international partners such as the Japan Aerospace Exploration Agency (Venus Climate Orbiter), European Space Agency (Mars Express), and most recently The Indian Space Research Organisation (Mars Orbiter Mission).



Deep Space Network complexes are distributed approximately 120° of longitude around the Earth ensuring spacecraft are visible to at least one at all times.

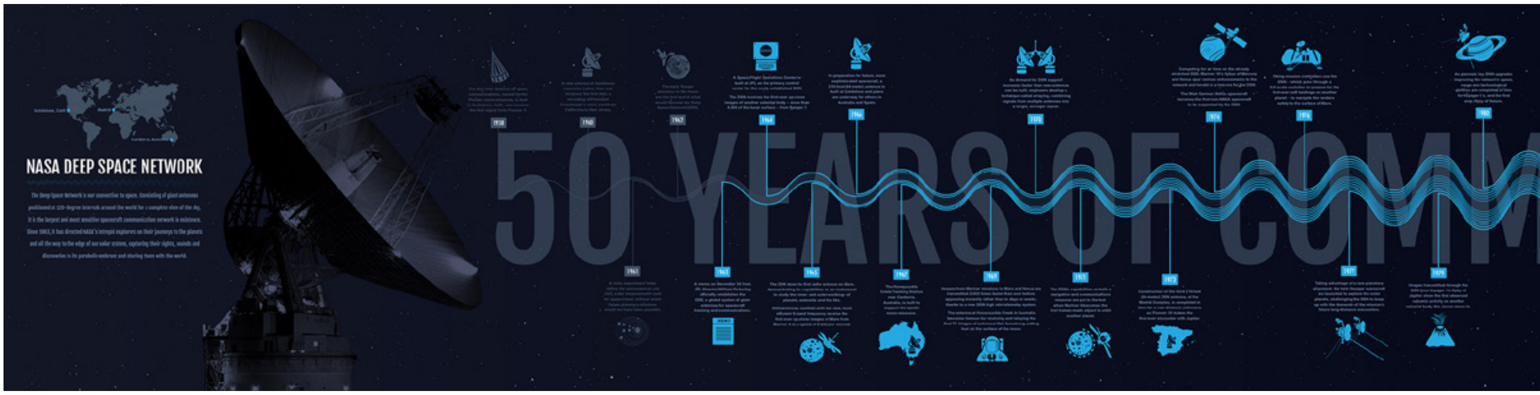
The Goldstone complex is located on the U.S. Army's Fort Irwin Military Reservation, approximately 72 km (45 miles) northeast of the desert city of Barstow, California. Credit: Doug Ellison/NASA/JPL-Caltech

An interplanetary communications network

These giant dishes do more than act as a cell phone network for distant missions. Some are also active in mapping asteroids via radar as well as radio astronomy. Radar experiments in 1961 helped define the astronomical unit (the average distance between the Earth and Sun), a critical measurement used by astronomers. There is even science in the radio waves themselves. Changes in those waves transmitted back to Earth are helping scientists reveal the interiors of moons and planets and even test Einstein's theory of relativity.

DSN data types:

- **Tracking:** Communication sessions start with an exchange of carrier waves between the antenna on Earth and on the spacecraft. Pure tones which are used to track the position, the lifeblood of engineers responsible for spacecraft navigation. Ranging data helps determine (within 1 meter) the distance to spacecraft. Doppler shift measured on the downlink carrier wave determines velocity within fractions of a millimeter per second.
- **Telemetry:** Greek for "far off measurements", telemetry is the digital engineering data gathered. Temperatures of key spacecraft parts, science data, as well as all those great images of places like Saturn and Titan from the Cassini mission and the surface of Mars from the Curiosity rover
- **Command:** Orders sent to spacecraft. Instructions for new science or course corrections for spacecraft en route.
- **Radio Science:** Signals change slightly as they pass through the atmosphere of a planet, moons, or the sun

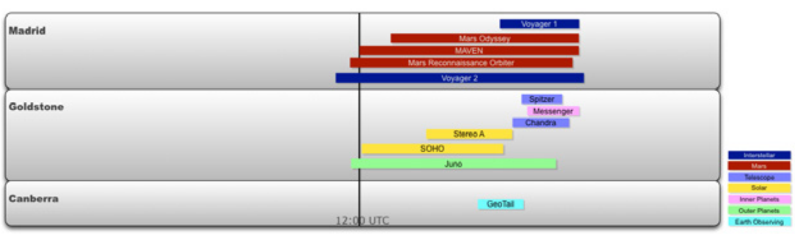


The Deep Space Network is our connection to space. Since 1963, it has directed NASA's intrepid explorers on their journeys to the planets and all the way to the edge of our solar system, capturing their sights, sounds and discoverie. View the full-size infographic at our website. Credit: Kim Orr/NASA/JPL-Caltech

or through planetary rings or gravitational fields. Radio Science Receivers record these changes for study

- **Very Long Baseline Interferometer:** Two or more DSN stations working together to create a giant antenna to observe spacecraft or astronomical objects such as quasars. Here on Earth VLBI can measure continental drift.

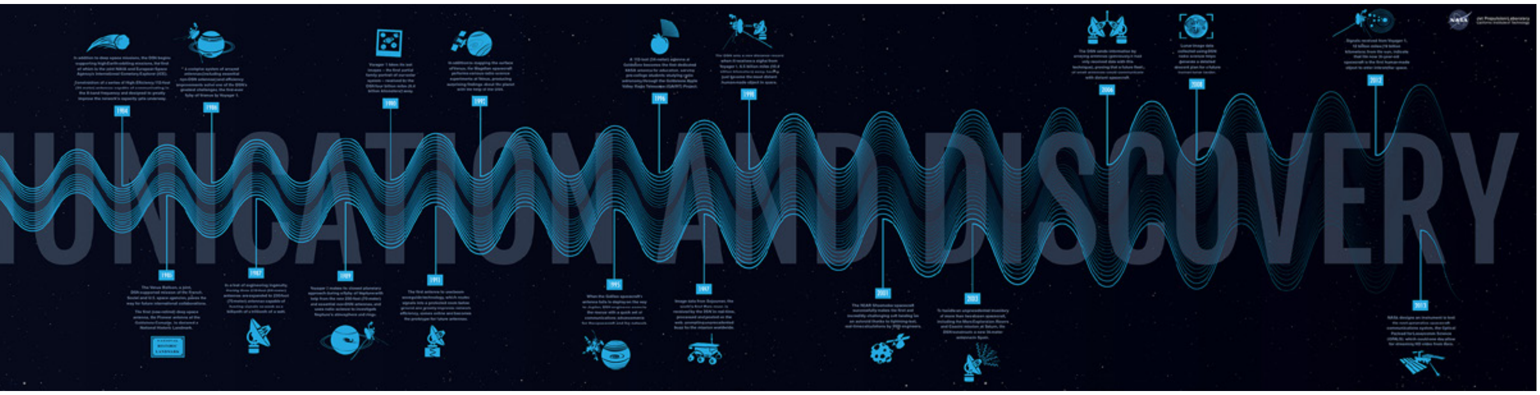
Each complex is equipped with a 70 m diameter (230 foot) parabolic dish antenna, weighing in at over 2.7 million kilograms (2,970 US tons). Huge antennae are needed to gather the weak signals.



September 3 was like any other day at the DSN. A wide variety of NASA and other spacecraft communicate via multiple antennae at each of the three complexes.

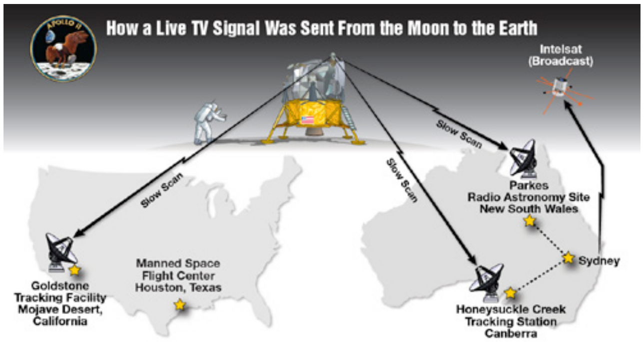
Transmitters on each spacecraft produce around 20 watts but the long trip across the solar system reduces that to one billionth of one billionth of a watt. DSN regularly hears from Voyager 2 over 9.7 billion miles from Earth. It takes over 14.5 hours for signals to make it to and from this spacecraft. Signals delivered by the dish to ultra-sensitive receiving systems capable of communicating with spacecraft more than 16 billion kilometers (10 billion miles) from Earth.

To achieve the precision needed to capture those faint signals each dish is carefully designed



and maintained. Each surface is maintained to within a centimeter (0.4 inches). That's like grooming the surface of a soccer field to vary no more than the height of a single LEGO brick.

Goldstone, Madrid and Canberra also have several 34-meter (111-foot) diameter antennas. These use two technologies, a high-efficiency antenna and beam waveguide antenna. Each site also has a 26-meter (85-feet) diameter antenna primarily used today to track spacecraft a bit closer to home, in Earth orbit only 100 and 620 miles (160 and 1,000 km) away. These smaller dishes were built to communicate with Apollo astronauts.



The images of the Apollo 11 landing watched live by over 500 million people worldwide were received through the Canberra complex. Credit: NASA HQ/Bob Jacobs/Mark Hess

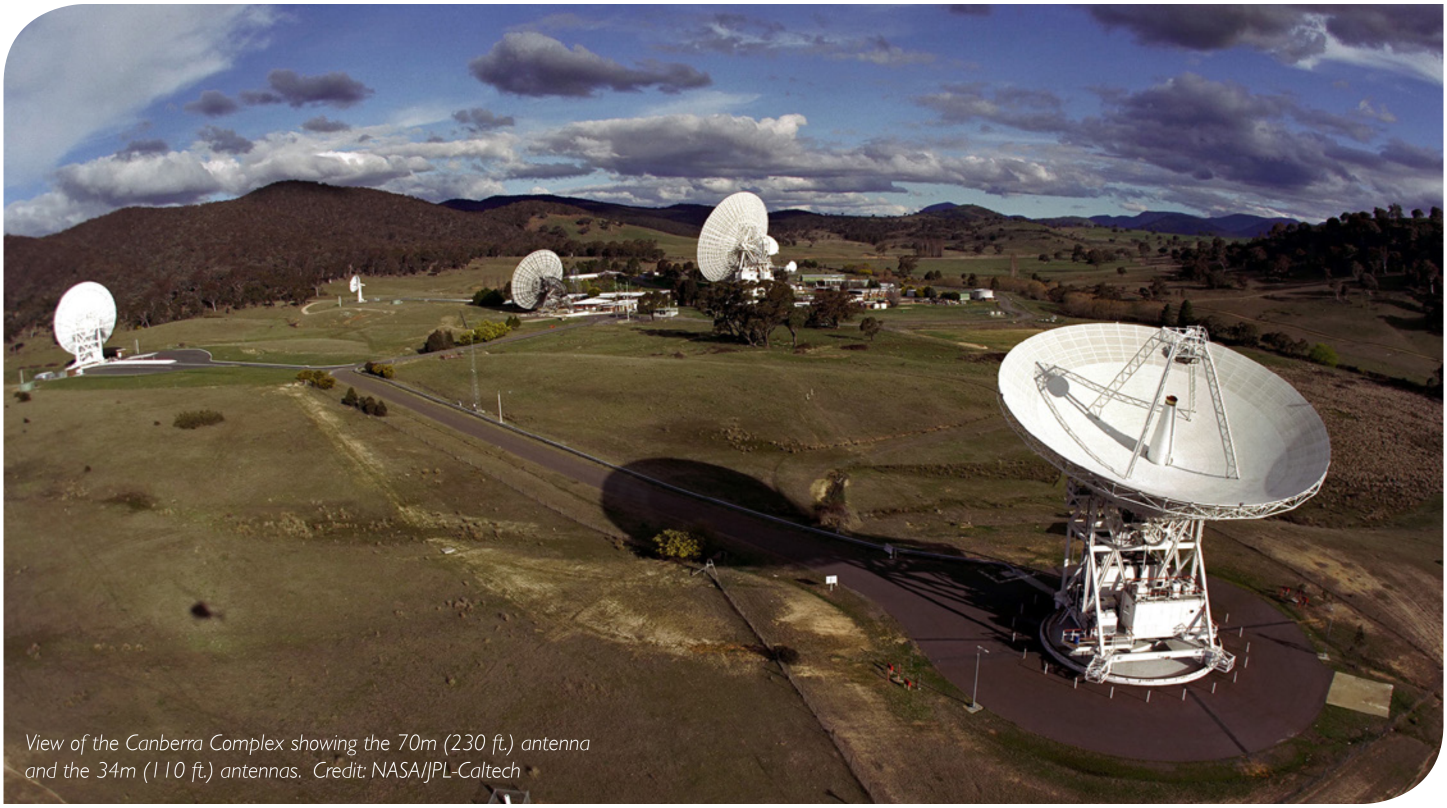
History

DSN dates back to the founding of NASA itself. In 1958, the Jet Propulsion Laboratory positioned portable tracking stations in Nigeria, Singapore and California to track Explorer 1, the first successful U.S. Satellite.

The network expanded in 1967 to support Apollo missions with the Honeysuckle Creek Tracking Station near Canberra. The iconic TV images of Neil Armstrong's "Giant Leap" were received through that antenna before retransmission via Intelsat to a dish to the Jamesburg Earth Station near Monterey, California. The slow scan format used by the cameras on the moon was converted to a standard broadcast format and again transmitted to Houston and then on to a half billion televisions around the world. Live video from Apollo missions was also received through antennae at Goldstone. The engineers involved were recognized for their technical innovations in 2009 with the Philo T. Farnsworth Primetime Emmy Award.

The DSN's capabilities to receive extremely weak signals helped bring the astronauts aboard Apollo 13 home safely when a ruptured oxygen tank crippled their capsule. Every bit of power was needed by spacecraft systems during re-entry leaving little for the transmitters. Engineers were able to maintain contact with

The Spanish complex is located 60 km (37 miles) west of Madrid at Robledo de Chavela. Credit: NASA/JPL-Caltech



View of the Canberra Complex showing the 70m (230 ft.) antenna and the 34m (110 ft.) antennas. Credit: NASA/JPL-Caltech

the ailing capsule pulling "whispers from space."

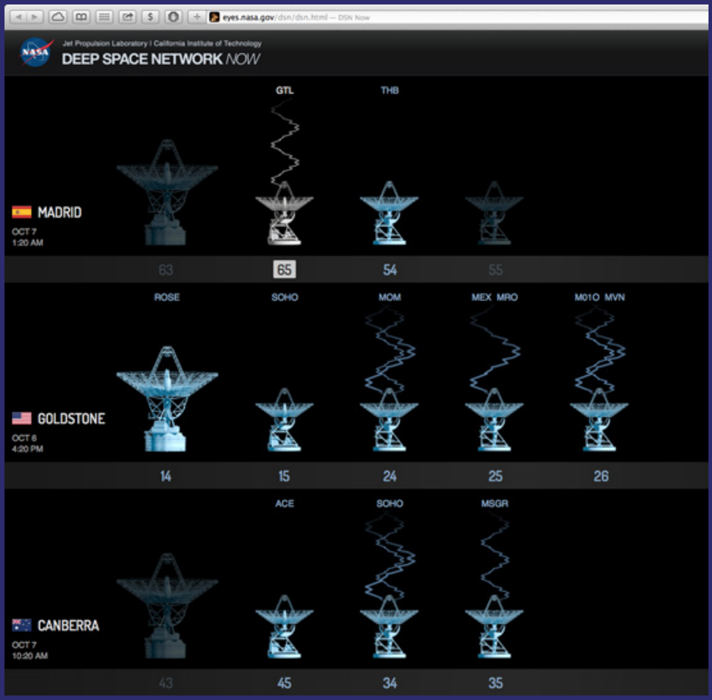
Larger more sensitive antennae were built in the 1970s to support the extending reaches of missions like Pioneer 10 as it imaged Jupiter for the first time. A series of highly efficient 34-meter (112 foot) antennae were constructed in the 1980s bringing communications in the X-band for the first time. With more missions to track and new partnerships with the European Space Agency, the DSN was even busier. DSN's importance was recognized when the first deep space antenna at Goldstone was named a National Historic Landmark in 1985.

The 1990s brought beam wave technology to the network. Signals are routed into a room below ground level with a greater variety of receivers and more security. Today NASA is experimenting with laser communications with the Optical Payload for Lasercomm Science (OPALS), which could enable streaming HD video from Mars.

How you can get involved with the Deep Space Network

NASA's Jet Propulsion Laboratory brought mission control to your desktop with Deep Space Network Now (http://eyes.nasa.gov/dsn/). The website brings the status of communications with the spacecraft exploring our solar system. This isn't a simulation but the same interface on the big screens in NASA/JPL building 230's Space Flight Operations Facility (a.k.a. JPL Mission Control) with real data updated every 5 seconds.

The Goldstone Apple Valley Radio Telescope (GAVRT) allows students to operate a 34 meter (112 foot) radio telescope via the internet from their classroom. They study black holes, planets and help monitor the health of spacecraft throughout the solar system. This is real science and the results go into databases used by astronomers and other scientists around the world. For more information, visit http://www.lewiscenter.org/.



Eight essential facts about NASA's Deep Space Network

- **As the World Turns: The DSN is Earth's only global spacecraft communication network**
  The Deep Space Network has three facilities - at Goldstone, Calif.; near Madrid, Spain; and Canberra, Australia, all with multiple parabolic dish antennas, including one dish each that is 230 feet (70 meters) across. Located about 120 degrees apart around Earth, the placement of the complexes provides round-the-clock coverage of the solar system. (A telescope needs a direct line of sight to "speak" with a spacecraft.)

- **One Small Step: The DSN showed us the first moonwalk**
  "That's one small step for man. One giant leap for mankind." The DSN received and relayed to the world the first TV images of astronaut Neil Armstrong setting foot on the surface of the moon in 1969.

- **Solar System Ambassador: DSN relays first close-up views of other planets**
  The historic network enabled the world to see the first-ever image of Mars, obtained by NASA's Mariner 4 spacecraft in 1965. Mariner 10 returned images of Mercury's surface in 1974. NASA's twin Voyager spacecraft were the first to fly by Jupiter, Saturn, Neptune and Uranus, capturing the first close-up images of these planets, plus some of their rings and moons. The DSN also relayed Voyager 1's portrait of Earth from 6 billion miles away, the iconic image Carl Sagan called "The Pale Blue Dot," as well as the spacecraft's entry into interstellar space.

- **Now Hear This: The DSN speaks with more than 30 spacecraft**
  During 1963, the DSN's first year of operation, it communicated with three spacecraft. In 2013, space was a much busier place with the DSN communicating with 33 spacecraft across the solar system. The DSN sends commands to spacecraft and receives telemetry, engineering and scientific data.

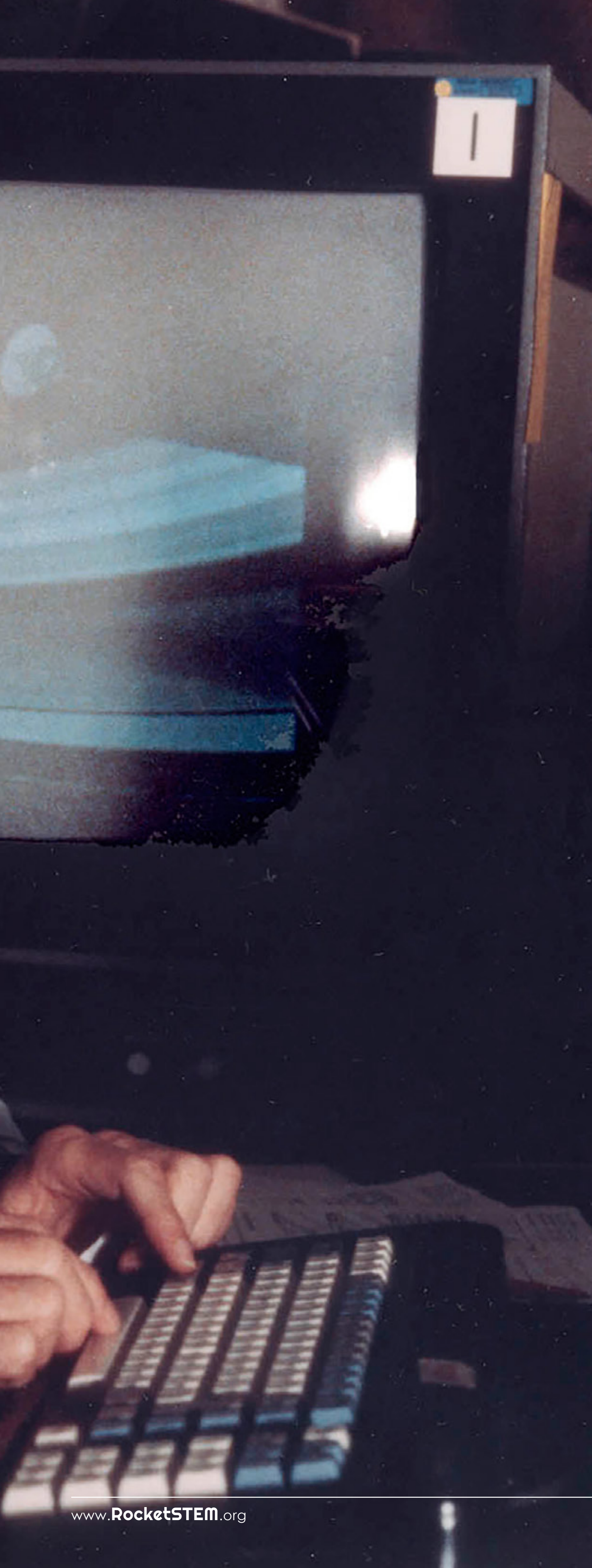
- **Not Just NASA: The DSN relays data on behalf of international space agencies**
  While the DSN tracks, sends commands to and receives data from all NASA spacecraft beyond the moon, the network also supports spacecraft from the European, Japanese, and Indian space agencies.

- **There's Always Room for Science: The DSN is used for scientific observation**
  In addition to its crucial role in two-way spacecraft communication, DSN dishes make direct science observations. There's radar science, in which waves are bounced off objects such as passing asteroids to create radar images; radio science, where changes in the steady radio link between a spacecraft and the DSN reveal the internal structure of another world; radio astronomy, which looks at naturally occurring radio sources such as pulsars and quasars; and geodetic measurements, which reveal changes in the crust of Earth by tracking how long it takes a radio signal from a quasar or other astronomical source to reach different telescopes.

- **Houston, We've Had a Problem: Apollo 13 relied on the DSN**
  The DSN was called on to support the nerve-wracking Apollo 13 mission after the rupture of an oxygen tank forced NASA to abort the planned lunar landing. During the critical re-entry of the capsule, it was essential that engineers on the ground maintain contact with the astronauts on board. The spacecraft's minimal power was needed for re-entry, with little left over for communications. The DSN was able to capture the "whispers from space," and helped bring home safely Jim Lovell, Jack Swigert and Fred Haise.

- **Animal Planet: Each DSN facility has a critter companion**
  Each of the three DSN facilities around the globe has a different native species as an unofficial mascot. Goldstone in the California desert has burros; Madrid has bulls; and Canberra, Australia, has kangaroos.

Goldstone Complex antenna.
Credit: NASA/JPL-Caltech



Charley Kohlhase

Ambassador to the planets

By Chris Starr, FRAS MBIS

Charley Kohlhase officially 'retired' from NASA's Jet Propulsion Laboratory in 1998. At his retirement party, a recording was played of Carl Sagan, who had died two years previously. '…. His voice suddenly, pleasingly rang through the room. From the afterlife, Sagan implored, "Charley Kohlhase's name should be as well known as Michael Jordan's!"' *(from 'Ambassadors from Earth' – Jay Gallentine, Nebraska University Press, 2009)*.

Sporting heroes today are celebrated with much media pomp and circumstance. On the other hand those who contribute to the advancement of science and technology generally remain unknown outside their field. Rocket scientists are among these real, unsung heroes of human progress. As rocket scientists go, Sagan was certainly right about Charley!

Charles E. 'Charley' Kohlhase, Jr. is one of the most accomplished and revered figures in unmanned spaceflight and solar system exploration. He worked for forty years at NASA's Jet Propulsion Laboratory (JPL), leading the mission design and management of many of their greatest successes, from the early days of Ranger and Mariner missions, through Viking, the Voyager 'Grand Tour' and Cassini. Since 'retiring' in 1998 he has continued to advise JPL until 2014, serving as a technical consultant for the Cassini, Mars Sample Return and other future Mars missions, Genesis, Kepler and the planned Jupiter Europa Orbiter, as well as participating in the choice of landing sites for the twin Mars Exploration Rovers and working on risk assessments for a variety of future programmes. He is also on the Advisory Council of the Planetary Society, an accomplished writer, speaker, digital artist, photographer and a committed environmentalist – a true Renaissance Man.

Charley spoke on the Voyager Panel at this year's Spacefest, and I had the opportunity to speak with him afterwards about his long and distinguished career at

James Blinn (far left) and Charles Kohlhase working at JPL on the revolutionary computer animations of the planned Voyager encounters with the outer planets. Credit: Charles Kohlhase

JPL. Here are extracts from the interview, the full version of which can be found on the RocketSTEM website, together with references for finding out more about his work, science, art, the environment and his world.

RocketSTEM: What motivated you to work in the space programme?

Charley KOHLHASE: "When I was young my grandmother used to tell me adventure stories. Later I got into science fiction adventures too. Sometimes, I found myself wishing to escape from regimented family life and the private military academy to which I had been sent by my father, a strict disciplinarian. School friends said they would see me lying on the lawn at night looking up at the stars. I also had an inspirational teacher at school who taught me to enjoy math and to reason. I was a dreamer, but I was also curious, and must have had an internal desire to know what was out there.

"My father did not encourage me in that direction, paying for my studies at Georgia Tech as long as I studied in the mechanical engineering department. At the end of my sophomore year, the call to science was very strong, so I changed to physics. My father cut off all support to me from that point on, so for the last two years I paid my own college expenses. I did well in physics and math, and I followed that pathway, even at the expense of being rejected by my father. I'm happy that I found the courage to follow this dream."

Charley at work in his home in 2010, designing a futuristic space scene.

RS: Were you reconciled with your father afterwards?

KOHLHASE: "Being a heavy smoker, he died of lung cancer, aged 59. When I was working at JPL, I flew back to see him in Georgia shortly before his death in 1969. Surprisingly he said 'Son, I'm proud of what you've done.' He had followed my work in newspapers and must have felt he knew enough about it then to say he was proud of me."

RS: You started at JPL when you were 24. How did you come to work there?

KOHLHASE: "I studied at Georgia Tech as a Naval Reserve Officer Training Candidate (NROTC) and earned my degree while also receiving a commission. When I graduated I had a commitment to put in time as an Ensign in the Navy and did my two years of service, starting in June 1957. However, after that, I knew I didn't want a career in the Navy.

"JPL excited me because I knew they were going to get into space exploration. I had a telephone interview with Vic Clarke, the supervisor of the lunar and planetary trajectory group. Not long after that I got an offer to go and work there in May 1959 when I finished with the Navy.

"JPL had been established in 1936. It had done early work for the Army, above all the Corporal and Sergeant missile programmes, which had started in the mid-1940s, as well as other classified rocket projects. NASA as the civilian space agency was created in 1958, the year before I started at JPL, so for me the timing was just right, at the dawn of the space age."

RS: These must have been very exciting times!

KOHLHASE: "They were! It was a unique experience, getting in on the early stages. We lived and breathed each mission, were self-motivated and highly responsible. I think we were a breed apart. We were dreamers and always excited about what we were doing. The years flew by. We were having fun."

RS: What was your first role when you began at JPL?

KOHLHASE: "I was only an associate engineer then in Vic Clarke's group, but it gave me the first opportunity to do something meaningful. Someone would say 'We want a trajectory from the Earth to the Moon that gets there efficiently and doesn't exceed the capability of our launch vehicle,' so I could apply the academic principles which I'd learned to do that job."

RS: I understand that you were thrown in at the deep end at one early morning meeting when you encountered two legends of spaceflight at the time.

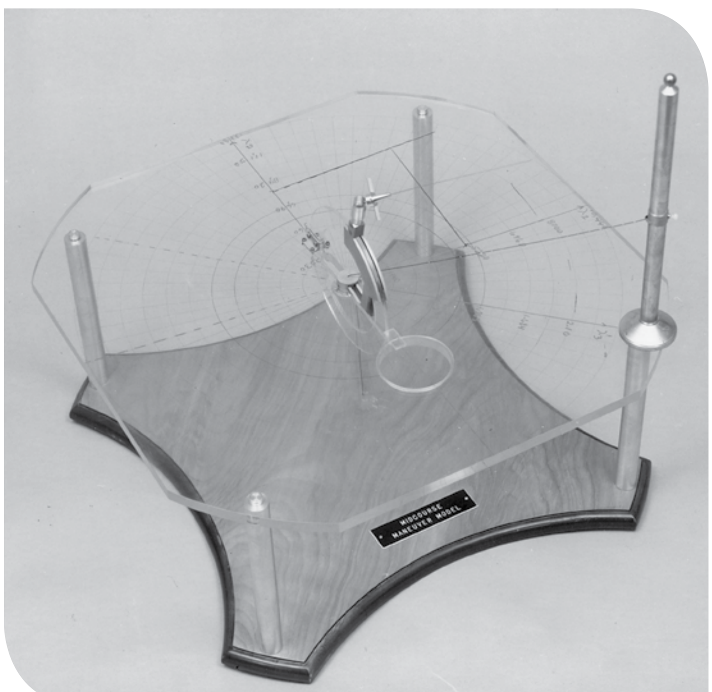
KOHLHASE: "Yes, it was early 1960. I'd been at JPL for about eight months when my supervisor asked me to design a trajectory to go from Earth to Mars at the next opportunity in the fall of 1962. He wanted to know the most favourable launch and arrival dates, and asked me to describe what Mars would look like if we planned a safe fly-by on the generally sunlit side of the red planet. By "safe," he meant not too close to risk impact, given navigation uncertainties.

"So, I walked into this small conference room in 1960, mentally rehearsed what I planned to say and draw on the blackboard concerning a Hohmann transfer ellipse to Mars. The door opened and in walked Dr. William Pickering *(Director of JPL)* and Dr. Wernher von Braun. They sat down next to me, Pickering on my left, von Braun on my right.

"My supervisor called the meeting to order and introduced me. I struggled on wobbly legs to reach the blackboard which, by now, was blurry and indistinct. I can still remember raising my hand to draw the Sun surrounded by the relevant orbits of Earth and Mars. I can usually make pretty good free hand circles and ellipses, but I suspect these were erratic. Pickering and von Braun followed with serious faces, eyes and ears trained on my modest delivery. I rambled on for some 20 minutes, a few questions were asked, and the two super-brains finally excused themselves. I have no idea how I came across, but I will never forget the experience."

RS: Before the Mars missions, you were part of the team designing missions aimed at going to the Moon?

KOHLHASE: "Yes. There were nine Ranger missions to the Moon *(between August 1961 and March 1965)*. Several of the early Rangers failed and the Lab was greatly criticised for that. Although many of those were mistakes by the launch vehicle contractor, and the later Rangers were generally successful, it was felt that the Lab had too academic an attitude. Soon this resulted in Deputy Directors coming in from the military to get us away from a perceived 'loose' Caltech-JPL attitude.



The Ranger Manoeuvre Model, designed by Kohlhase and Curkendall, used to check mid-course corrections on early unmanned flights to the Moon. Credit: Charles Kohlhase

"In that regard, a young engineer was doing the manoeuvre analysis for Ranger. This involved tracking the spacecraft after launch to determine its orbit and, if it was not on target for the Moon, making a mid-course correction by rotating the spacecraft and firing its engines to correct the trajectory. The young engineer gave the spacecraft team a series of turns and a burn to execute. However, these instructions took Ranger further from the Moon rather than closer because there had not been a firm agreement on the sign convention (minus or plus) to use in the calculations between the navigation team and the spacecraft team. That shook up the people at the lab and they didn't ever want that to happen again.

"For that reason, they asked me and Dave Curkendall to design an analogue device that could check all the Ranger manoeuvres from then on and make sure they didn't turn in the wrong direction. We would take all the Ranger orbit determination estimates from then on and actually rotate our device, like a slide-rule, to check them with the computer programme to see if they agreed. That was probably my main contribution to Ranger, making sure we never made another mid-course correction error."

RS: You mention the computer programme. What was the computer capability back then in the early 60s? Could you pre-programme much of what happened on board the spacecraft?

KOHLHASE: (Laughs). "Well, even much later on, in the Voyager spacecraft, the onboard computers have a total memory of only 8 KB. ***(Note:** a cell-phone today has over 100,000 times more memory than a Voyager spacecraft!)* For Ranger you could programme its simple 'computer' so that at a certain time in the future the spacecraft would turn or change course, you could turn the camera on, simple commands like that, but it wasn't nearly as sophisticated as Voyager. It couldn't carry out onboard fault protection or correct itself. You had to know in advance what you wanted to do as a function of time."

RS: Computing power was only one of the challenges you faced working in this totally new field of robotic planetary exploration?

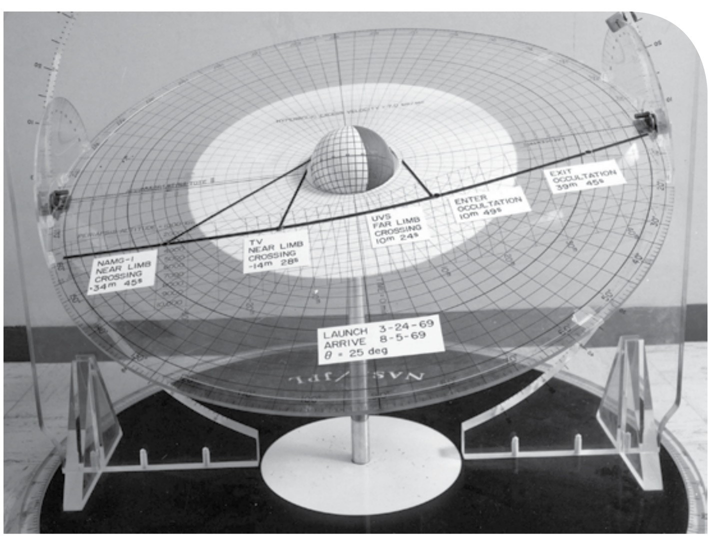
KOHLHASE: "There were many. But the secret was that once I did a job on any particular programme, whether it was Ranger, Mariner, looking at trajectories, navigation or targeting, as soon as I'd developed that particular job skill, and the supervisor said 'That's right, that's what we want', then I added a new tool to my experience kit. What helped me the most was that I had the ability to simplify almost anything. No matter how complicated a problem was, I could simplify it to two or three essential parameters. Then I could use those "rules of thumb" to bootstrap myself into each new challenge.

"It's basically about developing what we call an 'expert system', like the 'Prospector' computer programme developed at the time in the oil industry to deal with drilling problems, based on expert consultants' solutions for different situations. It consisted of statements such as 'If such and such happens, then do this'. They discovered that the consultants operated on no more than about 200 to 300 rules of thumb. It was found that the same was true for surgeons or rocket scientists. I knew what those principles were for rocket science and space mission design. With the ability to simplify, I was like an 'if … then … else' computer programme, which helped a lot."

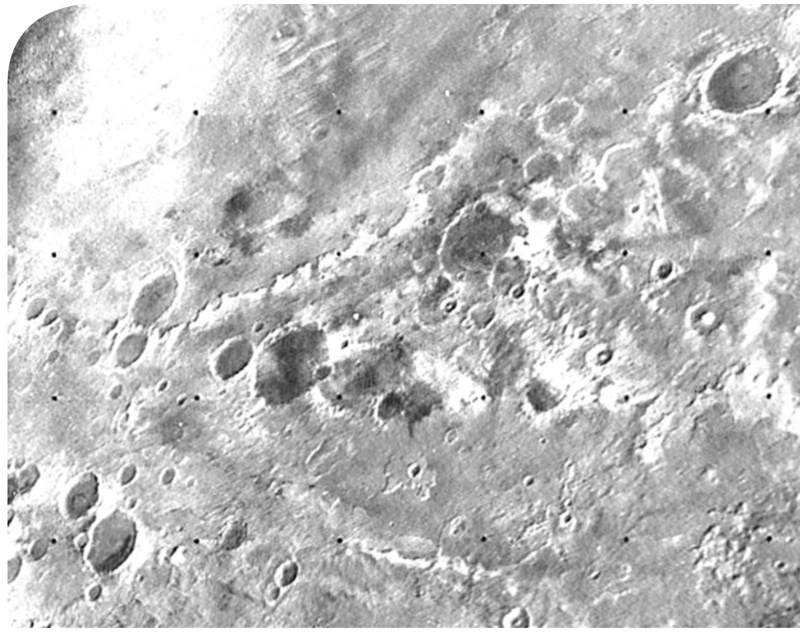
RS: It must have been more difficult when you moved from Ranger onto the Mariner Venus programme in 1962, aiming for another planet, rather than the Moon?

KOHLHASE: "Not really, because the principles carry across, whatever the target. Venus had a different mass and the approach speeds were different, but it was easy to translate the targeting concept from the Moon to a planet, taking into account gravity, celestial mechanics, Kepler's laws and so forth. Also, as the technology improved and we gained more experience, we felt more comfortable taking on more complex missions. Although we had fewer people to do the testing back then, it has always been my nature and that of most of my colleagues to check everything so carefully that nothing could possibly be overlooked, so most of the missions thereafter were successful, from the mid-1960s, when my own role carried more responsibility, through to the successful Cassini launch and Mars Pathfinder missions in 1997.

"However, we really wanted the Mariner-Venus mission to succeed at JPL, after the Ranger failures. Mariner 2



Mariner Mars '69 flyby model used in displaying the Mariner 6 and 7 encounters with the red planet. Credit: Charles Kohlhase



Mariner 7, following Mariner 6's flyby on July 31, had its closest approach at a distance of 3,524 kilometers, in what was the first dual mission to a planet. By chance, both craft flew over cratered regions and missed both the giant northern volcanoes and the equatorial grand canyon that were discovered by Mariner 9. Their approach pictures did, however, show that the dark surface features long seen from Earth were not canals, as once thought in the 1800s.

was the first successful planetary mission and it passed Venus more or less where we intended it to (within 22,000 miles of the planet). That was my first planetary mission, although I did yet not have a management role on it."

RS: Was the mood of excitement comparable with, say, that of the recent landing of Curiosity on Mars?

KOHLHASE: "We were excited that the spacecraft worked long enough to achieve the first planetary fly-by, but there were many fewer people then following the mission. It took time to establish confidence in the fact that we could successfully capture scientific results from far-away planets."

RS: And Mariner 2 did deliver good scientific observations from both Venus and the interplanetary environment during the cruise.

KOHLHASE: "It did and from then, as we began to succeed with each follow-on mission, the press began to take more interest, especially on Mariner 6 and 7, the first dual mission to Mars in 1969. First, though, after the Venus mission, Mariner 4 went to Mars in 1964 and was successful, capturing the first images of another planet. *(**Note:** Mariner 4 flew past Mars at a distance of 9,846 km on 15th July 1965, returning 22 images and detailed information on its atmosphere)*

"For me also there was a steady progression and I was able to bootstrap myself up through my navigation work on Ranger, then Mariner-Venus, Mars in 1964, and then Mariners 6 and 7 in 1969. At this point I was beginning to have more responsibility, to really be in control over the aiming points for the trajectories, the navigation, and the mission-spacecraft interactions, writing the reports and putting the requirements on the launch vehicles."

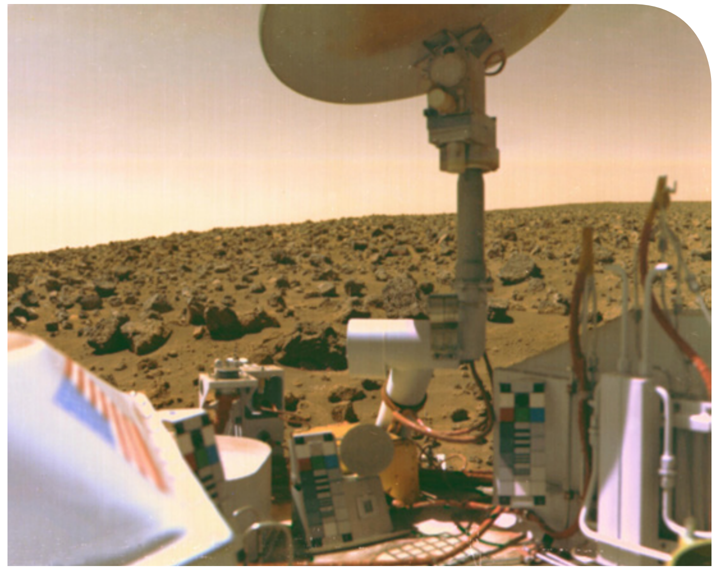
RS: From the science point of view, what were the reactions to the first images sent back from Mars in 1964, which showed a cratered world?

KOHLHASE: "Well, the early Mariners seemed to show Mars as a cratered, somewhat uninteresting place. Mariner 7's instruments did image the edge of the southern polar cap, showing frost or ice, but Mars did not emerge as a really interesting world until the first successful orbiter, Mariner-71 *(Mariner 9)*, which arrived in November 1971. We had to ride out a dust storm for a couple of months, but then the complexity of the surface and its atmosphere were revealed.

"I myself didn't work on Mariner-71. I jumped to Viking after the Mariner-69 missions. I was the Navigation Development Team Leader for Viking, but now also got more into the overall mission design, so I was writing mission requirements and documents on all the systems. In fact, I co-authored a high-level document referred to as the 'Mrs. D' - Mission Requirements on System Design."

RS: When was the decision made to mount the Viking mission and how did it come about?

KOHLHASE: "There was a desire to go to Mars on a project initially called Voyager, believe it or not. It was planned between 1966 and 1968 as part of the Apollo Applications Program, and was scheduled for launch in 1974–75. It was very risky. We were going to use a Saturn C5, the biggest launch vehicle in the US, and put two complete orbiter-lander missions on a single launch. They were firstly conceived as precursors for a manned landing on Mars in the 1980s. Then NASA realised that we'd have all our eggs in one basket, which would be a mistake, so that was cancelled. And Viking arose in its place in 1968, led by Project Manager James Martin, former assistant manager for the Lunar Orbiter Project. It separated the missions on different launch vehicles.



A boulder-strewn field of red rocks stretches across the horizon in this self-portrait of Viking 2 on Mars' Utopian Plain. Credit: NASA/JPL

"Viking was very interesting work. It was an expensive, challenging mission run out of Langley Research Centre. Martin Marietta of Denver was building the lander and JPL was building the orbiter.

"Now, I had a hard decision to make in 1974. I could stay with Viking and become the Navigation Team Leader for operations, or I could get on this great Voyager mission, where the planets only line up every 176 years. This would give me the chance to work with Bud Schurmeier again, with whom I'd worked on Mars '69. So, I left Viking in late 1974, even though it was an actively-funded project, and moved to Voyager and loved every minute of it! I did worry at first about whether I was capable enough to do the job, and I had some sleepless nights. But I had developed enough of the fundamentals of mission design, navigation and spacecraft performance to handle it."

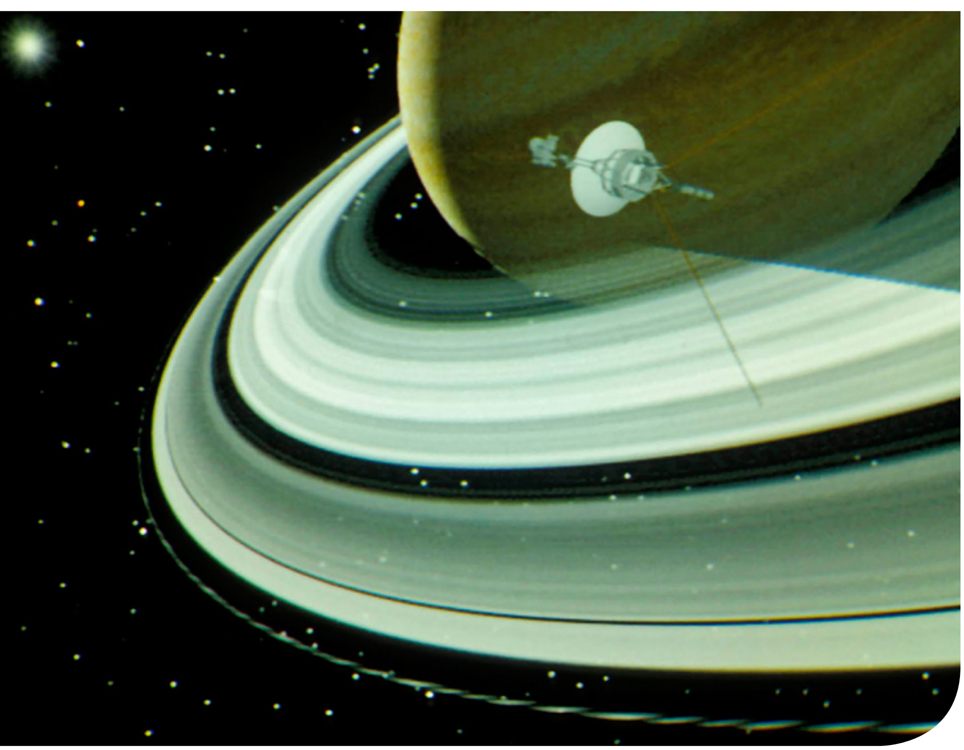
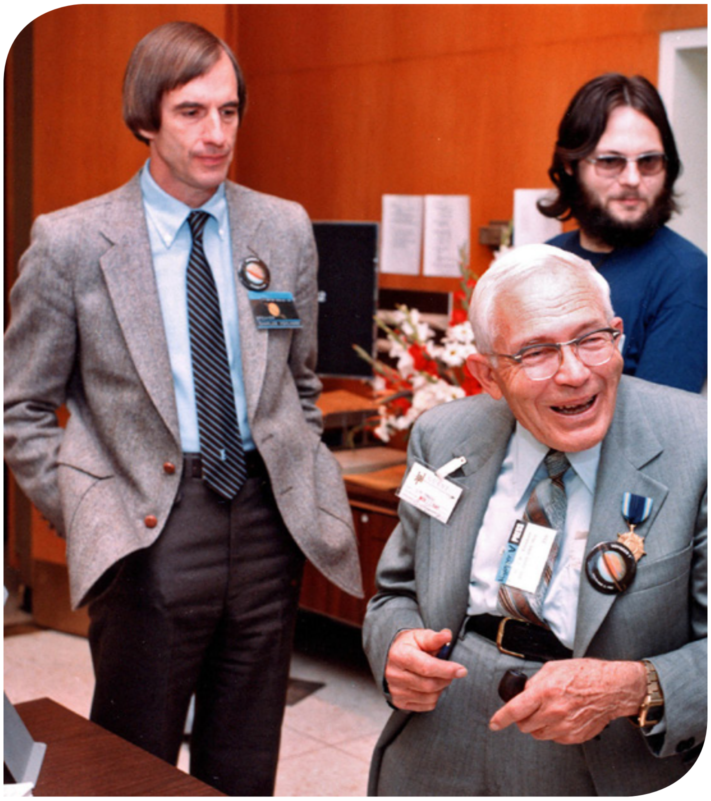


Image from the computer animation of the Voyager Saturn encounter, created by Blinn and Kohlhase, which was so important for public outreach for the missions. Credit: Charles Kohlhase

RS: At that stage, you were writing the rule books and procedures as the missions evolved.

KOHLHASE: "Yes, with Schurmeier looking over my shoulder initially, but he began to trust me and soon I was off on my own, generating the requirements and procedures on the project and mission systems for Ed Stone *(Voyager Project Scientist)* and the science team from then on."



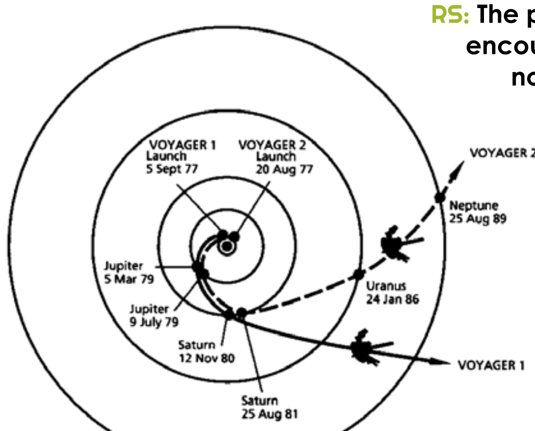
Kohlhase meets legendary astronomer, Clyde Tombaugh, discoverer of Pluto, at the Voyager Neptune encounter in August 1989. Credit: Charles Kohlhase

RS: For how long were you involved with Voyager?

KOHLHASE: "Most of my intense work was from 1974 until launch in 1977, designing all the options for the missions."

RS: You had to balance the interests of engineers and scientists. That must have been a difficult job, trying to satisfy the requirements of both groups?

KOHLHASE: "There were certain engineering constraints we felt pretty strongly about. We could lay those out in the launch date-arrival date space and make sure we avoided, say, flying behind one of the planets and looking back at the Sun if the Earth was in the same direction. There were many things to consider.



"I think the most interesting issue we had to deal with was the sheer number of trajectory possibilities. There were some 10,000 of these, taking into account the orbital periods of Jupiter and Saturn and those of their dozens of satellites. The trick was to find the best encounter dates at each planet that gave you the largest number of close encounters with bodies of interest. We also had three different launch opportunities in 1976, '77 and '78. 1977 was the 'Goldilocks' opportunity, with the arrangement perfect for flying through the region of the Galilean satellites.

"Then we wanted to fly by Io, which orbits Jupiter every 1.7 days, so we started dividing the encounter dates at Jupiter into 1.7-day increments. Titan goes around Saturn every 16 days, and we divided up the encounter at Saturn in this way too, but we also wanted to encounter Titan before we crossed the ring plane, rather than afterwards – we called these 'Titan-before' encounters. So, basically, my job was to choose the best opportunities. In the olden days we'd have to integrate the equations of motion in small steps to run trajectories, but we just could not afford the time needed to integrate thousands of trajectories. However, we knew we could use "patched conics" - ellipses, parabolas, hyperbolas and so forth – to approximate the integrated trajectories, so we developed software that could approximate and run hundreds of cases overnight on a computer. We picked those which satisfied all engineering constraints, then asked the science teams which ones best suited their needs, for example close flybys of certain satellites.

"Finally, out of 10,000 or so possible trajectories, we targeted 110 with the Titan-Centaur launch vehicle, and finally launched on two of them. By the time we had launched both Voyagers, we had come in within our development phase budget, about $387 million, as we'd promised to do." *(**Note:** This is out of a total mission cost of $865 million up to the end of the Neptune encounter in 1989.)*

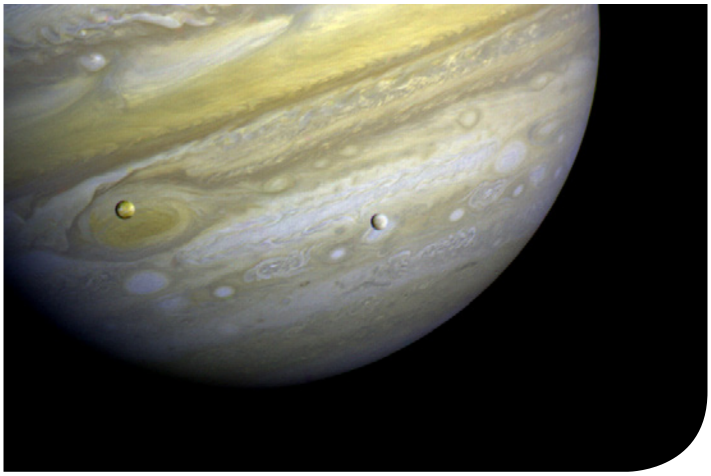
RS: There was a lot more press coverage of Voyager than the early missions you worked on.

KOHLHASE: "By the second Saturn encounter of Voyager there were huge numbers of press at JPL, perhaps 200 or so. I remember also, Clyde Tombaugh came to JPL for that encounter. I used to have sideburns then and I wanted to be in a picture with him. I got his autograph."

RS: The public perception of the Voyager encounters was also enhanced by your novel computer animations which visualised how they would unfold. This was ground-breaking digital work at that time.

KOHLHASE: "Yes, Jim Blinn and I created the first computer-animated flybys for each of the six Voyager encounters. Basically, he created the software and I used it to create the accurate flyby movies as might be seen by a viewer near the spacecraft as it passed through each planetary system.

"Now, as we released the animations before the flybys, we didn't know exactly what the moons looked like close-up, so well-known space artists Don Davis and Rick Sternbach helped us to visualise and render the surfaces of these, as yet, unknown worlds. Then, after the Voyager 1 encounters, when we had real photos of the moons, we substituted these into the animations."



Voyager 1 took this photo of Jupiter and two of its satellites (Io, left, and Europa) on Feb. 13, 1979. Io is about 350,000 kilometers (220,000 miles) above Jupiter's Great Red Spot; Europa is about 600,000 kilometers (375,000 miles) above Jupiter's clouds. Credit: NASA/JPL

RS: The two spacecrafts' cameras returned so many stunning and iconic images of these beautiful and strange worlds. Do you have a favourite image?

KOHLHASE: "It's impossible to pick a favourite, but one image has a special meaning for me. It's one taken by Voyager 1 several days out from Jupiter, showing Io and Europa in front of the Jovian disk. We were beginning to see detail on the surface of these Galilean satellites and they were beginning to look like their own fascinating worlds - we were seeing new worlds up close for the first time in human history."

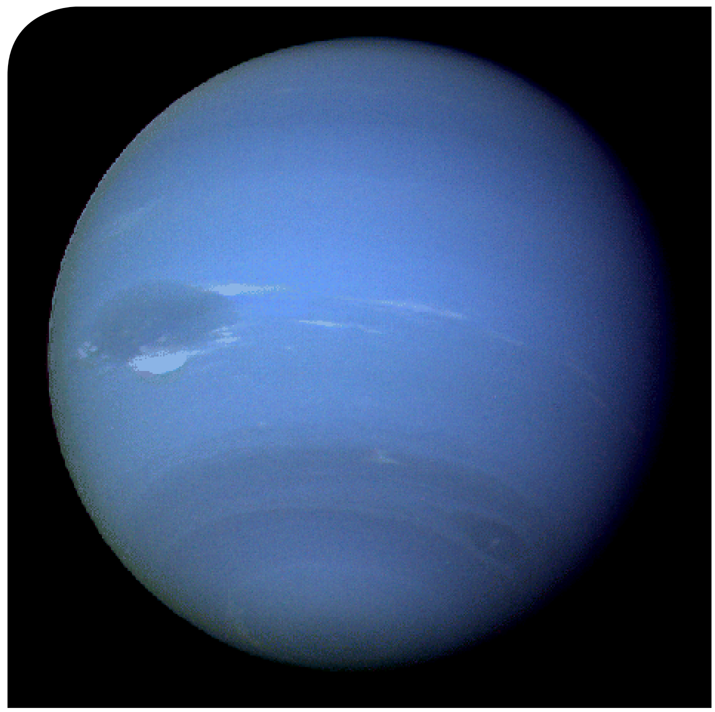
RS: How did your role on Voyager change after launch?

KOHLHASE: "In theory, and I'm always grateful to Casani for this *(**Note:** John Casani, Voyager Project Manager, Prelaunch Phase)*, once the Voyagers were launched I probably could have and should have gone to another project, but John said 'We'd like you to stay aboard, not as the Mission Analysis and Engineering Manager', which is what I'd been for nearly 4 years, 'but as the Mission Planning Manager to decide how much we could afford to do at each planet'. Here we have these two spacecraft with limited memory capacity. To programme them to do scientific observations requires manpower. There are constraints - we don't want to put demands on the Deep Space Network which they can't meet, we want to make sure we're not trying to send commands during occultations, and so on. Casani said, 'We also want you to limit the size of the computer-controlled scientific observation sequences, so that the sequence team has the time to build and carefully check each sequence load.' During the mission you send a load up and the spacecraft executes for several days, then you send another load up, and so on.

"So, my office basically took each encounter and produced in advance the mission planning guidelines and constraints that would be planned for and executed by the sequence team and the spacecraft team with the assurance that they would not place impossible demands on the other teams, while still ensuring that the spacecraft would be active enough to meet the scientists' desires.

"For example: the encounter period for Jupiter is going to start at minus 80 days and end at plus 30 days. It's going to be divided into three basic phases, such as far encounter, near encounter, and post encounter. Each phase will have a defined duration and prescribed number of sequence loads; this is the number of activities we'll have; here's how much we can afford to sequence, and so on.

"So, once we launched in '77 my job as Mission Planning Office Manager was balancing all this. I had a small office and group of people, but all well-chosen. I had a chance at various times to get off the project. I could have left after Saturn, but it was too exciting, the spacecraft were working, we were making constant and amazing discoveries, and we were going to Uranus and Neptune."



During August 16 and 17, 1989, the Voyager 2 narrow-angle camera was used to photograph Neptune almost continuously, recording approximately two and one-half rotations of the planet. Credit: NASA/JPL

RS: After the success of the previous three encounters, there were concerns in 1988-89 about the final encounter, and about how close Voyager 2 needed to get to Neptune. You wanted to do two occultations behind the planet *(Note: Both of the Earth and the Sun)* and also plunge down to reach Triton. This was your closest approach to a giant planet and there were worries that you might lose attitude in the atmosphere. How was the encounter planned?

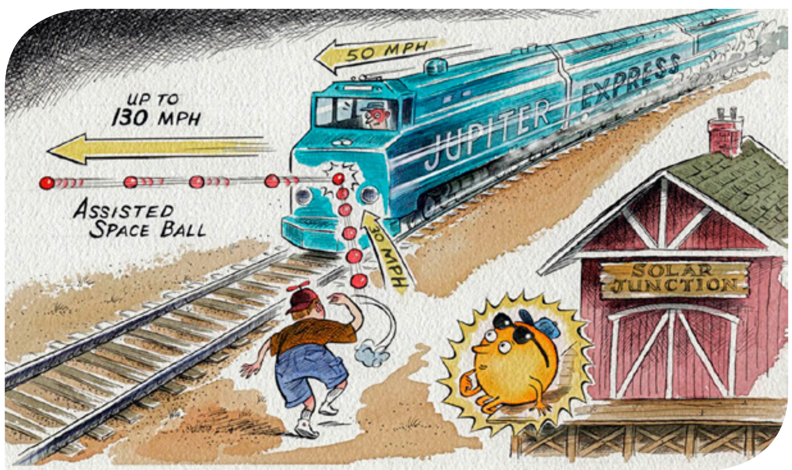
KOHLHASE: "The timing had to be very good. When you're deciding where to aim for a gravity assist you use a B-plane *(a target-plane attached to the assisting body, and is perpendicular to the line of the approaching* *trajectory)* to show different aiming points at the target, such that if you pass through one of these, then you will later fly through any chosen point beyond the planet.

"In the delivery of Voyager 2 to this targeting plane relative to Neptune, we only missed our two coordinates by about 6.5 kilometres. And the timing accuracy was better than one second. As you passed over the pole of Neptune, there were some amplifications of those errors, so the difference was greater when we got to Triton, but the accuracy was still phenomenal.

"It's the equivalent of sinking a golf putt from a distance of over 30,000 miles! And the target is moving."

RS: You talked earlier about having a few sleepless nights. Was the need for this degree of accuracy a cause for concern?

KOHLHASE: "One thing worried me on Voyager which would awake me in the middle of the night. I was responsible for the navigation and would calculate analytically, when we flew through the Jupiter system and experienced the gravity assist and deflection of the trajectory by roughly 90 degrees, how much it would cost us on the outbound leg leaving Jupiter to correct any navigation errors made when inbound. These errors would be amplified by Jupiter and the large Galilean satellites, and we only had a limited amount of propellant onboard to make corrections. Well, I did the analysis and the results showed that it wasn't going to be that bad, only 10 or 15 m/s. I thought 'That can't be right' and kept worrying about it, but it turned out OK, and the rest is history."



Charley's analogy of the gravity assist flyby of Voyager as it passed Jupiter. Credit: Charles Kohlhase with artwork by Gary Hovland.

RS: And then you moved onto another historic mission, Cassini.

KOHLHASE: "Yes, then I went to a large Saturn orbiter, and an international cooperative venture with the Europeans carrying their Huygens probe to Titan. I had the best job anybody could ever have."

RS: What was the situation at that early stage in planning Cassini?

KOHLHASE: "When I first joined Cassini, it was called Mariner Mark II. It was initially designed as two missions, one an orbiter to Saturn with a Titan probe, the other CRAF – Comet Rendezvous Asteroid Flyby. The comet mission was subsequently cancelled in 1992 because of reduced funding. *(**Note:** These were part of a planned JPL programme to explore the outer Solar System between 1990 and 2010, designed to be more affordable than the so-called multi-billion dollar 'flagship' missions of the 1970s. Mariner Mark II was replaced by the very successful lower-cost Discovery Programme)* I had people working on the comet mission who were heartbroken and had to leave and find other jobs.

"In fact, NASA Administrator Dan Goldin threatened to also cancel Cassini in '94. He was big on 'better, faster, cheaper' and Cassini as a Flagship Mission would cost NASA over $2 billion. But when word got out about this, the Director General of ESA, Jean-Marie Luton, wrote a special letter of appeal that went to Vice-President Gore. It more or less said 'We are partners with NASA on this project. We want you to know that if you cancel Cassini, don't look for any further international cooperation.' Our relationship with the Europeans would have been damaged. In my mind that letter saved Cassini and I stayed with the program from that point."

RS: And since then, Cassini, like Voyager, has been a major achievement in solar system exploration.

KOHLHASE: "It has been an enormous success, orbiting Saturn for the last ten years, studying the planet and its rings, finding the hydrocarbon lakes on Titan, the geysers on Enceladus, the intricate detail in the Saturn rings, and variety among the smaller icy satellites. A remarkable success."

RS: You were Science and Mission Design Manager for this very complex mission. How did you and your team plan for the orbital part of the mission after it arrived at Saturn?

KOHLHASE: "At the time of launch *(October 15th 1997)* the way Cassini worked was that, after gravity-assist flybys of Venus, Earth and Jupiter, we planned to go into orbit around Saturn then make an initial tour based on 45 flybys of Titan. Titan is big enough that, if you fly by at close range, it can reshape the trajectory of the spacecraft using the laws of gravity assist. Every flyby designed before launch was done for a purpose. We'd be raising the inclination of the orbit, or dropping down, altering the orbit to look at Saturn, its rings or icy satellites. And of course we looked at Titan itself every time we passed by. So, my team designed the complete first tour, which ran from July 2004 until July 2008."

RS: Cassini had a much bigger payload of experiments and instruments than the earlier missions you worked

In the Payload Hazardous Servicing Facility at the Kennedy Space Centre Kohlhase (left) and Cassini Programme Manager, Richard Spehalski, hold the DVD containing 616,400 digitized signatures of people from 81 countries which was sent to Saturn on board Cassini, seen behind them. Charley designed the disk with the flags of 28 nations and symbolic golden eagle wing feathers. Credit: NASA/JPL

on. How much harder was it for you and your team to plan, given the greater complexity of the spacecraft?

KOHLHASE: "It was more complicated because there were more interfaces between the instruments and the spacecraft.

"However, no matter how complex it may be, there are four secrets to working in this job. You have to be well-educated - you have to understand the physics, the math, the engineering, and of course the astronomy. You also need to be able to simplify. If you have a problem you reduce it to the two or three elements which really matter, using first principles that you've learned over time. You must also have absolute integrity. Never hide a problem. Share it immediately with the team to solve it. And finally, you must have a sense of humour! You might have a terrible problem, but you don't just wring your hands. It's good to laugh about it to break the ice, then get on and solve it.

"So – education, ability to simplify, integrity and humour – those are the four secrets to success."

RS: Talking of success, you have had a hand in many missions to the Moon and other planets during your time at JPL, and they've all been successful. That's quite a record!

KOHLHASE: "Let's see – Ranger, Mariners 2, 4, 6 and 7, Viking, Voyager, Cassini, and some of the recent Mars missions *(Mars Exploration Rovers)* – 10 missions or so. One of the Ranger missions might have been marginal."

RS: Have you played a role in the Equinox or Solstice Mission extensions to the Cassini programme since 2008?

KOHLHASE: "No, I came off the programme soon after launch. I arranged it so that I could officially retire in May 1998."

RS: You didn't really retire, though, did you?

KOHLHASE: "I have continued to consult at JPL until about 6 months ago. My latest work in 2013 was continuing to support the Mars Sample Return Campaign, as special senior advisor, by completing a major risk assessment study for the three missions comprising the campaign. And I'm sure I'll get another invitation soon to go in and give an opinion on something, so I'm not quite dead … just fading away slowly!" (Laughs)

RS: Fifty-five years and still at the cutting edge of planetary exploration - that's a wonderful career, Charley!

KOHLHASE: "It is, but, you know, today the environment is what I really care about the most. There's simply no greater problem. We should all be stewards of the Earth, not its destroyers."

RS: How can space exploration help us in this respect?

KOHLHASE: "We have a lot of Earth-orbiting satellites tracking the loss of biodiversity, natural resources and climate changes, but I don't see politicians using that data to make any difference, we don't have anybody with the courage to use it. We are consuming natural resources at five times the rate at which the Earth can replace them."

RS: Are you optimistic about the future of our global environment?

KOHLHASE: "As I get older, one of the few things that I can take some joy in is that I live in one of the last great eras for the Earth. For my grandchildren and their children, though, I think it'll be a severely reduced Earth. I'm basically an optimistic person, but I think that we won't act in time to save the Earth."

RS: Do you have any final advice for how each of us should live our lives?

KOHLHASE: "Rise early and seize each day. Learn much and use this knowledge well. Spend time with those you love. Never abuse your pets. Use logic to fight the irrational, for it is everywhere. Defend the environment and its wildlife. Meld mind and heart for greatest creativity. Follow your dreams, and become all that you can be."

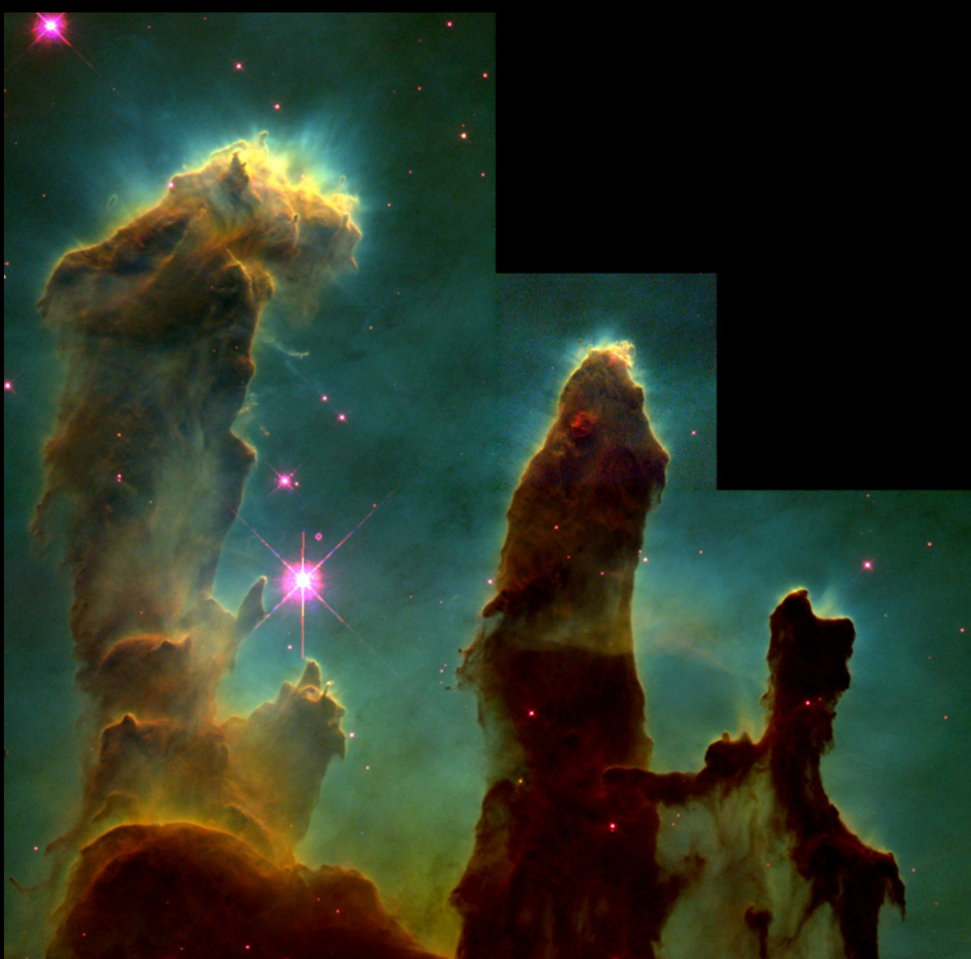
M16: The Eagle Nebula

By Mike Barrett

The Eagle Nebula is located in the constellation Serpens and is one of the most iconic star forming regions in our galaxy. The nebula is also known as Messier 16 or M16 in the catalog of celestial nebulas and star clusters compiled by French Astronomer Charles Messier.

This is probably one of the most famous and inspirational nebulas as it was the subject of one of the foremost space images produced by NASA's Hubble Telescope: The Pillars of Creation. The Pillars of creation is a small part in the center of the nebula that contains star forming hydrogen and dust. I, for one, was introduced to astronomy by this image as I am sure were many others. The Hubble Telescope created inspirational images encouraging thousands of people to look at the night skies in a different way.

The image of the Pillars also introduced the concept of the "Hubble Palette" where different parts of the nebula's emission spectrum imaged in narrowband are assigned to the red, green and blue channels which make up a normal image. Compare the Pillars of Creation image to the full nebula which was taken using normal RGB. The hydrogen gases can be seen to dominate the main picture, whereas the sodium and oxygen bring out different details in the Pillars of Creation.



Above: Inside the Eagle Nebula stand the Pillars of Creation portrayed in the Hubble Palette as captured by the Hubble Space Telescope. Credit: NASA/ESA/STScI/J. Hester and P. Scowen (Arizona State University)

Right: M16, the Eagle Nebula, captured in RGB. Credit: ESO

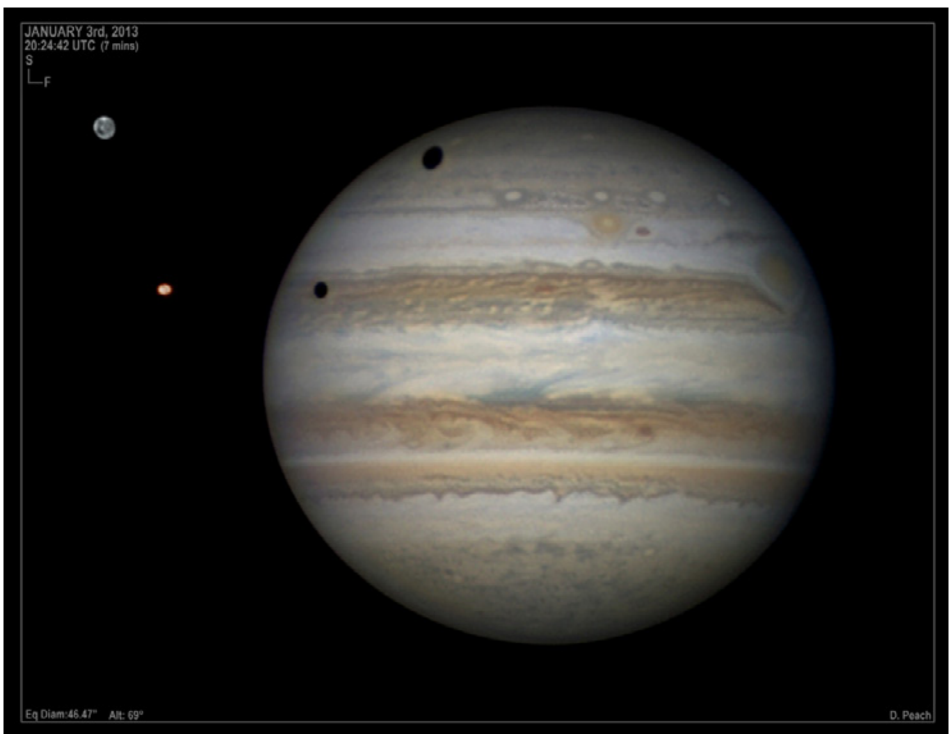
Starting in astronomy

beginner's guide to stargazing

By Mike Barrett

How to photograph the planets

For the last couple of issues our object spotlights have been located within our solar system. It is quite easy to see them, Jupiter and the Moon in particular, but quite difficult to image them. The term for imaging the solar system is Planetary Imaging despite the fact that both the planets, the moon and the sun are all imaged in this manner.



High resolution image of Jupiter taken with a Professional CCD camera. Credit Damian Peach (www.damianpeach.com)

This two part article will take you through the steps required to take some good pictures of the astronomical bodies in the solar system. The first part will concentrate on equipment and capturing the images, the next article will look at how to process them.

Unlike conventional deep space photography you do not just point your camera at the object and then take a long exposure image. You can get some acceptable pictures of the moon with a long telephoto lens and a single exposure, but the best way to create a still image is using a video!

That may sound a little counter-intuitive, but there are good reasons for this process. First we need to think about how the video works. A video consists of a series of still images that are played back rapidly to create the illusion of movement. This is the core principle behind the way imaging of planetary bodies works. You take hundreds of images and then discard most of them leaving a large number of good quality images. These good images are then combined to enhance the detail and produce the final picture.

Why is this better than taking a single image? There are a number of factors involved, but the main disruptor to imaging is a constantly moving atmosphere between the camera and the target. As the atmosphere shimmers with the thermal currents so the image is distorted. This effect can be clearly seen when looking through a telescope at say Jupiter as the planet seems to wobble and shift in and out of focus as you are observing it. This is the effect that needs to be removed.

The easiest way to do this is with an internet camera often referred to as a webcam. This can be either a purpose bought device or a cheap converted computer web camera. They are essentially the same thing.

Equipment for planetary imaging

The equipment that you will need is as follows:

1) Mount-tripod or telescope mount
2) Telescope
3) Webcam
4) Computer
5) Capture software
6) Processing software

The mount:

The ideal mount would be a tracking mount that will keep the object in the middle of the frame during the exposure. This is not critical though and a normal camera tripod can be used. The main thing is for the telescope and camera to have a solid base to attach to.

The telescope:

Any telescope is suitable for the Moon, and telescopes with longer focal lengths are good for both the Moon and planets. In photographic terms I have used a William Optics GTF-81 with a focal length of 478mm a Celestron C90 Mak (1250mm) and a Celestron C130 SLT (650mm) all with good results. Planetary imaging is better with the longer focal lengths and the Moon is good with all of the telescopes I have tried. The longer the focal length, the greater the magnification, resulting in a larger image on the webcam sensor.

The computer:

Although planetary imaging can be achieved on a Mac computer the main software components are designed to run on a PC platform. Out of preference I use a laptop running Windows XP, but the software runs on all versions of Windows. The laptop is useful to position near the telescope to enable easy focusing and adjustment of the equipment.

Capture software:

In order to transfer video from the webcam to the computer some software is required. If you have a specialised astronomy planetary camera or webcam then this will have software included to control the camera and save the output onto the computer. If you do not have capture software then there are a number of free applications available to download from the web. Two examples are SharpCap (http://www.sharpcap.co.uk) and wxAstroCapture (http://arnholm.org/astro/software/wxAstroCapture/).

Processing software:

Again a commercial planetary camera will come with processing software, but it will mainly be the same freeware or shareware software that you can download from the Internet. The most popular processing application is called Registax (http://www.astronomie.be/registax/). This analises the video, determines which are the good images on them, aligns them, and stacks them all into a single image. There are then some post processing options that can be applied to the image to bring out the detail.

A $10 Xbox webcam can take good images. The most difficult part of the Xbox webcam conversion was opening the casing. Credit Mike Barrett (www.wired4space.com)

Webcam:

I deliberately left the webcam to last as there are so many options that you have available. These range from buying a dedicated 'Planetary Imaging' or 'Solar System Imager'; using a telescope guide camera; to modifying a standard computer webcam. Celestron have a range of webcams available from $90 to $280 and Orion Telescopes from $60 to $200. There are many other makes available as well.

For my first venture into planetary imaging I modified an old XBox Live webcam for about $10, the cost of a replacement nose piece which screws onto the body and has the same dimensions as normal eyepiece. The results obtained from this $10 imager were about the same as my $200 dedicated camera. If you have an old webcam lying around and are not afraid of destroying it then it is not a difficult modification. Indeed the most difficult part is removing the casing. There are many tutorials on the web, Astro-Beano (http://astrobeano.blogspot.co.uk/2012/01/xbox-360-webcam-for-astrophotography.html) has a good one. Just look at the updates towards the bottom where he removes the IR filter and fits a purpose built eyepiece adapter.

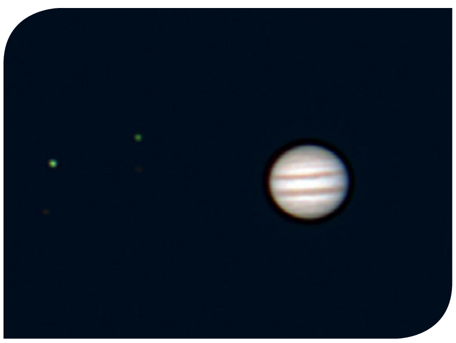
Managing expectations

Before going any further it is a good idea to understand what you can get from this type of setup. What you will not get is a full color A4 size print except possibly for the Moon. Using modest telescopes you can expect to get large images of the Moon, but relatively small ones for Jupiter and Saturn and very small ones for other planets.

That is not to say that planetary

imaging is not fulfilling. I remember the first time I managed to capture Saturn. It was the only planet in the sky at the time and I was impressed with the tiny image showing the planet and rings in less than 150x100 pixels. There was a strong feeling of accomplishment having captured and processed the image with my modified computer web camera.

Having decided that this was something I really wanted to do I then purchased a 5MP Celestron NexImage 5 expecting to take much better images as the sensor was much larger 5MP compared to 0.3MP. I was wrong! All I managed to achieve was to get more dark sky in the image (explained later). The camera did have other benefits so I was not complaining. I also found that it was impossible to video at 5MP and process the video. The frame rate drops dramatically and the files that are large at lower resolutions suddenly become huge!



Jupiter and moons captured with Celestron NexImage 5. Credit: Mike Barrett

Getting started

Once you have your telescope pointing in roughly the right direction with all the connections made you will probably find it quite difficult to locate the planet that you are trying to image. This is most likely because the telescope is not at the correct focus point. When the focus is a long way out you will not be able to see anything on the preview. So when first starting out it is best to pick a large object like the Moon. The Moon is so bright that even with an out of focus telescope you will still see a silver disk. If you are trying to locate Jupiter or Saturn and you are not close to focus then you will struggle.

Having located the moon the first thing to do is to focus the telescope with the webcam attached to the eyepiece. Obviously the easiest way to do this is with the computer very close to the telescope. This will allow you to turn the focusing knob at the same time as viewing the image on the screen. At this time it is probably best for the camera to be set to Auto Gain and Auto Exposure. When you have achieved focus make a note of roughly where the focuser is on the telescope. This will enable you to get the setup focused faster next time.

Comparison of the 1.2MP QHY5L-II and 5MP NexImage sensors. Credit: Mike Barrett

If you are imaging the Moon then you are ready to go. If you are trying to capture one of the planets you now need to point the telescope to the planet (Jupiter is the easiest to start with) and then focus again. The fact that you have already focused on the moon will mean that the focus will be almost right for the planet.

With a nice sharp image on the screen you will see that the target object appears to wobble a bit, sometimes quite a lot. This is the effect of the turbulent atmosphere and sometimes the wind. If people are walking around your setup then this can also transmit vibrations to the telescope. Now you can see the issues we need to remove from the video to get a great image.

Framing the shot

When imaging the planets they are quite small on the sensor of the camera. Setting the camera to capture at the highest resolution is a waste of resources and will lead to issues when processing. Jupiter at 2592x1944 will expose exactly the same number of pixels as at 640x480, the software just crops the image from the camera sensor. The object here is to get the smallest frame size possible to image the objective. This will generate the smallest video files making the processing easier. When framing the shot allow some room for the motion of the object whilst setting up and capturing the movie.

The QHY5L-II guide camera used as a webcam. Credit: Mike Barrett

You will obviously have your imaging session dictated by the location of the planet or the Moon. If you have choices then it is far better to image when the target is as high in the sky as possible. This is because there is less atmosphere for the light to penetrate therefore less atmospheric disturbance to image through. With some planets and phases of the Moon it is not possible to get a high elevation shot so you will have to take more video to compensate.

Exposing the image

Exposure for the video can be a little tricky. With capturing the Moon it is a little easier as there is more of the moon in the frame than dark sky, but with planets the majority of the image will be dark sky. The trick here is to lower the exposure control and possibly raise the gain until the detail of the planet is visible.

If you are capturing Jupiter then when you have the exposure correct for the planet surface you will find that the Jovian moons have disappeared. This is because to correctly expose the planet it will underexpose the moons. To overcome this I take two videos: one for the planet; and one for the moons. The video with the moons correctly exposed will leave the planet hugely overexposed. I then process the two images separately and then merge them to create a composite picture with all parts exposed correctly.

It can be a good compromise to use a higher gain and a corresponding higher frame rate. This is especially true if the atmosphere is very turbulent during your imaging session. Increasing gain increases the grain and decreases image quality. Increasing frame rates is like shortening the shutter speed on a camera, the faster the frame rate, the less movement is captured. This can be effective for countering atmospheric effects.

All set up and ready for a night of lunar imaging. Credit Mike Barrett

Capturing the video

The video is now ready to be recorded. I normally ensure that I take around 2000 frames. If the atmosphere is particularly unstable then the more frames you take the better. It is easy to drop bad frames, but impossible to get additional ones later. In fact that is a good rule of thumb: Take as many frames as possible. The only thing to watch out for is excessively big files.

One final thing to bear in mind, particularly with Jupiter, is that the planets not only move through the sky but also revolve around their axis. This means that you can only really use content from the same video to create an image as features on the planet will have revolved.

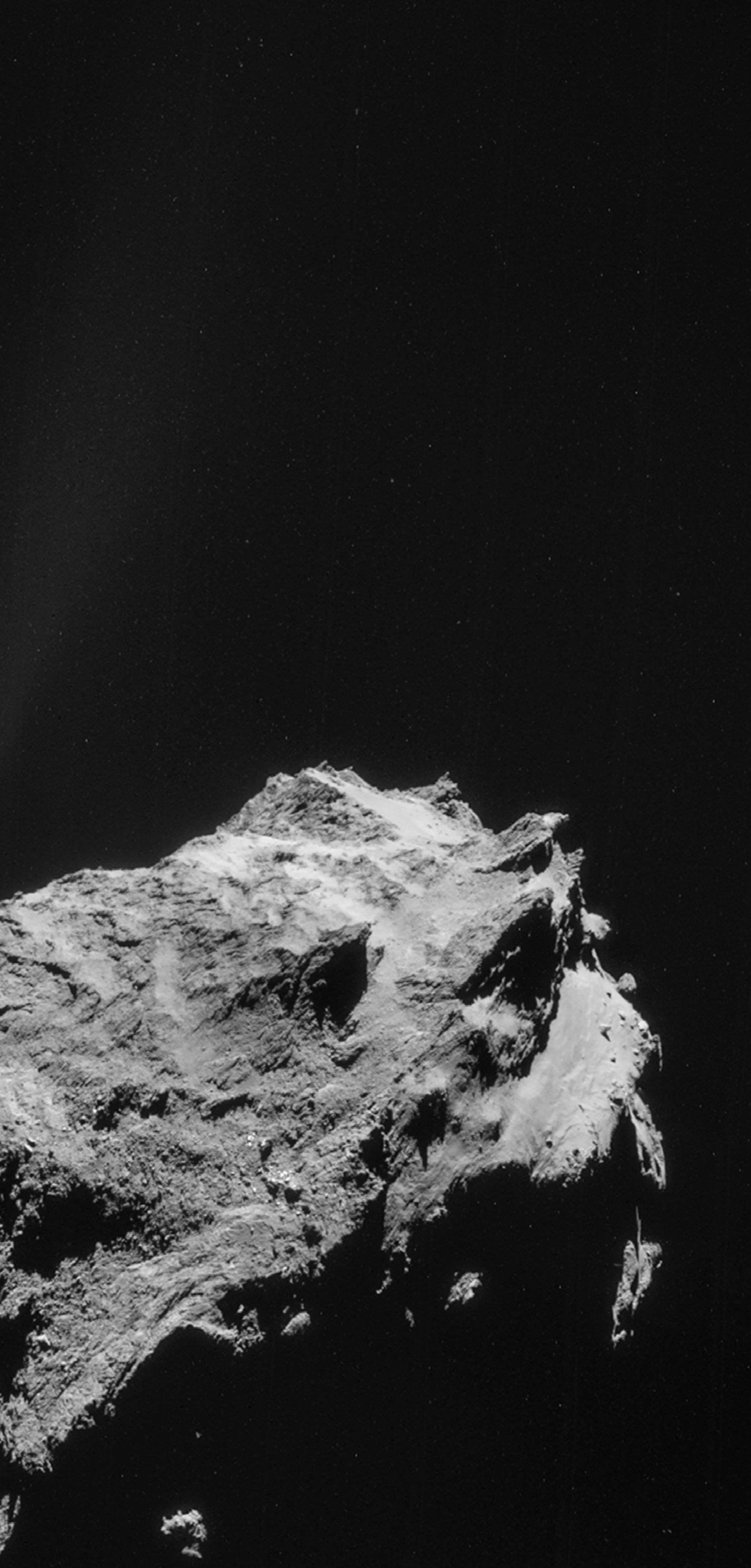
Conclusion

Planetary Imaging is all about compromise.

The main factor that affects the quality of the images is the Earth's atmosphere. Being able to image through as little of the atmosphere as possible and on good stable days will vastly improve the quality of the videos, which in turn will lead to better images.

In the next issue the processing of the video into a single image will show how a wobbly and blurred video can generate a stunning final result.

Four-image NAVCAM mosaic of Comet 67P/Churyumov-Gerasimenko, using images taken on 19 September 2014 when Rosetta was 28.6 km from the comet. Credit: ESA/Rosetta/NAVCAM



Rosetta is deciphering comet's tale

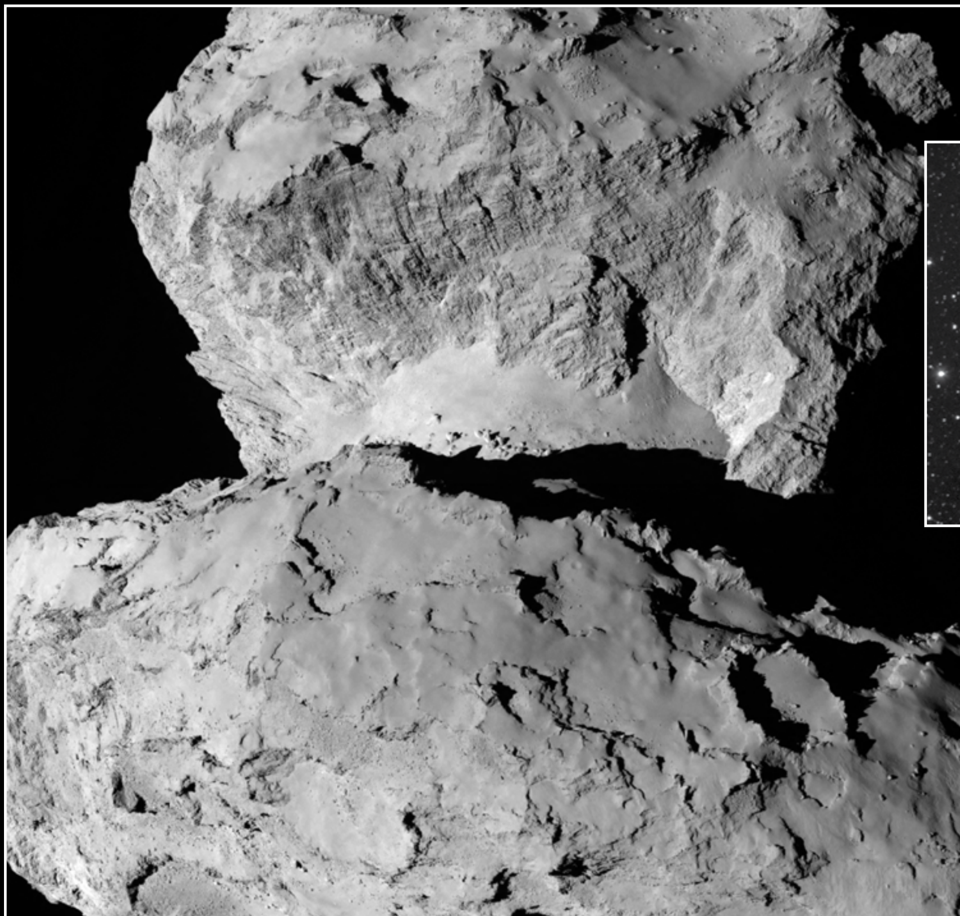
By Dr. Sten Odenwald

Comet 67P/Churyumov-Gerasimenko (I'll call it Comet 67P) has been minding its own business for billions of years as it quietly looped around the Sun every 6.5 years. Discovered in 1969 by astronomers Klim Ivanovych Churyumov and Svetlana Ivanovna Gerasimenko, it spins around on its own axis every 12 hours and is about 2 miles across. Even with a mass of 10 billion tons, it is still small compared with the giants of its class, like Hale-Bopp, at 40 miles across!

So far, spacecraft have visited Halley's, Tempel-1, Hartley-2, Wild-2 and Borrelly, so Comet 67P joins a very select group of "dirty icebergs" gliding through space in orbits favorable for human scrutiny. Despite their brilliance in the night sky, their hard nuclei are as dark as aspault, reflecting less than 5 percent of the sunlight that falls on their surfaces. Far from featureless ice balls, they show amazing surface detail that in most cases has been studied at high resolution. Take a look at this recent image of Comet 67P taken by the European Space Agency's Rosetta spacecraft just last month.

This beautiful view shows off a wide range of the comet's features: from the jets emanating from the 'neck' region, to the steep cliffs towering over both smooth and grooved terrain, and to the hundreds of boulders scattered across the surface.

In the image at the top left of the next page, you see boulders a few dozen yards across sitting in a depression where they have probably been for the last million years. Then there are surface shapes that look like landslides, which we shouldn't find surprising, since the surface is constantly eroding as it evaporates. What is bizarre is that this cosmic iceberg has so little mass that it barely has any gravity at all. So how does the debris "know" to move in one direction that looks like down-slope to us? Does the centripetal force of its 12-hour rotation help, somehow?



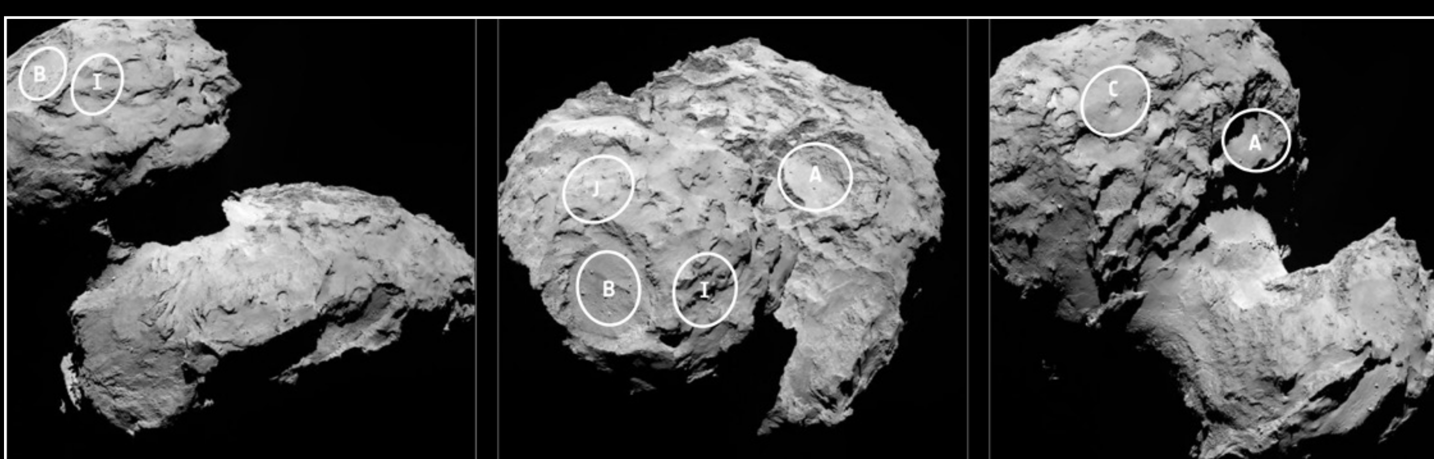
Rosetta's first sighting of its target was taken on 21 March by the OSIRIS Narrow Angle Camera. The comet is indicated by the small circle next to the bright globular star cluster M107. The image was taken from a distance of about 5 million kilometres to the comet. Credit: ESA/Rosetta/MPS for OSIRIS Team

Rosetta's OSIRIS narrow angle camera captured this image of the comet on 7 August from a distance of 104 km. Credit: ESA/Rosetta/MPS for OSIRIS Team

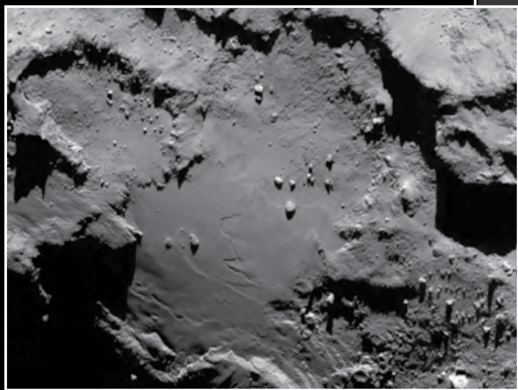
In preparation for the November 12 landing of the companion Philae spacecraft, Rosetta is taking up an orbit only 19 miles above the surface of the comet. The final landing site was chosen as the primary landing site because the majority of terrain within a square kilometre area has slopes of less than 30° relative to the local vertical and because there are relatively few large boulders.

Because the gravity of the 10-billion-ton nucleus is so weak, Philae will actually approach the surface at about 2 miles per hour and "dock" with the surface, just like NASA's Space Shuttle used to dock with the International Space Station. To avoid bouncing off, Philae will immediately launch two harpoons into the icy surface to anchor itself.

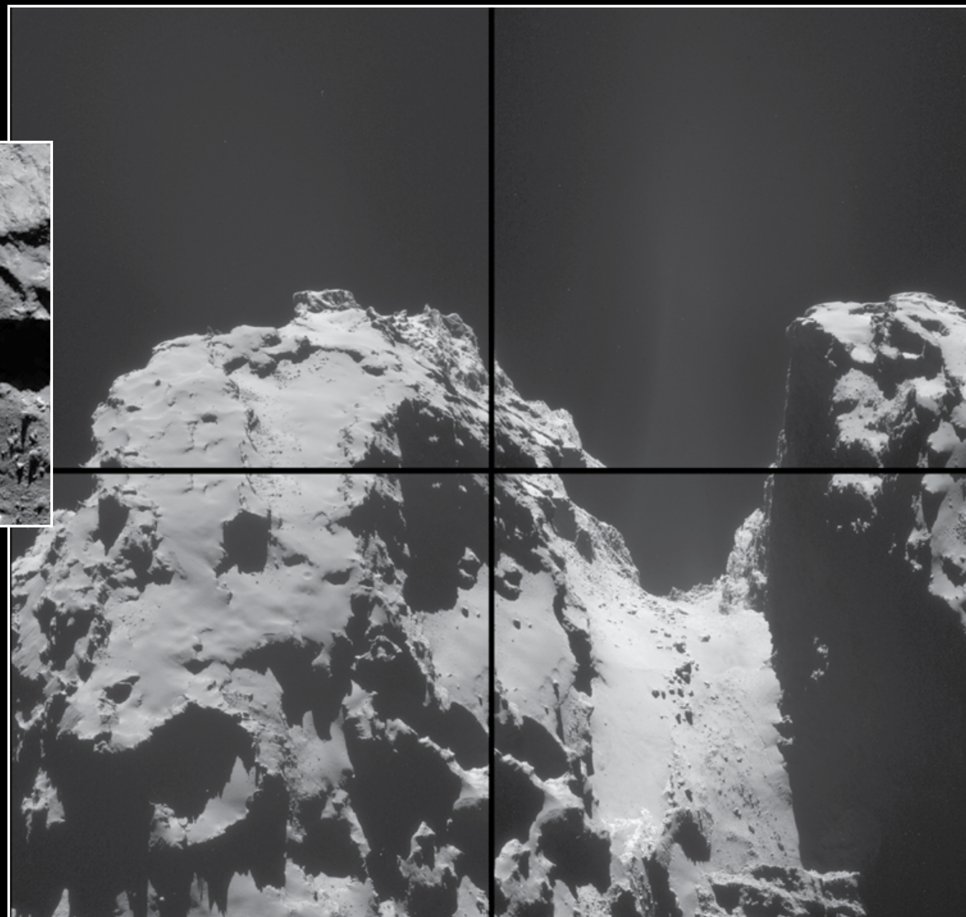
The comet reaches its closest point to the Sun, called perihelion, on Aug. 13, 2015, and the Rosetta mission ends in December 2015, so we will at last be able to see how the comet nucleus outgasses to form a tail. Because perihelion is 30-percent farther from the Sun than Earth's orbit, the comet will not heat up very much, so the flow of vaporized water and other volatiles from the surface will be pretty weak. The comet's



Five candidate sites (from an initial selection of 10 possible sites) were identified for landing of the Philae probe. The approximate locations of the five regions are marked on these OSIRIS narrow-angle camera images taken on 16 August from a distance of about 100 km. Credit: ESA/Rosetta/MPS for OSIRIS Team



Stunning close up detail focusing on a smooth region on the 'base' of the 'body' section of comet 67P/Churyumov-Gerasimenko. The image clearly shows a range of features, including boulders, craters and steep cliffs. Credit: ESA/Rosetta/MPS for OSIRIS Team



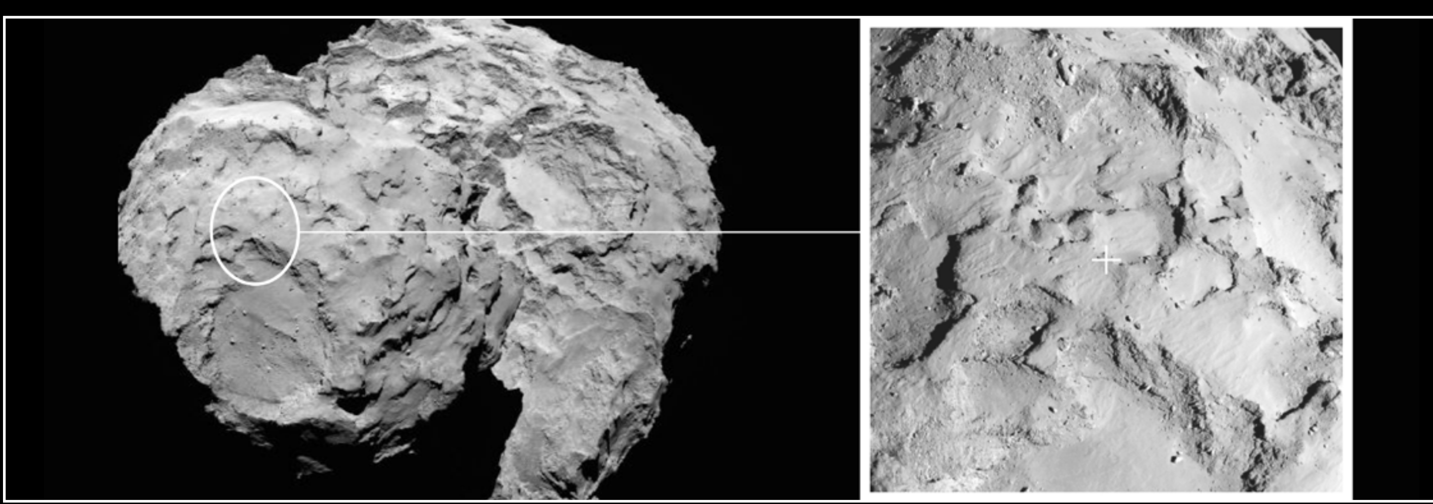
Four-image montage comprising images taken by Rosetta's navigation camera on 2 October from a distance of 19 km from the centre of the comet. Credit: ESA/Rosetta/NAVCAM

diminutive tail will only be visible with a telescope. From the surface, Philae may only see a thin fog as a hint that the process is occurring; hardly the conflagrations you saw in the movies Deep Impact and Armageddon. Still, the instruments on Rosetta and Philae will be able to sniff what comes out to form the tail and search for organic molecules and amino acids frozen for billions of years while the comet has lapped the Sun countless times. Even at its closest point to the Sun, it will be invisible to the naked eye, some 100 times fainter than the faintest star you can see. Even a small telescope will have trouble distinguishing it from the countless other faint stars in the field.

All in all, it will be fun to see what turns up in the Rosetta and Philae images and data from this comet! Astronomy is always full of surprises when you see something at high resolution for the first time.

Landslides on comets...who would have thought?

Dr. Sten Odenwald is an astronomer and educator at the National Institute of Aerospace. He also runs an online resource called The Astronomy Cafe (www.astronomycafe.net).



Site J, the location of the primary landing site for Rosetta's lander Philae, is shown in these two images. Credit: ESA/Rosetta/MPS for OSIRIS Team

The mission

Rosetta is the first mission designed to orbit and land on a comet. It consists of an orbiter, carrying 11 science experiments, and a lander, called 'Philae', carrying 10 additional instruments, for the most detailed study of a comet ever attempted.

Rosetta gets its name from the famous Rosetta stone that led to the deciphering of Egyptian hieroglyphics almost 200 years ago. Similarly, scientists hope that Rosetta will unlock the mysteries of how the Solar System evolved.

Rosetta's launch was originally scheduled for January 2003 on an Ariane-5 rocket. Rosetta's target at that time was Comet 46P/Wirtanen, with the encounter planned for 2011. However, following the failure of the first Ariane ECA rocket, in December 2002, ESA and Arianespace took the joint decision not to launch Rosetta during its January 2003 launch window. This meant that Rosetta's intended mission to Comet 46P/Wirtanen had to be abandoned.

In May 2003, a new target comet and launch date for Rosetta were selected: the spacecraft was launched in March 2004 and arrived at its new target, 67P/Churyumov-Gerasimenko, earlier this year.

Still image from animation of Philae separating from Rosetta and descending to the surface of comet 67P/Churyumov-Gerasimenko in November 2014. Credit: ESA/ATG medialab

Objectives

ESA's comet-chaser will be the first to undertake a lengthy exploration of a comet at close quarters. After entering orbit around Comet 67P/Churyumov-Gerasimenko in 2014, Rosetta will release its Philae small lander onto the icy nucleus.

Rosetta will orbit the comet for about a year as they head towards the Sun. Once they have passed perihelion (closest distance to the Sun), Rosetta will keep orbiting the comet for another half year, while the comet moves back out towards the orbit of Jupiter.

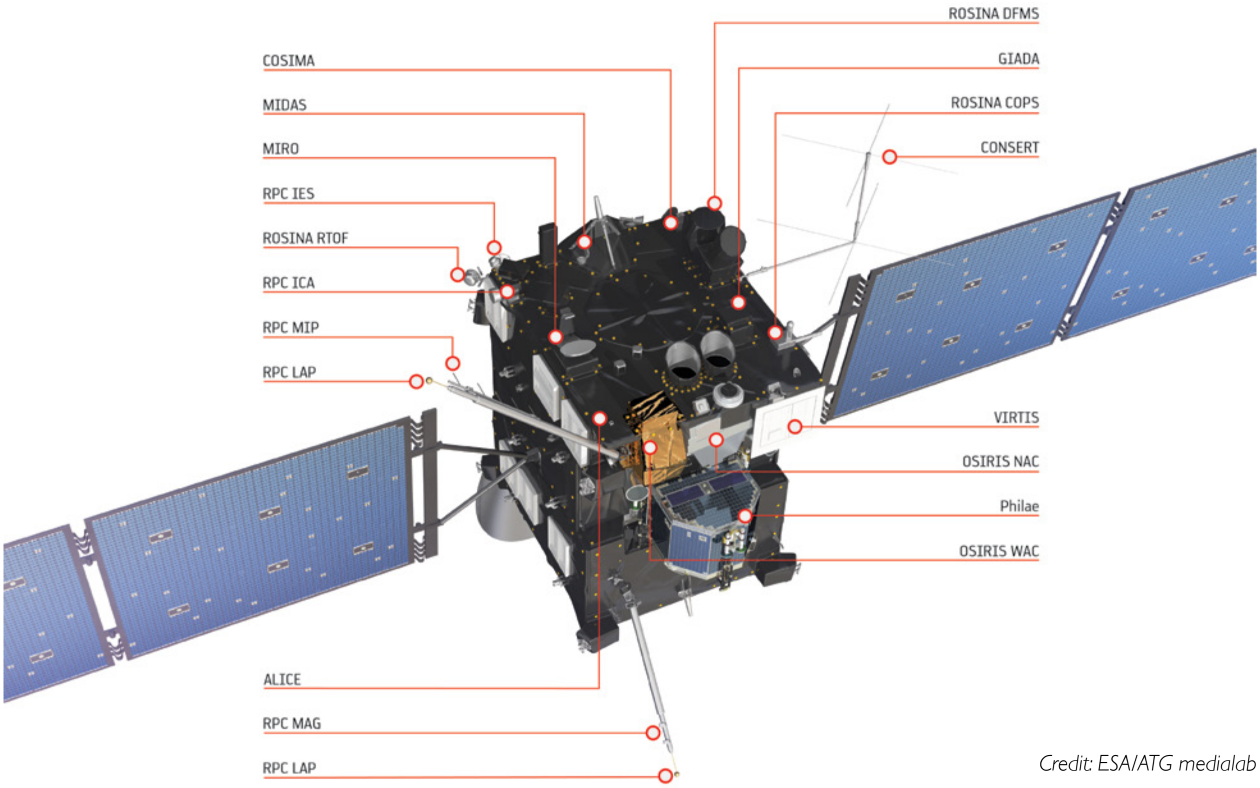
As the most primitive objects in the Solar System, comets carry essential information about our origins. Their chemical compositions have not changed much since their formation, therefore reflecting that of the Solar System when it was very young and still 'unfinished', more than 4600 million years ago. By orbiting Comet 67P/Churyumov-Gerasimenko and landing on it, Rosetta will allow us to reconstruct the history of our own neighbourhood in space.

Rosetta will also help to discover whether comets contributed to the beginnings of life on Earth. Comets are carriers of complex organic molecules, delivered to Earth through impacts, and perhaps played a role in the origin of life. Moreover, volatile light elements carried by comets may also have played an important role in forming Earth's oceans and atmosphere.

During its long journey, Rosetta was scheduled to have two close encounters with asteroids of the main asteroid belt that lies between the orbits of Mars and Jupiter. The first was with (2867) Steins, a rare E-type asteroid. The flyby started on 4 August 2008 with optical navigation of the asteroid itself – a technique never before used in ESA spacecraft operations. The closest approach was on 5 September 2008, 18:58:19 UTC, when (2867) Steins was 2.14 AU from the Sun and 2.41 AU from Earth. The encounter occurred with a relative velocity of 8.62 km/s and reached a minimum distance of 802.6 km. The flyby took place on the Sun side of the asteroid in the plane defined by the relative velocity and the Sun direction. The flyby strategy allowed continuous observations of the asteroid before, during and after closest approach as well as passing through phase angle zero. To keep the asteroid in the field of view of the scientific instruments during the closest approach phase, the spacecraft had to target with an accuracy of better than 2 km and to perform an attitude flip manoeuvre lasting 20 minutes, after which autonomous tracking of the asteroid started.

On 10 July 2010 Rosetta had its second asteroid close encounter, this time with (21) Lutetia, a large asteroid (dimensions: 126 km x 103 km x 95 km – about 10 times bigger than Steins). The flyby was a spectacular success with Rosetta performing faultlessly, passing the asteroid at 15 km/s. The spacecraft had its closest approach at 15:44:57 UTC, at a distance of 3162 km. The cameras and other instruments had been working for hours and in some cases days before and after closest approach providing important new insights about the nature of this heavily cratered asteroid that has suffered many impacts during its 4.5 billion years of existence.

The Rosetta orbiter



Credit: ESA/ATG medialab

Rosetta resembles a large black box. The scientific instruments are mounted on the top of the box (the payload support module), while the subsystems are on the 'base' (bus support module). On one side of the orbiter is the steerable 2.2 m-diameter communications dish, while the lander is attached to the opposite face. Two enormous solar wings extend from the other sides. Both panels can be rotated through ±180°.

The orbiter's scientific payload includes 11 experiments, in addition to the lander. Scientific consortia from institutes across Europe and the United States provided these state-of-the-art instruments.

Ultraviolet Imaging Spectrometer - ALICE will analyse gases in the coma and tail and measure the comet's production rates of water and carbon monoxide and dioxide. It will provide information on the surface composition of the nucleus.

Comet Nucleus Sounding Experiment - CONSERT will probe the comet's interior by studying radio waves reflected and scattered by the nucleus.

Cometary Secondary Ion Mass Analyser - COSIMA will analyse the characteristics of dust grains emitted by the comet, such as their composition and whether they are organic or inorganic.

Grain Impact Analyser and Dust Accumulator – GIADA will measure the number, mass, momentum and velocity distribution of dust grains coming from the cometary nucleus and other directions (deflected by solar radiation pressure).

Micro-Imaging Dust Analysis System - MIDAS will study the dust around the comet. It will provide information on particle population, size, volume and shape.

Microwave Instrument for the Rosetta Orbiter - MIRO will determine the abundances of major gases, the surface outgassing rate and the nucleus subsurface temperature.

Optical, Spectrocopic and Infrared Remote Imaging System - OSIRIS has a wide-angle camera and narrow-angle camera that can obtain high-resolution images of the comet's nucleus.

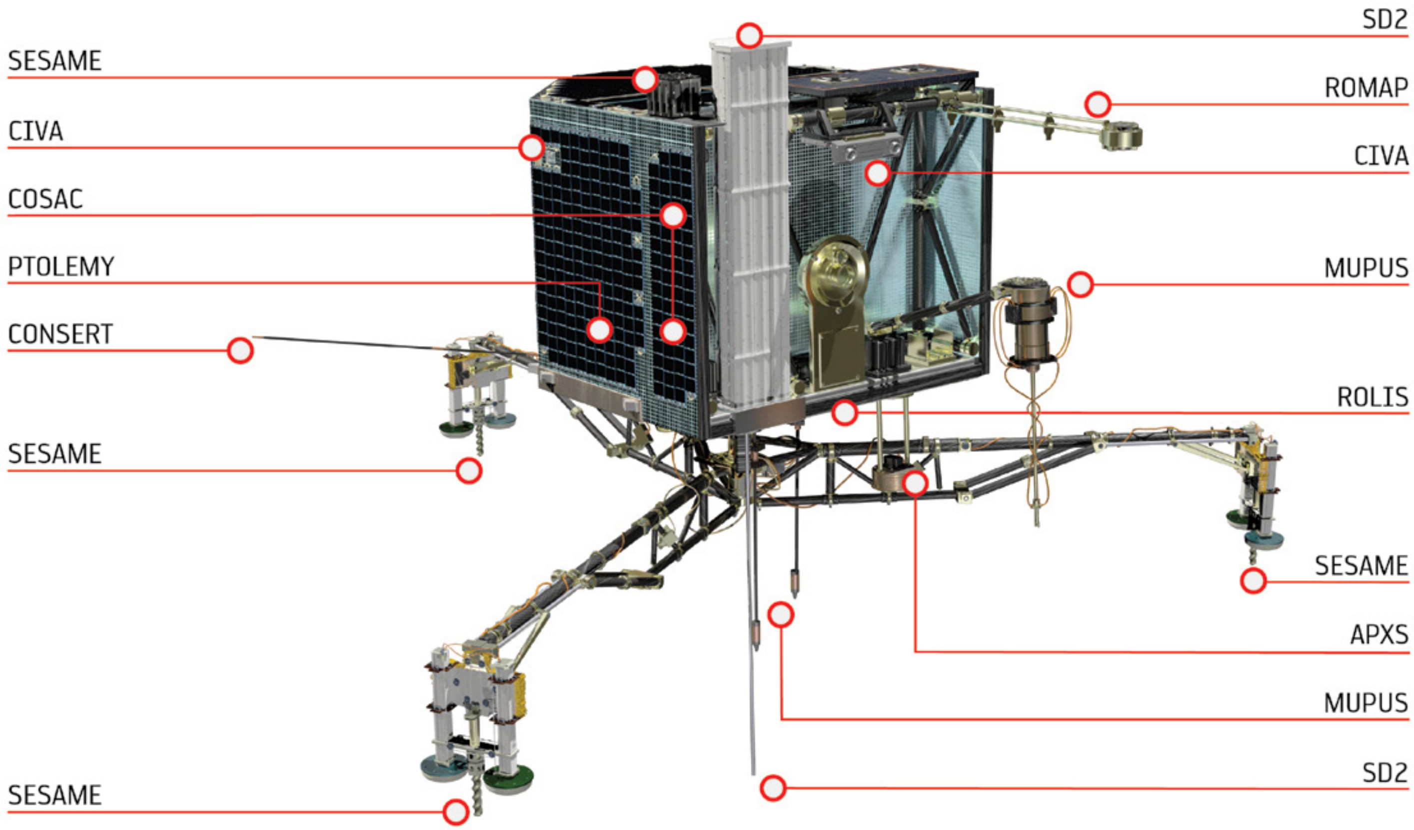
Rosetta Orbiter Spectrometer for Ion and Neutral Analysis - ROSINA will determine the composition of the comet's atmosphere and ionosphere, the velocities of electrified gas particles and reactions in which they take part.

Rosetta Plasma Consortium - RPC will measure the physical properties of the nucleus, examine the structure of the inner coma, monitor cometary activity, and study the comet's interaction with the solar wind.

Radio Science Investigation - RSI will, by using shifts in the spacecraft's radio signals, measure the mass, density and gravity of the nucleus, define the comet's orbit, and study the inner coma.

Visible and Infrared Mapping Spectrometer - VIRTIS will map and study the nature of the solids and the temperature on the surface. It will also identify comet gases, characterise the physical conditions of the coma and help to identify the best landing sites.

The Philae lander



Credit: ESA/ATG medialab

The lander's structure consists of a baseplate, an instrument platform and a polygonal sandwich construction, all made of carbon fibre. Some of the instruments and subsystems are beneath a hood covered by solar cells. An antenna transmits data from the surface to Earth via the orbiter. The lander carries nine experiments, with a total mass of about 21 kg. A drill will sample the subsurface material.

Alpha Proton X-ray Spectrometer - Lowered to within 4 cm of the ground, APXS will detect alpha particles and X-rays to gather information on the elemental composition of the comet's surface.

Rosetta Lander Imaging System - ÇIVA/ROLIS is a CCD camera that will obtain high-resolution images during descent and stereo panoramic images of areas sampled by other instruments. Six identical micro-cameras will take panoramic pictures of the surface. A spectrometer will study the composition, texture and albedo (reflectivity) of samples collected from the surface.

Evolved Gas Analyser - MODULUS PTOLEMY is another evolved gas analyser that will obtain accurate measurements of isotopic ratios of light elements.

Comet Nucleus Sounding - CONSERT will probe the internal structure of the nucleus. Radio waves from CONSERT will travel through the nucleus and will be returned by a transponder on the lander.

Cometary Sampling and Composition experiment - COSAC is one of two 'evolved gas analysers'. It will detect and identify complex organic molecules from their elemental and molecular composition.

Multi-Purpose Sensor for Surface and Subsurface Science - Mupus will use sensors on the lander's anchor, probe and exterior to measure the density, thermal and mechanical properties of the surface.

Rosetta Lander Magnetometer and Plasma Monitor - Romap is a magnetometer and plasma monitor that will study the local magnetic field and the interaction between the comet and the solar wind.

Sample and Distribution Device - SD2 will drill more than 20 cm into the surface, collect samples and deliver them to different ovens or for microscope inspection.

Surface Electrical, Seismic and Acoustic Monitoring Experiments - SESAME's three instruments will measure properties of the comet's outer layers. The Cometary Acoustic Sounding Surface Experiment will measure the way sound travels through the surface. The Permittivity Probe will investigate its electrical characteristics, and the Dust Impact Monitor will measure dust falling back to the surface.

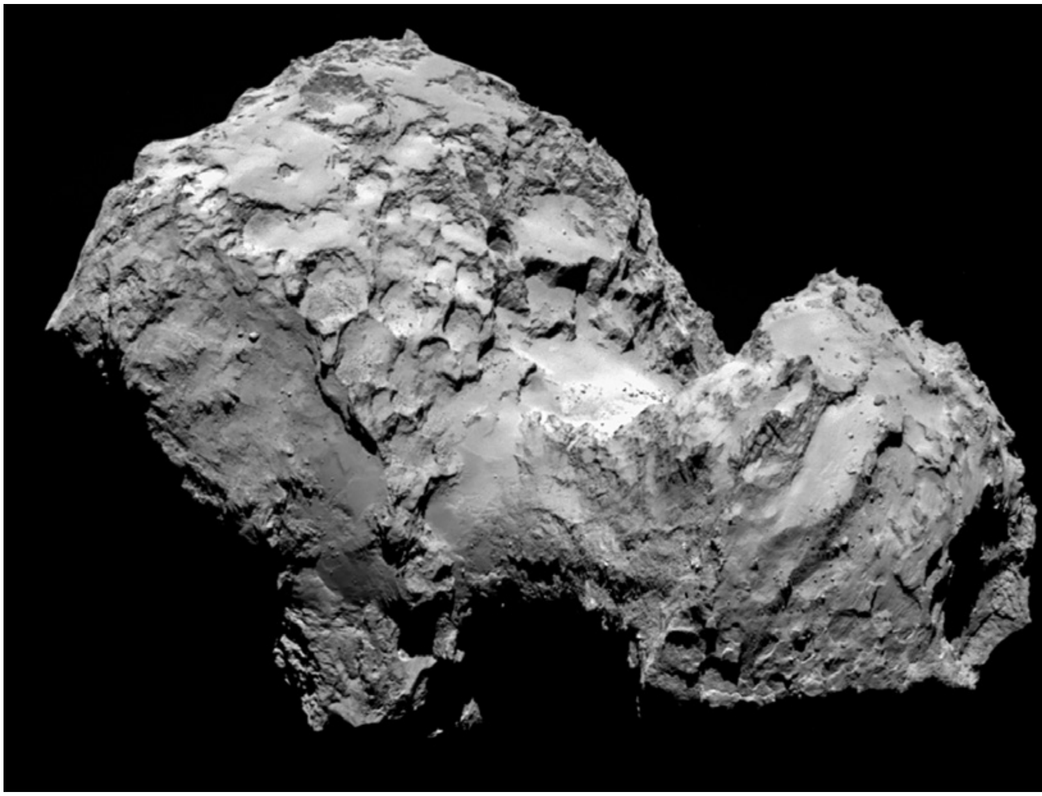
Exploring the surface of a comet

On August 6, 2014 after a decade-long journey chasing its target, ESA's Rosetta has today become the first spacecraft to rendezvous with a comet, opening a new chapter in Solar System exploration. Comet 67P/Churyumov–Gerasimenko and Rosetta now lie 405 million kilometers from Earth, about half way between the orbits of Jupiter and Mars, rushing towards the inner Solar System at nearly 55,000 kilometers per hour.

This image shows the comet close-up from a distance of 283 kilometers. The image has a width of 5 kilometers.

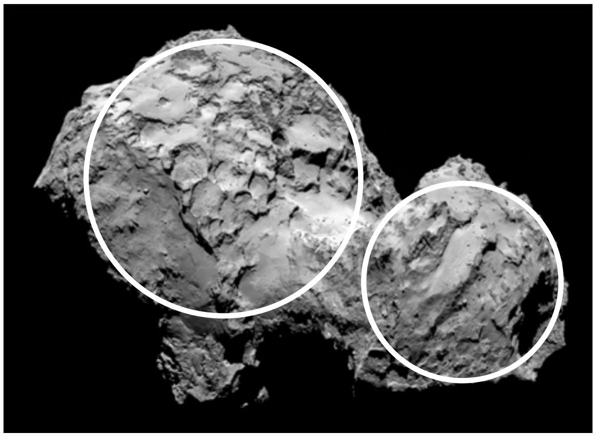
Problem 1 – Approximate the shape of the dumbbell-shaped nucleus as two spheres. What is the total volume of the nucleus in cubic meters?

Problem 2 – If the average density of the material is 300 kg/m^3, about what is the total mass of the nucleus in metric tons?



Credit: ESA/Rosetta/MPS for OSIRIS Team

Answer Key



Problem 1 – Approximate the shape of the dumbbell-shaped nucleus as two spheres. What is the total volume of the nucleus in cubic meters?

Answer: The image shows one way to draw two spheres inside the nucleus to represent the volume. From the scale of the image the larger sphere has a radius of about 1200 meters and the smaller sphere has a radius of about 840 meters. From the volume of a sphere $V = 4/3\ \pi\ R^3$,we have

Large sphere $= 1.3 \times 3.1 \times (1200)^3$
$= 7.0 \times 109$ cubic meters

Small sphere $= 1.3 \times 3.1 \times (840)^3$
$= 2.4 \times 109$ cubic meters.

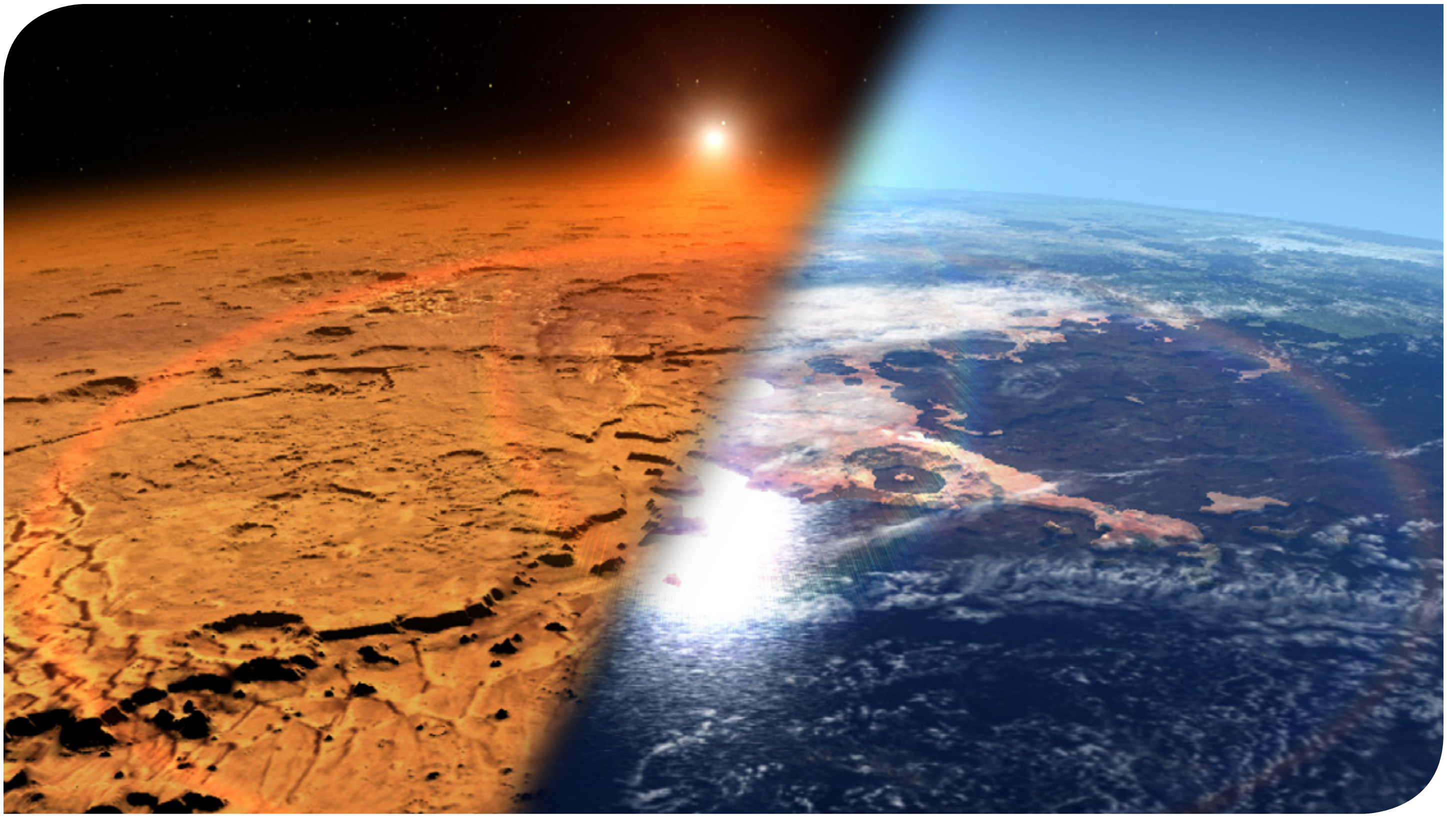
Problem 2 – If the average density of the material is 300 kg/m^3, about what is the total mass of the nucleus in metric tons?

Answer: The total volume is just 7.0 x 109 + 2.4 x 109 = 9.4 x 109 cubic meters.

From Mass = density x volume we then get
$= 300\ kg/m^3 \times 9.4 \times 109\ m^3$
$= 2.8 \times 1012$ kg

Since 1 ton = 1000 kg, the mass is about 2.8 billion tons!

SpaceMath@NASA introduces students to the use of mathematics in today's scientific discoveries. Through press releases and other articles, it explores how many kinds of mathematics skills come together in exploring the universe. Visit http://spacemath.gsfc.nasa.gov to discover hundreds of math problems you can solve on your own.



This artist's concept depicts the early Martian environment (right) – believed to contain liquid water and a thicker atmosphere – versus the cold, dry environment seen at Mars today (left). NASA's Mars Atmosphere and Volatile Evolution is in orbit of the Red Planet to study its upper atmosphere, ionosphere and interactions with the sun and solar wind. Credit: NASA's Goddard Space Flight Center

MAVEN and MOM arrive safely at Mars

By Ken Kremer

Earth's invasion fleet at the Red Planet now stands at a record breaking seven spacecraft following the successful arrival of a new pair of probes from the US and India in late September 2014.

NASA's newest Mars mission, the Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft successfully entered orbit around the Red Planet on Sept. 21, 2014 at 10:24 p.m. EDT, to conduct the first detailed study of the planets tenuous upper atmosphere and unlock mysteries on its habitability. The MAVEN spacecraft completed the crucial Mars Orbit Insertion (MOI) maneuver after firing its six braking thrusters for approximately 34 minutes and 26 seconds.

Space history was made again two days later when India's car sized Mars Orbiter Mission (MOM) successfully fired its braking rockets and arrived in Mars orbit on Sept. 23 EST/Sept. 24 IST on the nation's first attempt to explore the Red Planet. Indeed MOM is India's maiden interplanetary voyager ever.

MAVEN

"You only get one shot at Mars Orbit Insertion and we nailed it," said David Mitchell, MAVEN project manager from NASA's Goddard Space Flight Center, Greenbelt, Maryland, at a post MOI media briefing at the Lockheed Martin operations center in Littleton, Colorado, where the spacecraft was built. "It was about 11 seconds longer than planned. My thanks to all who worked so hard on this project."

"A post MOI assessment indicated we are in a stable capture orbit of approximately 35 hour duration. Five additional burns will reduce that to the planned 4.5 hour science mapping orbit," Mitchell noted.

MAVEN arrived after a trouble free and fantastic 10-month interplanetary voyage of 442 million miles from Earth to the Red Planet.

"As the first orbiter dedicated to studying Mars' upper atmosphere, MAVEN will greatly improve our understanding of the history of the Martian atmosphere, how the climate has changed over time, and how that has influenced the evolution of the surface and the potential habitability of the planet," said NASA Administrator Charles Bolden, in a statement. "It also will better inform a future mission to send humans to the Red Planet in the 2030s."

NASA is currently building the Orion crew spacecraft and SLS rocket to send humans on deep space destinations to Asteroids and Mars.

MAVEN joined an armada of five spacecraft already exploring Mars in great detail but with different science goals.

"NASA has a long history of scientific discovery at Mars and the safe arrival of MAVEN opens another chapter," said John Grunsfeld, astronaut and associate administrator of the NASA Science Mission Directorate at the agency's Headquarters in Washington. "Maven will complement NASA's other Martian robotic explorers—and those of our partners around the globe—to answer some fundamental questions about Mars and life beyond Earth."

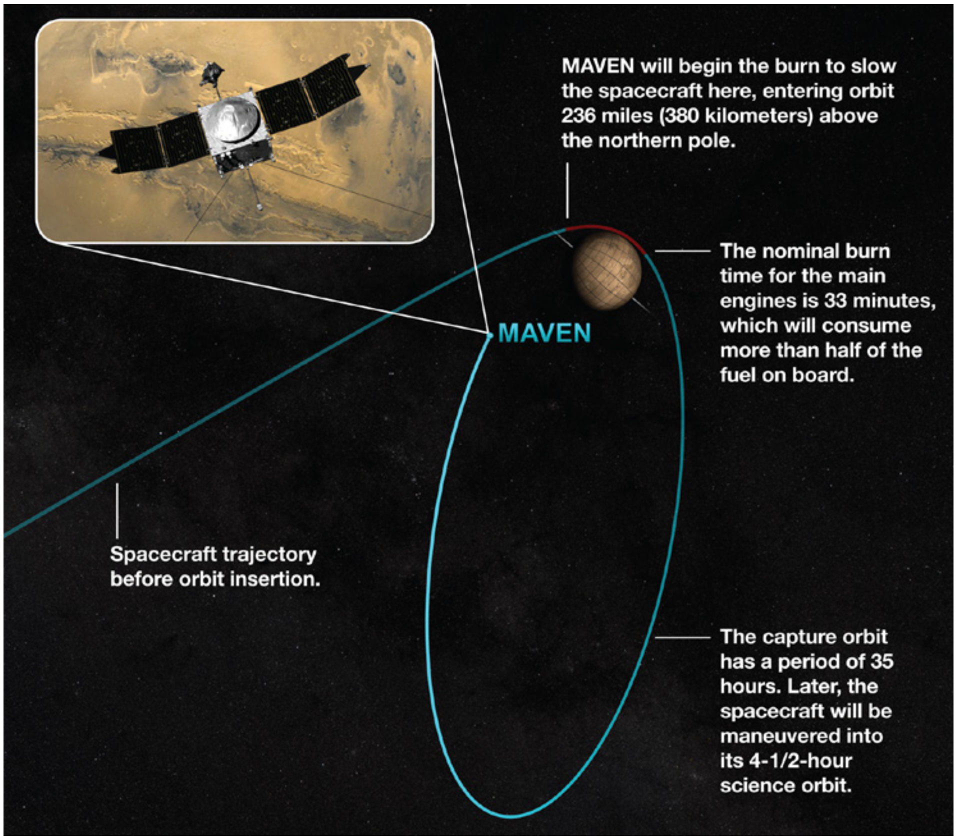
"Stepping back and thinking what this represents it amazing to think about what has been accomplished," Grunsfeld said at the briefing.

"We are now in orbit at Mars after 11 years of hard work," said Bruce Jakosky, MAVEN principal investigator with the Laboratory for Atmospheric and Space Physics at the University of Colorado, Boulder (CU/LASP), gleefully at the briefing.

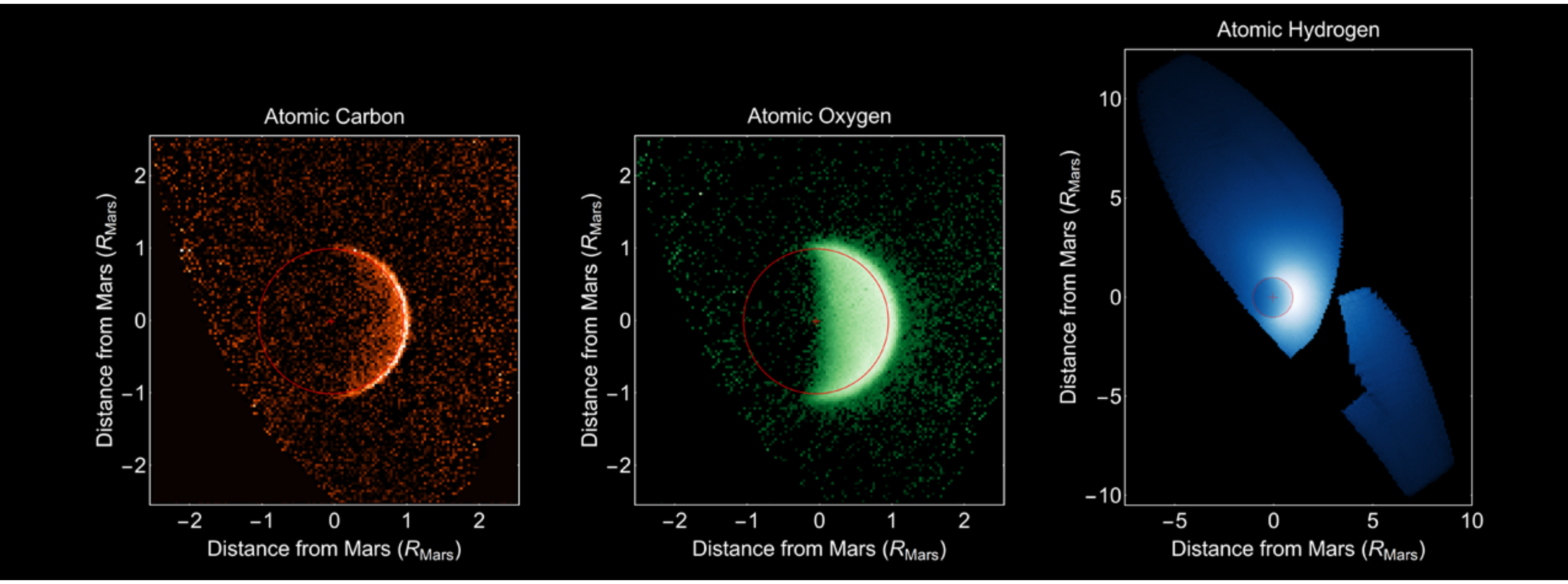
"My heart is about ready to start again. We had an absolutely flawless performance tonight. Over the next six weeks we will do the commissioning work to prepare the spacecraft for its science mission. Four booms need to be deployed and one cap needs to be broken off."

"Early November is the official start of the science mission. But we'll have five days of bonus science with the unexpected flyby of Comet Siding Spring in mid-October."

The primary mission includes five "deep-dip" campaigns, in which MAVEN's periapsis, or lowest orbit altitude, will be lowered from 93 miles (150 kilometers) to about 77 miles (125 kilometers). These measurements will provide information down to where the upper and lower atmospheres meet, giving scientists a full profile of the upper tier.



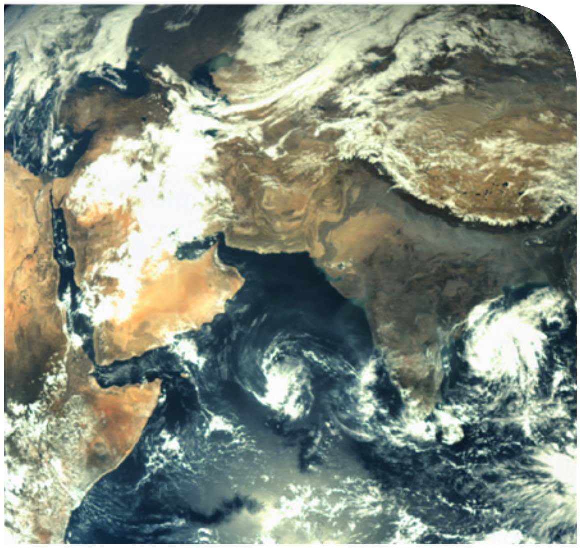
This image shows an artist concept of the trajectory of NASA's MAVEN mission as it approached the Red Planet. MAVEN entered orbit around Mars on Sept. 21, 2014, completing an interplanetary journey of 10 months and 442 million miles (711 million kilometers). Credit: NASA's Goddard Space Flight Center/Univ. of Colorado



This is the first observation received from NASA's Mars Atmosphere and Volatile Evolution (MAVEN) spacecraft and was taken by the Imaging Ultraviolet Spectrograph (IUVS) instrument just 8 hours after achieving orbit on Sept. 21, 2014. Credit: Laboratory for Atmospheric and Space Physics, University of Colorado/NASA

MAVEN will investigate Mars transition from its ancient, water-covered past, to the cold, dry, dusty world that it has become today. It is NASA's first orbiter specifically dedicate to investigate the planets thin upper atmosphere and begin solving the riddles of Mars' climate mysteries, atmospheric and water loss and habitability.

"Where did the water go and where did the carbon dioxide go from the early atmosphere? What were the mechanisms?" notes Jakosky.


First image of the Earth taken by the Mars Orbiter Spacecraft taken on Nov 19, 2013 from 67975 km altitude. Credit: ISRO

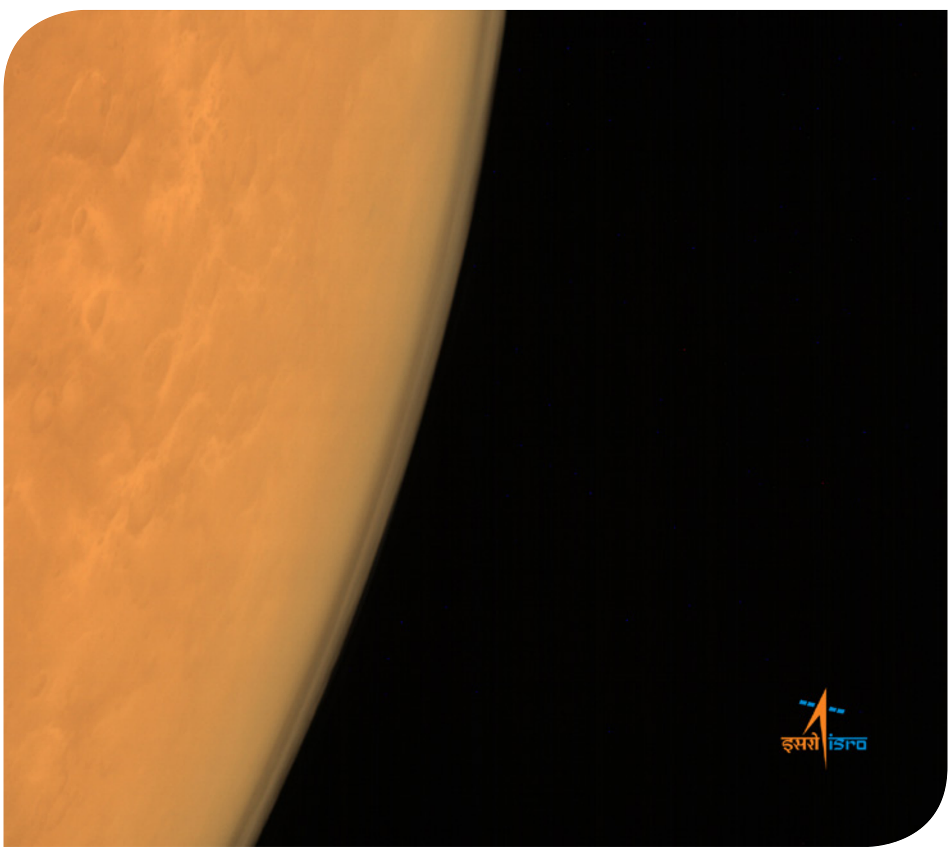
The 5,400 pound MAVEN probe carries nine sensors in three instrument suites to study why and exactly when did Mars undergo the radical climatic transformation.

"I'm really looking forward to getting to Mars and starting our science!" Jakosky told me recently.

MAVEN thundered to space on Nov. 18, 2013 following a flawless blastoff from Cape Canaveral Air Force Station's Space Launch Complex 41 atop a powerful Atlas V rocket and thus began a 10 month interplanetary voyage from Earth to the Red Planet.

MOM

With MOM's orbital insertion at the Red Planet, India joined an elite club of only three other entities who have launched probes that successfully investigated Mars - following the Soviet Union, the United States and the European Space Agency (ESA).


Taken using India's Mars Color Camera from an altitude of 8449 km, this image has a spatial resolution of 439 m and is centered around Lat: 20.01N, Lon:31.54E. Credit: ISRO

Wild applause erupted with beaming smiles from ear to ear at India's Bangalore mission control center after signals confirming a successful full duration firing of the crafts engines for 24 minutes and 13 seconds for the crucial Mars Orbital Insertion (MOI) maneuver that placed MOM into orbit, were received precisely as planned at 10:30 p.m. EDT (Sept. 23) or 8:00 IST (Sept. 24).

Traveling at the speed of light it took nearly 12.5 minutes for the good news signals to arrive on Earth from Mars across the vast expanse of some 140 million miles (225 million kilometers) of interplanetary space.

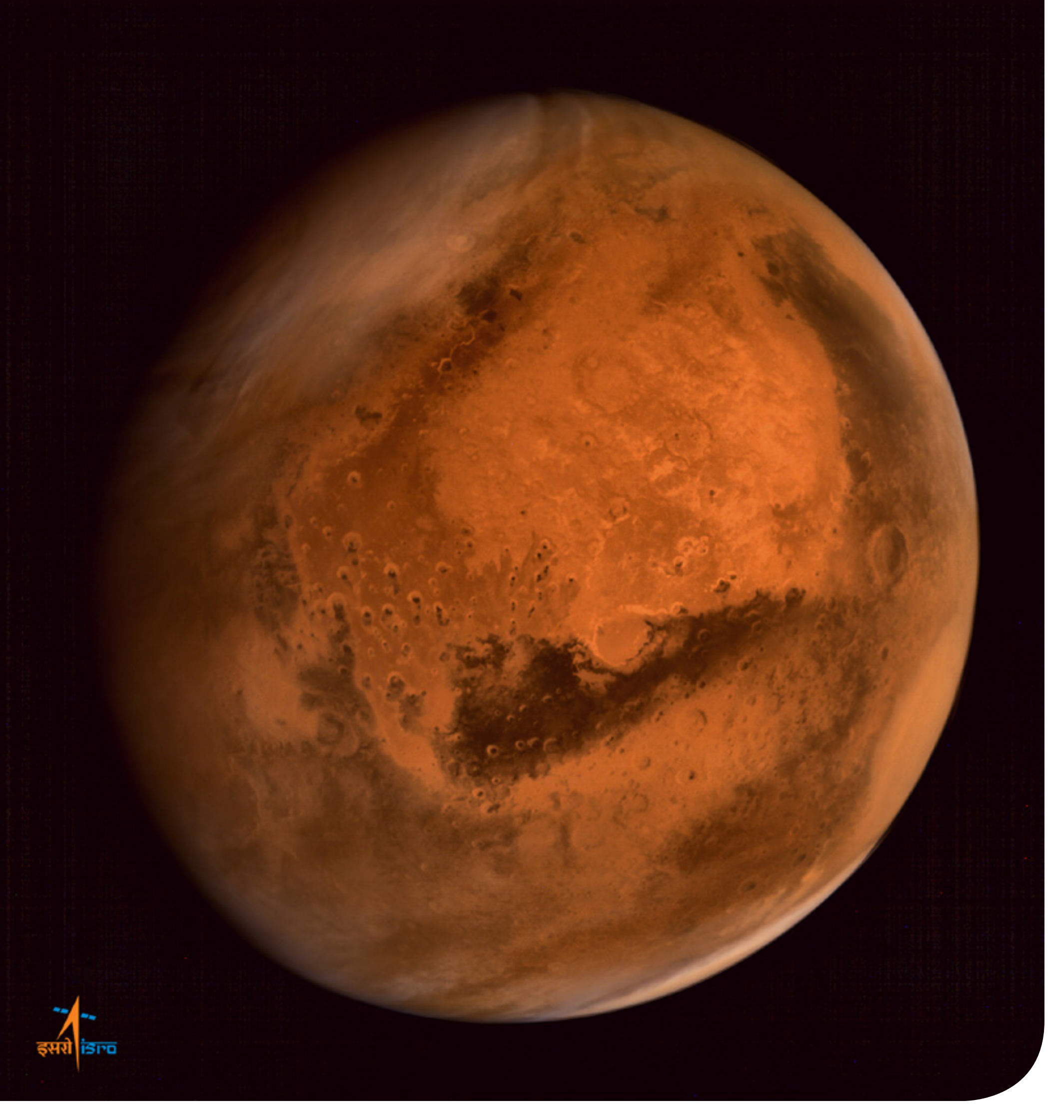
MOM's Red Planet arrival was webcast live worldwide by the Indian Space Research Organization (ISRO), India's space agency which designed and developed the orbiter. ISRO's website also gave a play by play in real time, announcing the results of critical spacecraft actions along the arrival timeline just moments after they became known to the engineers.

The do-or-die MOI breaking maneuver slowed MOM's velocity by 1099 m/s (2457 mph) vs. an expected 1098.7 m/s - using the combined thrust of the 440 Newton Liquid Apogee Motor (LAM) main engine and eight smaller 22 newton liquid fueled engines.

The entire MOI maneuver took place fully autonomously under the spacecrafts preprogrammed sole control due to the long communications lag time and also during a partial communications blackout when the probe was traveling behind Mars and the signal was blocked.

"India has successfully reached Mars!" declared Indian prime minister Narendra Modi, who watched the events unfold from mission control at ISRO's Telemetry, Tracking and Command Network (ISTRAC) in Bangalore.

"History has been created today. We have dared to reach out into the



Regional dust storm activities over northern hemisphere of Mars - captured by the ISRO's Mars Orbiter Mission. The image was taken from an altitude of 74500 km from the surface of Mars. Credit: ISRO

unknown and have achieved the near-impossible. I congratulate all ISRO scientists as well as all my fellow Indians on this historic occasion."

Modi gave a stirring and passionate speech to the team, the nation and a global audience outlining the benefits and importance of India's space program. He implored the team to strive for even greater space exploration challenges, sounding very much like US President John F. Kennedy over 50 years ago!

"We have gone beyond the boundaries of human enterprise and imagination," Modi stated. "We have accurately navigated our spacecraft through a route known to very few. And we have done it from a distance so large that it took even a command signal from Earth to reach it more than it takes sunlight to reach us."

MOM's goal is to study Mars surface features, morphology, mineralogy and the Martian atmosphere with five indigenous scientific instruments. Among other goals it will sniff for methane as a potential marker for biological activity.

"We have prevailed. We have succeeded on our first attempt. We put together the spacecraft in record time, in a mere three years from first studying its feasibility," Modi elaborated.

"These are accomplishments that will go down in history. Innovation by its very nature involves risk. It is a leap into the dark .. . and the unknown. Space is indeed the biggest unknown out there. Through your brilliance and hard work [at ISRO] you have made a habit of accomplishing the impossible."

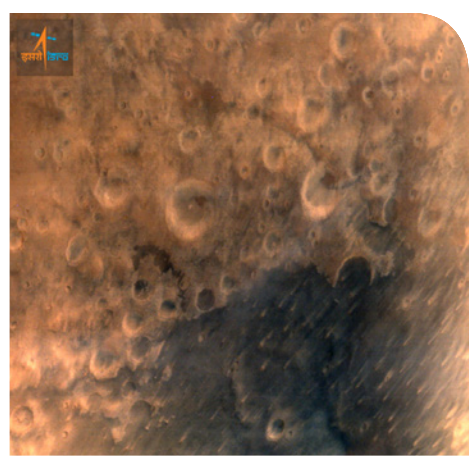
"The success of our space program is a shining symbol of what we are capable of as a nation. Our space program is an example of achievement which inspires us all .. and future generations … to strive for excellence ourselves."

On her over 10 month interplanetary voyage, MOM crossed an interplanetary gulf of some 442 million miles (712 million km) from Earth to the Red Planet. MOM was launched on Nov. 5, 2013 from India's spaceport at the Satish Dhawan Space Centre, Sriharikota, atop the nations indigenous four stage Polar Satellite Launch Vehicle (PSLV).

MOM and MAVEN join Earth's newly fortified armada of seven spacecraft currently operating on Mars surface or in orbit - including Mars Odyssey (MO), Mars Reconnaissance Orbiter (MRO), Mars Express (MEX), Curiosity and Opportunity.

Scientists from MAVEN, Curiosity, Opportunity and all the orbiters will work in concert utilizing all the data to elucidate the history of Mars potential for supporting life - past and present.

Both MAVEN and MOM have already transmitted their first scientific results and images amidst all the work of their commissioning phases, indicating that both probes and all the scientific instruments and healthy and functioning properly. We'll detail their ongoing Red Planet research and close encounter with Comet Siding Spring on Oct 19, 2014, in future issues of RocketSTEM.



Mars Orbiter Spacecraft captures its first image of Mars. Taken from a height of 7300 km; with 376 m spatial resolution. Credit: ISRO

Spaceport America

Three different views of Spaceport America. Credit: Spaceport America

A convergence of ideas and events

By Loretta Hall

The rumble of a rocket engine and then a distant sonic boom break the breezy silence of a remote desert plain. Another unmanned commercial rocket has been launched from Spaceport America. Soon, perhaps in a few months, Virgin Galactic will begin space tourism flights with a futuristic spacecraft air launched from a mothership using Spaceport America's 12,000-foot runway for takeoff and landing.

How did this, the world's first purpose-built commercial spaceport, come to be built in southern New Mexico? It was the continuation of more than seven decades of space development in a geographic setting ideally suited for it.

A fruitful desert

It was Robert Goddard, inventor of the liquid fuel rocket, who first recognized New Mexico's suitability for space research. After his dramatic fourth test launch in his home state of Massachusetts in 1929, the state fire marshal forbade any more launches. Goddard began searching for another location with the best possible features: a large expanse of flat open space, little vegetation to catch on fire, few people who could be frightened or injured during his tests, generally good weather throughout the year, power availability, and access to rail and air transportation. A higher elevation was also desirable for fuel conservation. He consulted with a meteorologist and with aviator Charles

A spectacular New Mexico sunset as backdrop to the Virgin Galactic Gateway to Space terminal. Credit: Spaceport America.

An early morning at Spaceport America with the Virgin Galactic vehicles shown in their hangar bay. The western portion of the terminal and hangar building is earth bermed for energy efficiency and view preservation from El Camino Real historic trail, which passes 3 miles west of the spaceport. A taxiway runs eastward from the terminal and hangar building to the spaceport's 12,000-foot runway. Credit: Mark Greenberg

Lindbergh, who had flown over much of the country.

Finally, Goddard chose the town of Roswell in southeastern New Mexico. He and his assistants moved there in July 1930. His first rocket launch, in December 1930, reached an altitude of 2,000 feet and a speed of 500 miles an hour, far surpassing the 90 feet altitude and 60 mile-an-hour speed he had accomplished in Massachusetts. Working in New Mexico until 1942, he launched the first manmade vehicle to travel faster than the speed of sound and sent a rocket to an altitude of nearly 9,000 feet.

For essentially the same reasons Goddard had selected southern New Mexico for his test site, the US Army established White Sands Proving Ground a hundred miles west of Roswell in 1945. They launched their first atmosphere-testing rocket, the WAC Corporal, at White Sands three months later. Rocket development still continues at the White Sands facility, which was renamed White Sands Missile Range (WSMR) in 1958. Nearly all of the in-flight training for landing space shuttles was conducted at White Sands.

During the 1950s and early 1960s, researchers conducted vital experiments on human tolerance for space travel at Holloman Air Force Base, 50 miles east of White Sands Missile Range. Those experiments examined the effects of cosmic radiation, microgravity, acceleration and deceleration forces, and the physical and psychological effects of confinement in a small capsule in a near-space environment. The chimpanzees launched early in NASA's Mercury program were trained at Holloman.

Ideas for commercializing space

By 1990, southern New Mexico had been involved with space programs for sixty years. It was part of the local culture in Las Cruces, a city twenty miles west of White Sands Missile Range. Burton Lee, whose mother lived in Las Cruces, was a consultant to NASA on the idea of developing an industry to supply commercial reentry capsules for research and commercial use. That program needed a recovery site for the capsules in the United States. Lee talked to a couple of leaders of the Physical Science Laboratory at New Mexico State University in Las Cruces and the director of the WSMR Flight Safety Office about possibly using the missile range for that purpose.

"At the same time, I was pursuing, on my own initiative, this idea of a spaceport," Lee said on The Space Show in December 2006. "I wrote the initial market study, strategic plan, and business plan. I went to Washington to speak with [New Mexico] Senator [Pete] Domenici's staff about what the spaceport could mean for the economic development of southern New Mexico." In 1992, a group of aerospace executives joined him to form the Southwest Regional Spaceport Task Force to explore the viability of an inland commercial spaceport and its potential for economic development.

Meanwhile, in the early 1990s, the US government was pursuing the development of a reusable single-stage-to-orbit launch vehicle. The first prototype, the Delta Clipper Experimental (DC-X) developed by McDonnell Douglas, was flight tested at White Sands Missile Range between 1993 and 1996. After the DC-X test vehicle was disabled on its final test landing, NASA officials decided to pursue a different type of reusable single-stage-to-orbit launch vehicle, VentureStar, developed by Lockheed Martin. That company wanted to test its prototype at a commercial spaceport rather than a government facility. It requested bids for a launch site in 1998.

The New Mexico legislature had created an Office of Space Commercialization in its Department of Economic Development in 1994 to market and promote the state's space-related resources and to coordinate, develop, and manage its regional spaceport program. Its staff wrote a proposal for hosting the VentureStar tests in southern New Mexico.

Fourteen states submitted bids for the VentureStar program, but the project was cancelled in 2001, just before site selection results were to be announced. In January 2002, a Lockheed Martin official told members of the New Mexico Space Commission, "You were number one. Your proposal was head and shoulders above the rest." In response, the New Mexico Office for Space Commercialization's executive director, Hanson Scott, said, "Even though there is no VentureStar program, New Mexico has proven that we have a strong team and other advantages from the point of view of being evaluated by a major aerospace company for a reusable space launch vehicle."

To ensure a safe descent without excessive heating of the spacecraft, SpaceShipTwo's wings will rotate to a 60-degree angle. They will return to horizontal before landing on the Spaceport America runway. Credit: Virgin Galactic

During the 2002 election season, Bill Richardson was campaigning to be governor of New Mexico, and Rick Homans was his deputy campaign manager. "The first that we heard the word spaceport was campaigning in southern New Mexico," Homans said. "We didn't really understand it all too well, but we heard a lot of excitement, support, and enthusiasm about it."

Richardson won the election and appointed Homans the state's Secretary of Economic Development. A delegation from the Southwest Regional Spaceport Task Force visited Homans within weeks after he took office in January 2003. "They laid out this concept of an inland spaceport that would be very useful and workable with the development of reusable launch vehicles and reusable booster systems," Homans said. "They said, in a very visionary kind of way, 'We're not asking you to do anything except to listen and to understand and to wait for the right time. The biggest mistake would be to move forward prematurely. We have to wait for this industry to begin to emerge, and that's when we go forward.'"

Virgin Galactic founder Richard Branson, New Mexico Governor Bill Richardson, and NMSA Chairman Rick Homans appeared at the 2010 dedication of the Spaceport America runway. Credit: Loretta Hall

Commercial space events

They didn't have to wait long. In a few months, a package arrived on Homans' desk. In it was an invitation to bid on being the host site for an annual competition for commercial space vehicles. Competition was already underway for the Ansari X Prize, a $10 million award for development, without government funding, of a three-person reusable suborbital spacecraft. Twenty-six teams were competing for that prize, and at most one would win by the contest deadline of December 31, 2004. Peter Diamandis, organizer of the Ansari X Prize, wanted to encourage contenders to continue developing their concepts after that deadline, so he created the X Prize Cup. It would be an annual event held in the same place every year for commercial space industry competitions and for stimulating public interest.

"As I opened this envelope and laid it out, there were

The three-story terminal and hangar facility, the Virgin Galactic Gateway to Space, seen here from the north, is designed to blend into the landscape. Virgin Galactic customers will enter the Gateway to Space through a walkway in the western portion of the building. Credit: Spaceport America

8-by-10 color glossies of different kinds of technologies from all over the world for reusable launch vehicles [for the Ansari X Prize competition]," Homans said. "And as I had it out there and saw this description of the X Prize Cup, it just hit me that this is what the beginning of a new industry looks like. We realized if we are going to claim the right to help give birth to this new industry, we have to win the right to hold the X Prize Cup."

New Mexico's was one of four proposals submitted for hosting the X Prize Cup. In May 2004, New Mexico was selected over Florida, California, and Oklahoma. "It took many years of environmental studies and technical feasibility safety studies to prove that inland launch would be safe," Lee said. "Those original studies were done for the single-stage-to-orbit [VentureStar] program and laid the technical basis ... to propose to the X Prize Foundation to host the X Prize Cup and to base Spaceport America out of the Las Cruces area."

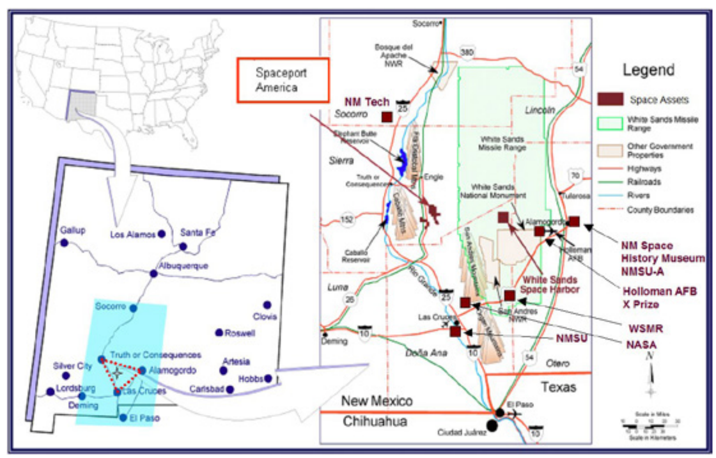
Defining the first competition, raising prize money, and allowing development time for competitors would take time, but Diamandis wanted to start encouraging public interest more quickly. A preliminary event, the Countdown to the X Prize Cup, featured exhibits and demonstrations of existing technologies in October 2005 in Las Cruces. Between 10,000 and 15,000 people attended several events over a four-day period.

NASA signed on as the sponsor of the first X Prize Cup competition. It offered $2 million for two levels of awards in two categories for preliminary development of an unmanned lunar lander. In general terms, the rocket-powered vehicle had to rise to a specified height above a launch pad, travel a specified distance horizontally, and land on another pad after a minimum flight time. The vehicle could then be refueled before repeating the flight and landing back on the original launch pad. Each team had two and a half hours to move their vehicle from a staging area to the launch pad, complete both legs of the flight, and return the vehicle to the staging area.

Four teams signed up, but only one was ready to compete in the first X Prize Cup in October 2006 at the Las Cruces airport. No prizes were awarded, but 15,000 to 20,000 people watched the lunar lander challenge and other events.

The 2007 X Prize Cup was held at Holloman Air Force Base. Again, only one of the teams was ready for competition, and no prize was awarded. The two-day event attracted at least 80,000 people.

Because of funding and scheduling issues, the X Prize Cup event was not held in 2008. However, the lunar lander challenge competition was held at the Las Cruces airport that October. Armadillo Aerospace won the first of the prizes with a successful pair of flights by its Mod vehicle. In 2009, teams were allowed to attempt the lunar lander competition at individual sites of their choosing. Armadillo Aerospace and Masten Space Systems won the remaining three prizes in Texas and California, respectively.



Several areas adjacent to White Sands Missile Range can be evacuated temporarily for flights requiring more space than the actual range. The Western Call-up Area extends to Spaceport America. Credit: Spaceport America

Creating the spaceport

The X Prize Cup might be considered the tipping point for getting New Mexico's spaceport from a vision to a reality. In June 2004, a month after his state was selected for the competition site, Homans went to California to observe the first full test flight of SpaceShipOne, a leading contender for the Ansari X Prize. On that flight, the commercial spacecraft was air-launched from a mothership and flew just above the 62 miles required to win the prize. Two months later, it would fly even higher and repeat the feat in less than two weeks to win the prize. The test flight impressed Homans on both emotional and practical levels. "It did not escape us, the huge significance of this being the beginning of a whole new industry in which New Mexico will play a very big role," he said.

The significance of SpaceShipOne also did not escape Richard Branson, founder of the Virgin family of companies. He established Virgin Galactic, which he envisioned as the world's first commercial spaceline, offering passenger spaceflights as an airline offers commercial airplane flights. He contracted with Burt Rutan, the designer of SpaceShipOne, to expand the concept into a mothership and spaceship (SpaceShipTwo) that could carry a pilot, a copilot, and six space tourists. Homans saw it as another opportunity for New Mexico's space industry. "Just like with the X Prize Cup, we said that it was absolutely essential that we recruit Branson to operate out of New Mexico," he said.

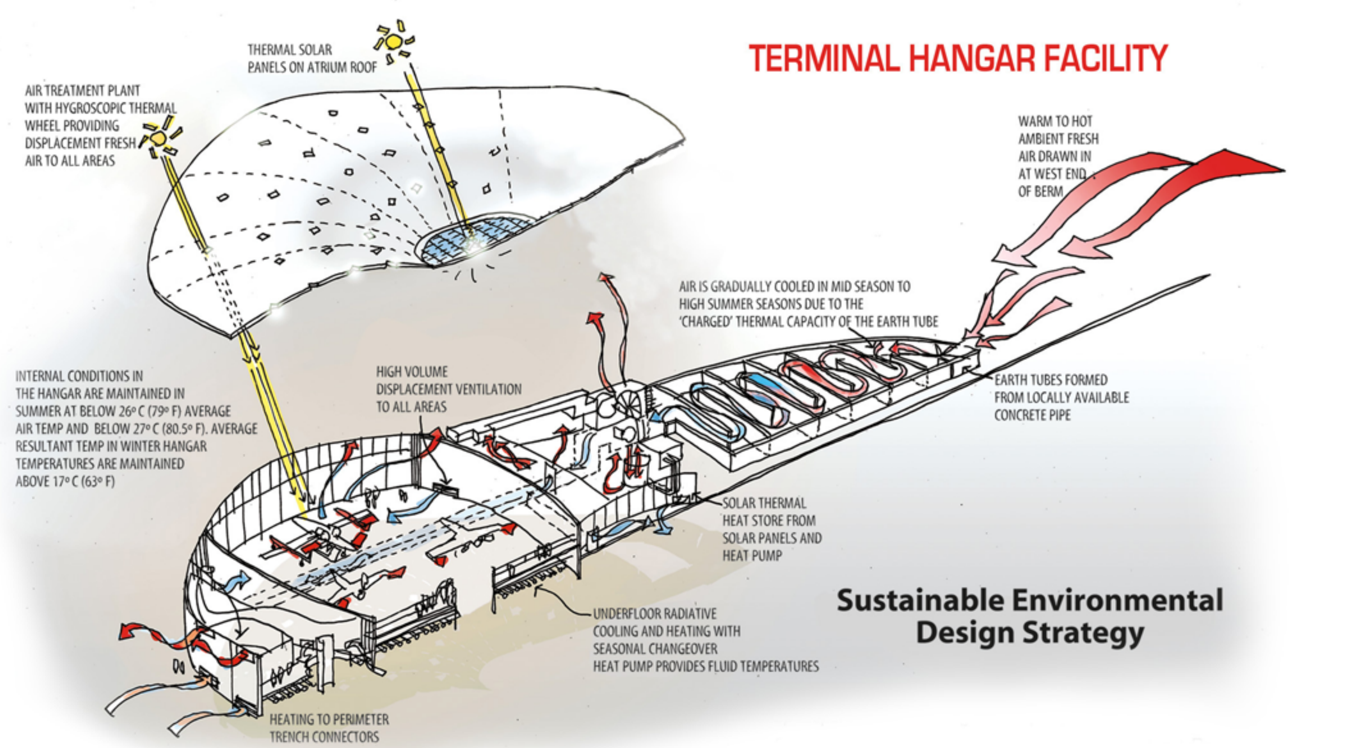
In 2005 New Mexico established the state's Spaceport Authority, with Homans as its first chairman. He and Richard Kestner, the director of the Office of Space Commercialization, flew to London to pitch a new spaceport to Virgin Galactic officials. They were armed with several space tourism polls and economic impact studies. In December 2005, Branson announced that the world headquarters of Virgin Galactic would be established in New Mexico. The following month, he came to Santa Fe to lobby New Mexico legislators. The lawmakers appropriated $110 million toward building the Southwest Regional Spaceport, which was soon renamed Spaceport America. Two counties directly affected by the spaceport's location passed tax increases to provide the rest of the $210 million needed to design and build the facility.

The location chosen for the spaceport is a 28-square-mile parcel 45 miles north of Las Cruces. It is adjacent to the western boundary of White Sands Missile Range, which has restricted air space to unlimited altitudes and offers support with flight tracking and payload recovery.

Spaceport activity

Virgin Galactic signed on as the anchor tenant for Spaceport America, but it would not be the only tenant. In 2006, UP Aerospace began launching unmanned suborbital rockets carrying government research payloads, student experiments, and commercial cargo. At that time, the spaceport's only facilities were a launch pad and three small buildings. By January 2014, UP Aerospace and Armadillo Aerospace had conducted twenty unmanned vertical launches from the spaceport. A larger launch facility is being constructed for use by SpaceX, which signed a three-year agreement to test its Falcon 9R rocket there.

The most visually appealing part of Spaceport America, the Gateway to Space, received a certificate of occupancy in late 2012 and the interior is currently being fitted out by Virgin Galactic. A combination terminal and hangar, the building will house up to two motherships and five spaceships. It will also have lounge and observation spaces for ticket holders and their guests. As of this writing, Richard Branson plans/hopes to be on the first passenger-carrying flight from Spaceport America during the spring of 2015.



The Spaceport America Terminal Hangar Facility was designed to be environmentally friendly. Credit: URS/Foster + Partners.

Gliding a spaceship back to Earth

Vocabulary

- **Altitude:** The distance a spacecraft is above a given point on the ground
- **Distance From Spaceport:** The ground distance from the edge of the runway to the spacecraft
- **Glide Distance:** The distance the Landing Laser measures to the spacecraft
- **Glide Slope (Ø):** The angle a spacecraft makes to the horizontal
- **Landing Laser:** The laser used to determine the line-of-sight distance to a spacecraft

Narrative

Most spacecraft returning from space are always out of propellant. This is because all of the propellant is used up during the trip into space; consequently, there is none available for the trip back.

Wait. What? So how does it land?

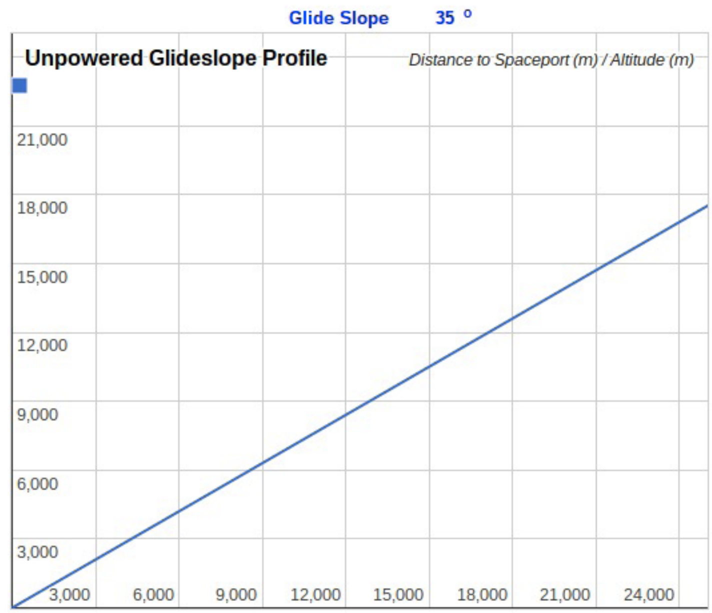
All machines that have wings can glide, that is, fly with the engine(s) turned off. Some glide better than others, but still, they all glide.

The key to gliding in an unpowered spacecraft is speed. The faster the spacecraft flies through the atmosphere, the more efficient the wings. Thus a more efficient glide. Altitude is the other important component, in that altitude allows the spacecraft to build up speed if needed. This is why spacecraft come in with their nose down; they are maintaining their airspeed. As they cross over the edge of the runway, the nose is pulled up and the spacecraft flattens out its glide as air is packed underneath the wings. It's then just a simple matter of letting the spacecraft sink to a gentle touchdown. Once on the ground the nose is kept in the air "wheelie" fashion, so that speed can be bled off without using brakes because they can get very hot very quickly. After the nose comes down on its own, the brakes can then be (sparingly) applied. Eventually, the spacecraft rolls to a full stop. Back home once again!

Analysis

So, at any point in the glide, what was the Altitude and the Distance from the Spaceport of the spacecraft that just landed? Good question! Why, just the other day some high school students at The Learning Community

For a more in-depth treatment of this high school project by Joe Maness & Rich Holtzin visit www.stemfortheclassroom.com.

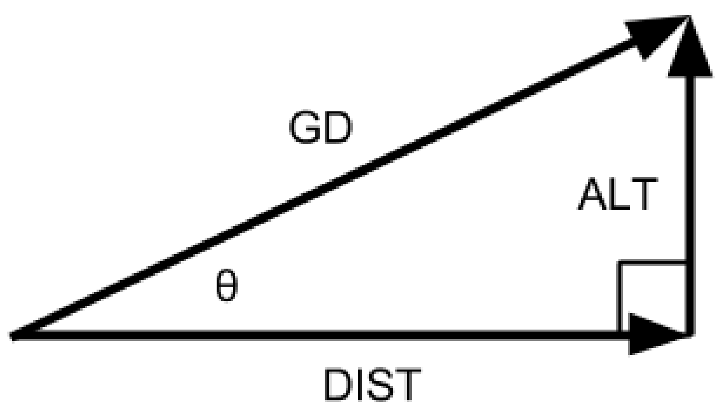


Graph of a spacecraft gliding in for an unpowered glide landing.

Charter School (www.tlcnm.net) were asking the same question.

We need two pieces of information to get started: the Glide Distance (GD) and the Glide Slope (Ø). We will use the Landing Laser to determine this distance and the angle. It will take a "snapshot" of this information whenever we need.

Once we have Glide Distance and Glide Slope, which is to say, once we have a side and an angle, we can form a Right Triangle.



A Pythagorean Triangle showing the relationship between altitude, glide slope(Ø), and the distance from the Spaceport.

Therefore, we can use trigonometric identities to solve for the other two sides. We also see that the Glide Distance becomes the hypotenuse of the right triangle. Moreover, since cosine is defined as the adjacent side

Virgin Galactic's WhiteKnight2 and SpaceShipTwo soar above the runway at the New Mexico Spaceport. Credit: Mark Greenberg

divided by the hypotenuse, and sine is defined as the opposite side divided by the hypotenuse, we can write the two trigonometric equations using this information.

cosØ = DIST / GD
sinØ = ALT / GD

Solving for Distance and Altitude, we get

DIST = GD * cosØ
ALT = GD * sinØ

We can now calculate the altitude and the distance to the Spaceport for our spacecraft.

Note: *we will be using degrees instead of radians to keep things a little simpler. We will, of course, always continue to convert to S.I. units.*

Example

The Landing Laser at this moment in time reads a Glide Slope of 35 degrees with the spacecraft at 15 miles distant. What is the altitude and ground distance from the Spaceport of the returning spacecraft?

We must first convert 15 miles to meters, which comes to about 24,140 m. Therefore,

ALT = 24140 * sin(35) = 13,846 m
DIST = 24140 * cos(35) = 19,774 m

Conclusion

When the spacecraft is about 15 miles distant, it is at an altitude of 13,846 m (8.6 mi) above the ground, and is 19,774 m (12.3 mi) from Spaceport America.

Is there a way that we can make a quick check of our results? Sure there is! Use the Pythagorean Theorem. Leaving the units in miles, we get:

$a^2 + b^2 = c^2$

$(8.6)^2 + (12.3)^2$?= $(15)^2 = 225$

$(73.96) + (151.29) = 225.25$

The result is close enough to 15 squared. We therefore are on track to a safe landing!

S.T.E.M. education...
Don't come home without it.

SpaceShipOne (left) on short final approach after its first flight into space on June 21, 2004.
Credit: Jim Campbell/Aero-News Network

The White Knight turbojet aircraft (above) climbs over the Mojave desert with SpaceShipOne attached below.
Credit: Scaled Composites, LLC

Mike Melvill celebrates atop SpaceShipOne (right) after completion of his first of two trips to outer space aboard the vehicle.
Credit: The Howling Phaedrus (flickr)

Blazing a trail into outer space:

SpaceShipOne and the Ansari X Prize

By Amjad P. Zaidi

"What kind of man would live where there is no daring? I don't believe in taking foolish chances, but nothing can be accomplished without taking any chance at all."

– Charles Lindbergh

October 4th 2014 marks the 57th anniversary of Sputnik 1's launch, the beginning of the Space Age. But ten years before that date another milestone in spaceflight was achieved. On October 4th 2004, the world's first privately developed spacecraft, "SpaceShipOne", rocketed to suborbital space winning the $10 million Ansari X Prize and into history. It was not the first record breaking flight of this pivotal spacecraft, however on that day it proved private spaceflight was achievable at lower cost and could have a fast turnaround. In doing so, SpaceShipOne echoed the Orteig Prize won by Charles Lindbergh in 1927. Lindbergh made the world's first non-stop transatlantic crossing in his plane "The Spirit of St Louis" which boosted today's $746 billion aviation industry. SpaceShipOne's successful flight above 100 km was the second within the 14 day window needed to win the X Prize. Like Lindbergh's flight and the launch of Sputnik 1, SpaceShipOne was the long awaited lift off for the nascent commercial space industry achieving what was once thought to be only possible by governments and nations.

Gathering of visionaries

As with the race to the Moon in the 1960's a convergence of events, conditions and people created the same drive to start the commercial space race. Despite the promise over time of affordable and safe access to space, national space programs have remained at the governmental level with essentially the same launch technology, high costs and risks. These have progressively become less favourable to our increasingly risk averse administrations and the public at large. Occasionally costly accidents pushed back programs for years and took lives. For those aspiring to a future where spaceflight was commonplace, the time had come to seize their own destiny.

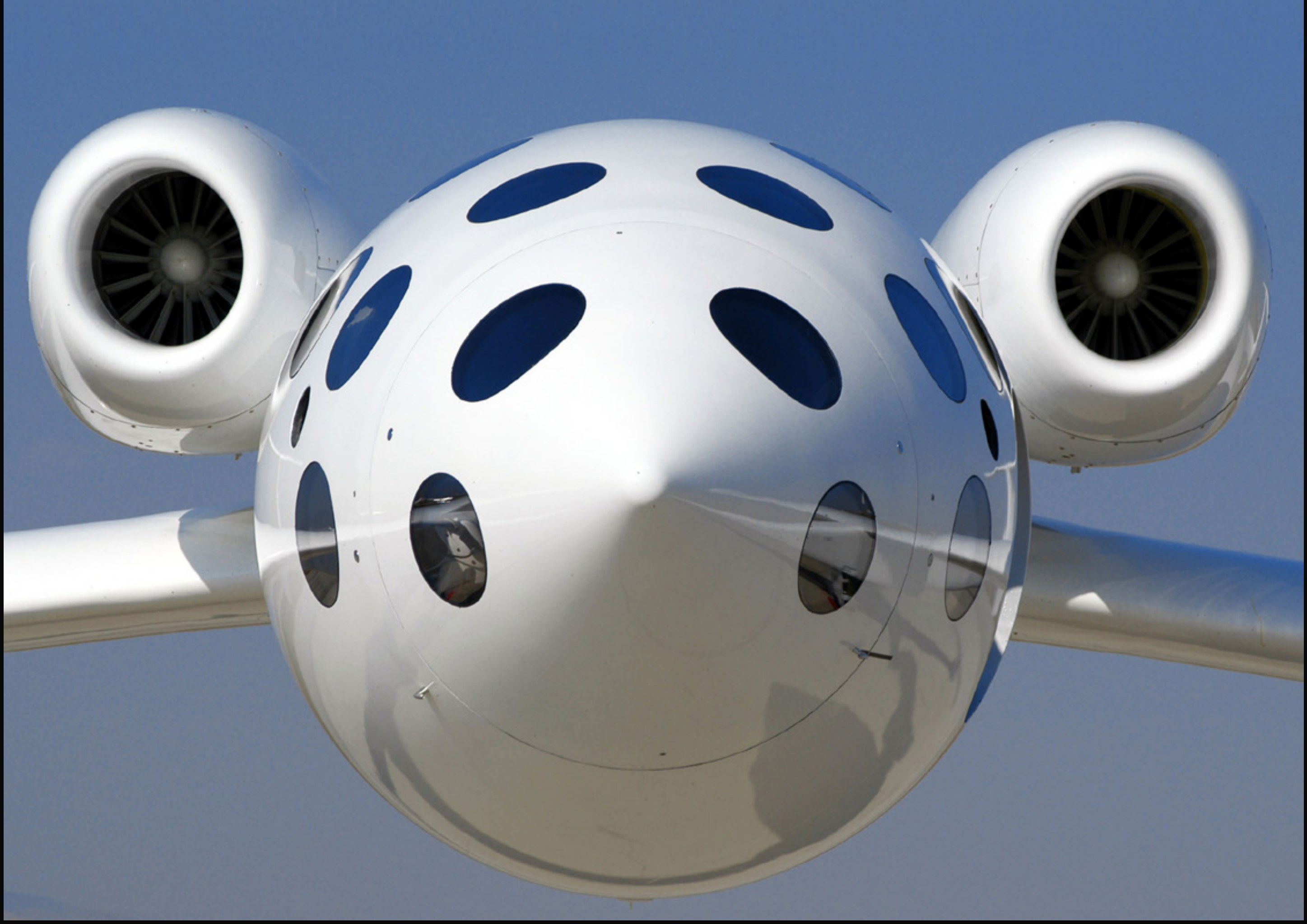
Over three decades visionary plane designer Burt Rutan had created at least one original aircraft a year including some notable firsts, such as the circumnavigatory Voyager. In the 1990s he began setting his sights higher, challenging the established approach of discarding single use expensive chemical rockets and returning to the concept of lifting bodied craft, like the X-15 in the 1960s, as a way to reach space. To that end he directed a secret project, "Tier One" through his small private company Scaled Composites in Mojave. The result was the production of a new twin boom mother-ship "White Knight" (which would be the high altitude carrier craft) and SpaceShipOne, the eventual spacecraft that would launch a new era. However getting these designs off the drawing board required funding.

Microsoft cofounder Paul Allen, met with Rutan to discuss various projects. As both became acquainted with each other, Allen revealed his shared enthusiasm for space exploration and was excited by Rutan's designs for low cost suborbital spacecraft. In 2000, Allen agreed to form Mojave Aerospace Ventures with Rutan and fund their target to reach space.

Paul Allen (left) and Burt Rutan discuss the results after a test flight of SpaceShipOne. Credit: Scaled Composites, LLC

Around the same time, entrepreneur Peter Diamandis, founder of the X Prize Foundation had rediscovered the Orteig Prize as a template for incentivised revolution through competition. Enlisting title sponsor and the first female Iranian civilian astronaut Anousheh Ansari, a cash prize of $10 million was announced in 2002.

A new space race began attracting 26 competitors from seven countries. Scaled Composites had the head start on many of its peers before the Ansari X Prize was even announced, but winning was far from easy. Yet that is exactly what this small company did with two spaceflights within five days. The brainchild of one man, Burt Rutan, coupled with the visionary dreams of Allen,



A head-on view of the unusual-looking White Knight cockpit. Credit: Scaled Composites, LLC

Diamandis and Ansari converged at a point in time. A point where this generation of innovators that grew up during the Apollo era decided to make their dreams of private spaceflight into a reality, rather than wait another 40 years for their national governments to do the same. For Rutan, this achievement brought him closer to the dream of floating weightless in his own black sky.

Simplicity and elegance

Rutan's approach with Scaled Composites was to operate as a small custom build factory. Aerodynamic designs resulted from a mix of computer simulations, flight tests and even mounting aircraft parts on speeding flat-bed trucks to take readings. Commonalities in fabrication methods, materials and designs between White Knight and SpaceShipOne gave synergised simplicity to the creation of both vehicles. However, it was SpaceShipOne's ingenious design that was a crucial foundation to the Tier One project.

The dangers of re-entry to spacecraft were well known, requiring complex systems and high risk manoeuvres to safely traverse the atmospheric threshold. Rutan conceived a "feather" manoeuvre and mechanism which essentially folded the spacecraft in two at its suborbital apogee. This meant SpaceShipOne could stably realign itself and fall vertically back to Earth like a badminton shuttlecock would. Pilots called this a "care free" mode. As drag greatly increased through the rapidly thickening atmosphere, there were much lower structural and thermal stress build ups over a shorter re-entry window. Even at Mach 3.25 SpaceShipOne would not get as hot as a returning spacecraft would from orbit at conventional re-entry angles and super (Mach 20+) speeds.

Upon descending to 70,000 feet, the feather mechanism was retracted and locked. SpaceShipOne was reconfigured as a glider and able to safely land. This distinctive feather capability was unlike any design envisioned for a spacecraft but its elegant simplicity came out of Rutan's need to avoid re-entry tragedies of the past.

"Research should be defined as doing something where half of people will think it's impossible and the other half think maybe it'll work. Whenever there's a true breakthrough you can go back and find a time period when the consensus was that idea was nonsense. What that means is that a true creative researcher has to have confidence in nonsense."

– Burt Rutan

The cockpits of White Knight and SpaceShipOne are configured identically to one another. Credit: Scaled Composites, LLC

Pushing the envelope

Upon winning the Ansari X Prize in 2004, billionaire Richard Branson backed Rutan's winning Tier One vehicles, base-lining his next generation fleet of privately developed space tourism craft on them. Virgin Galactic's "SpaceShipTwo" and "WhiteKnightTwo" would continue to be manufactured by Scaled Composites under "Tier 1b" with Rutan as the Chief Technical Officer.

As with all great engineering endeavours there has been trial and error in the last ten years and Scaled Composites is no exception. New designs for the larger capacity, multi-purpose payload spacecraft and carriers needed maturation and system redundancies. Consequently a larger hybrid rocket engine for SpaceShipTwo was being tested on the ground but on 28th July 2007 a fatal accident occurred injuring others. The passing of employees Eric Blackwell, Todd Ivens and Glen May hit the close knit company and Rutan hard. All production and testing was stopped for a year while investigations into the accident proceeded. Findings of probable contamination led to revised procedures and safety checks for the already safety conscious company. A stark reminder of the past;

"If we die we want people to accept it. We're in a risky business, and we hope that if anything happens to us it will not delay the program. The conquest of space is worth the risk of life"

-Apollo 1 Commander Gus Grissom

Following the accident and investigation, Scaled Composites returned to work on SpaceShipTwo in 2008 with WhiteKnightTwo making its maiden flight later that year. By October 2010, SpaceShipTwo began glide test flights with incremental improvements to the spacecraft, safety, customer flight experience and ground based processes. Retaining the same feathering design lineage of SpaceShipOne, its successor demonstrated this feature in flight in May 2011. Since that time the Scaled Composites team have had three successful rocket powered flight tests of SpaceShipTwo, steadily pushing the envelope to build a safe spacecraft and a compliant, sustainable spaceline for Virgin Galactic.

21st century gold rush

SpaceShipOne's successes not only opened the doors for Virgin Galactic, but also whet the appetites of those eager to claim the high ground in the new commercial race to space. As of 2014, 700 would be astronauts have signed up for a ride on the new SpaceShipTwo paying $250,000. The $50 million America's Space Prize orbital spaceflight competition ran from 2004-10 and the X Prize Foundation has teamed up with Google

Mike Melvill earned his astronaut wings. Credit: Scaled Composites, LLC

SpaceShipOne undergoing preflight inspection. Credit: Scaled Composites, LLC

Mission control during flight 15P. Credit: Scaled Composites, LLC

Peter Diamandis, Paul Allen, Burt Rutan and Brian Binnie celebrate. Credit: Don Logan

to offer the $30 million Lunar X Prize. NASA has also ventured into the incentivised commercial arena with its own Centennial Challenge Prizes since 2005 looking for innovative solutions to technical issues from a wider field. They have recognised the successes in the private space sector and initiated commercial partnership competitions with companies from Blue Origin to SpaceX under the commercial development, crew, cargo and orbital transportation services programs.

Many of the diverse private competitors from the Ansari X Prize are still pursuing their goals to reach space. In 2009 the $2 million Northrop Grumman Lunar Lander X Challenge top prizes were shared among Masten Space Systems and Armadillo Aerospace. Technological and private sector legislative compliance remain as hurdles to be overcome yet the boom in the private spaceflight industry continues to gather pace. Wider potential economic growth is also offered by new private prospecting, research and exploration companies. These have plans to mine off world fuels and resources to release new economies, prosperity, scientific breakthroughs and release the pressure on dwindling natural resources at home.

Days of future passed

As for the legacy of Burt Rutan and SpaceShipOne, the last decade since that historic flight has seen the expansion of technology, investment and customer appetite not just for Virgin Galactic and SpaceShipTwo but for the commercial space sector as a whole. Closer to home many Scaled Composites employees have matured through the ranks of this growing familial company and gone on to greater things. Rutan retired in 2011 but remains as founder and a mentor to other Tier 1b designers. He still maintains goals of a Tier 2 program for orbital projects and a Tier 3 program to reach other bodies in space.

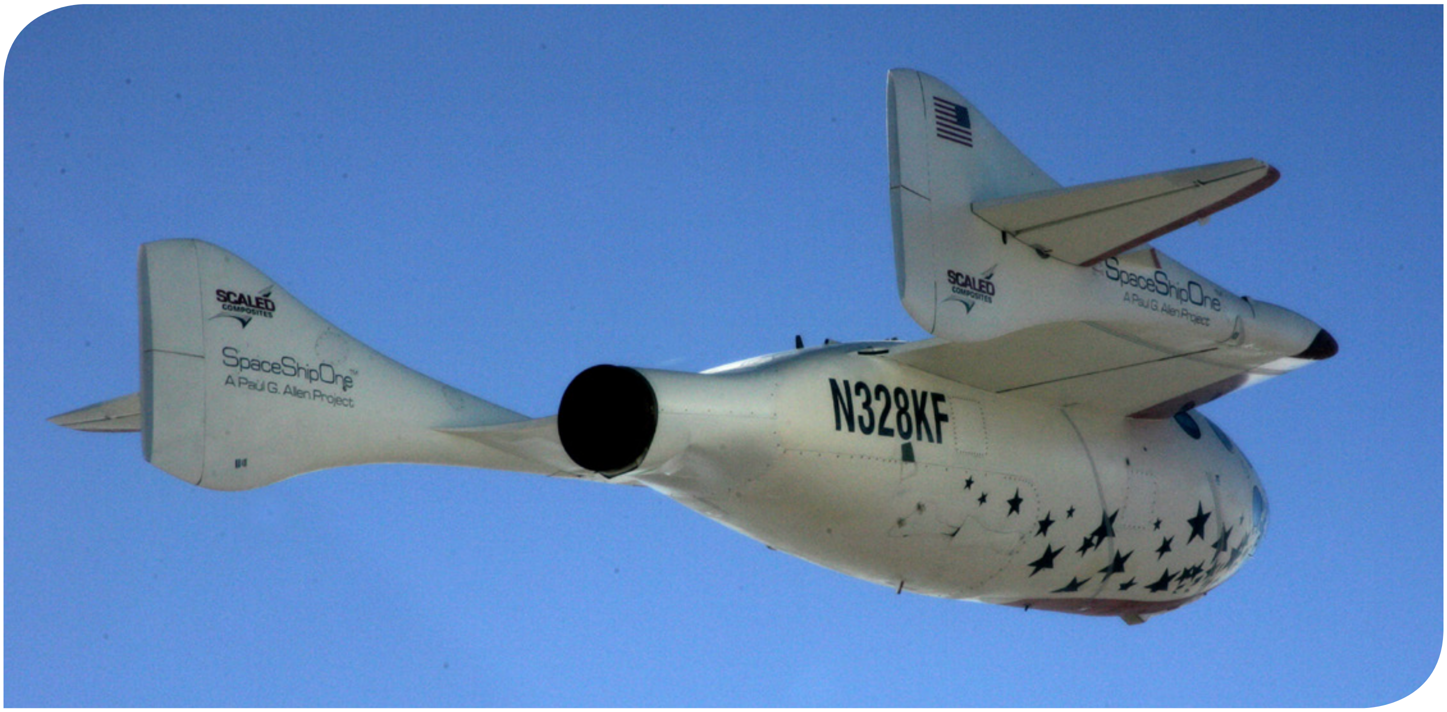
For Rutan, receiving a National Student Design Award in 1964 at an AIAA (American Institute of Aeronautics and Astronautics) meeting led to an encounter with Werner Von Braun which made a lasting impression. He still strongly believes that the current generation needs the courage and excitement to take risks in huge funding and technology development for massive breakthroughs and achievements as happened during the space race. Solving safety concerns and making aerospace investment profitable will be the game changing shift driving true revolution.

The remarkable spacecraft itself now exists in two places. At the Smithsonian's National Air and Space Museum in Washington DC, SpaceShipOne has taken its place alongside the sound barrier breaking Bell X-1 "Glamourous Glennis" and Charles Lindbergh's "Spirit of St Louis". In recognition of Rutan's achievement, the New Horizons spacecraft carries a piece of SpaceShipOne with it to a historic rendezvous with Pluto in July 2015. From suborbital flight to the furthest reaches of our solar system, SpaceShipOne is the little ship that keeps on flying higher. It and Burt Rutan's legacies are secure in the pages of aerospace history.

"I strongly feel that, if we are successful, our program will mark the beginning of a renaissance for manned space flight. This might even be similar to that wonderful time period between 1908 and 1912 when the world went from a total of ten airplane pilots to hundreds of airplane types and thousands of pilots in 39 countries. We need affordable space travel to inspire our youth, to let them know that they can experience their dreams, can set significant goals and be in a position to lead all of us to future progress in exploration, discovery and fun. Thanks to the X PRIZE for the inspiration."

– Burt Rutan, 18th April 2003 Unveiling of the Tier One Program Press Release

* *Please visit our website for the entire list of source material consulted during the writing of this article.*



SpaceShipOne is shown gliding back to the Mojave Airport after a successful flight beyond the edge of space. Credit: Jim Campbell/Aero-News Network

The Chalkboard:
SpaceShipOne curriculum connections

By Christine Nobbe

After reading the article, ask students to respond to questions that require analysis, evaluation, and synthesis. These questions connect to the Common Core State Standards, English Language Arts Reading: Informational Text standards:

How has SpaceShipOne made a difference in space travel? Or has it? Defend your response.

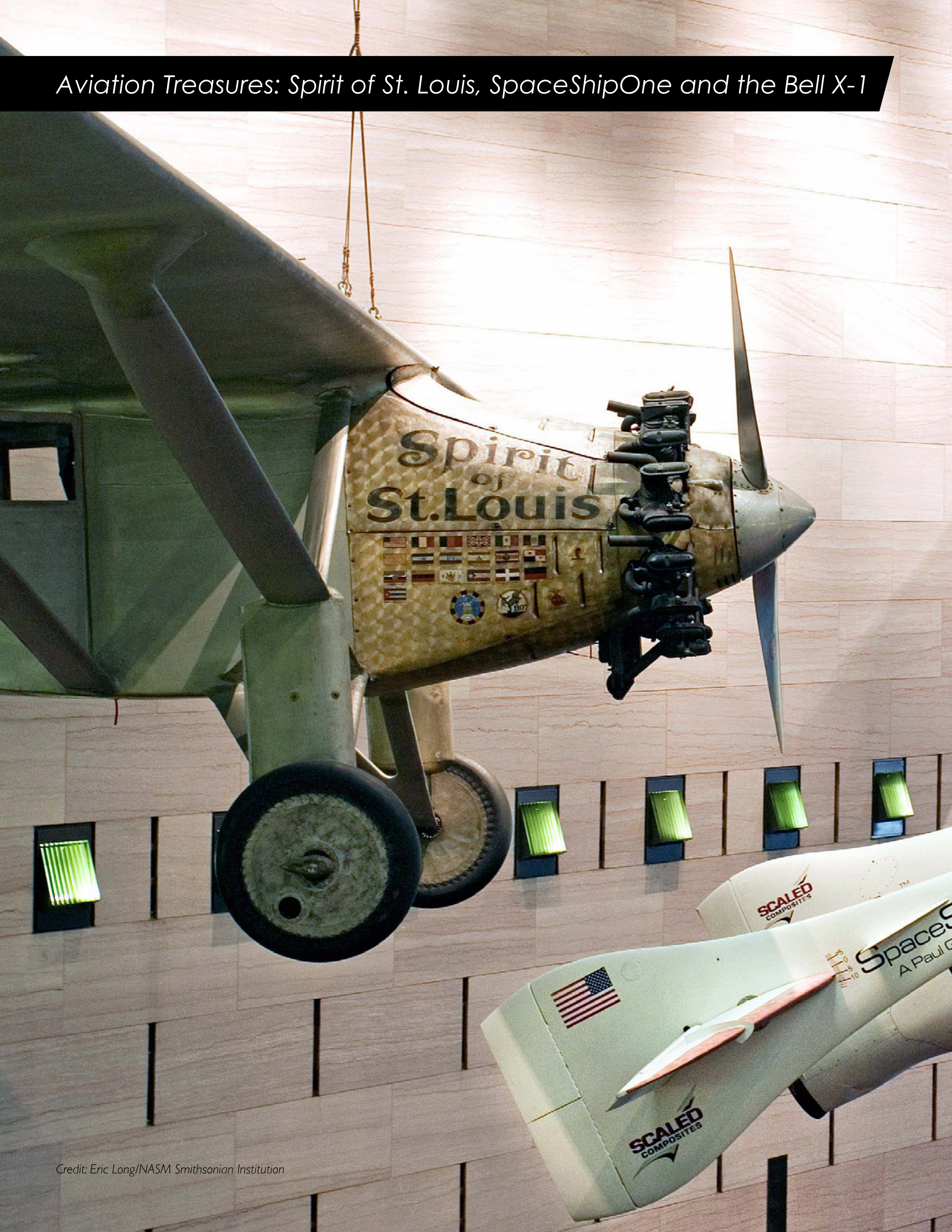
The author concludes, "From suborbital flight to the farthest reaches of our solar system, SpaceShipOne is a little ship that keeps on flying higher. It and Burt Rutan's legacies are secure in the pages of aerospace history." Do you agree with the author that the legacies are secure in the pages of aerospace history? Why or why not? Use information from the article to defend your answer.

Study the gatewaytospace.org St. Louis and Space webpage to learn more about the importance of Charles Lindbergh and X Prize. (See: http://gatewaytospace.org/st-louis-and-space/) After reading both articles, decide which aerospace events are the most historic and important. Use information from the articles to defend your ideas.

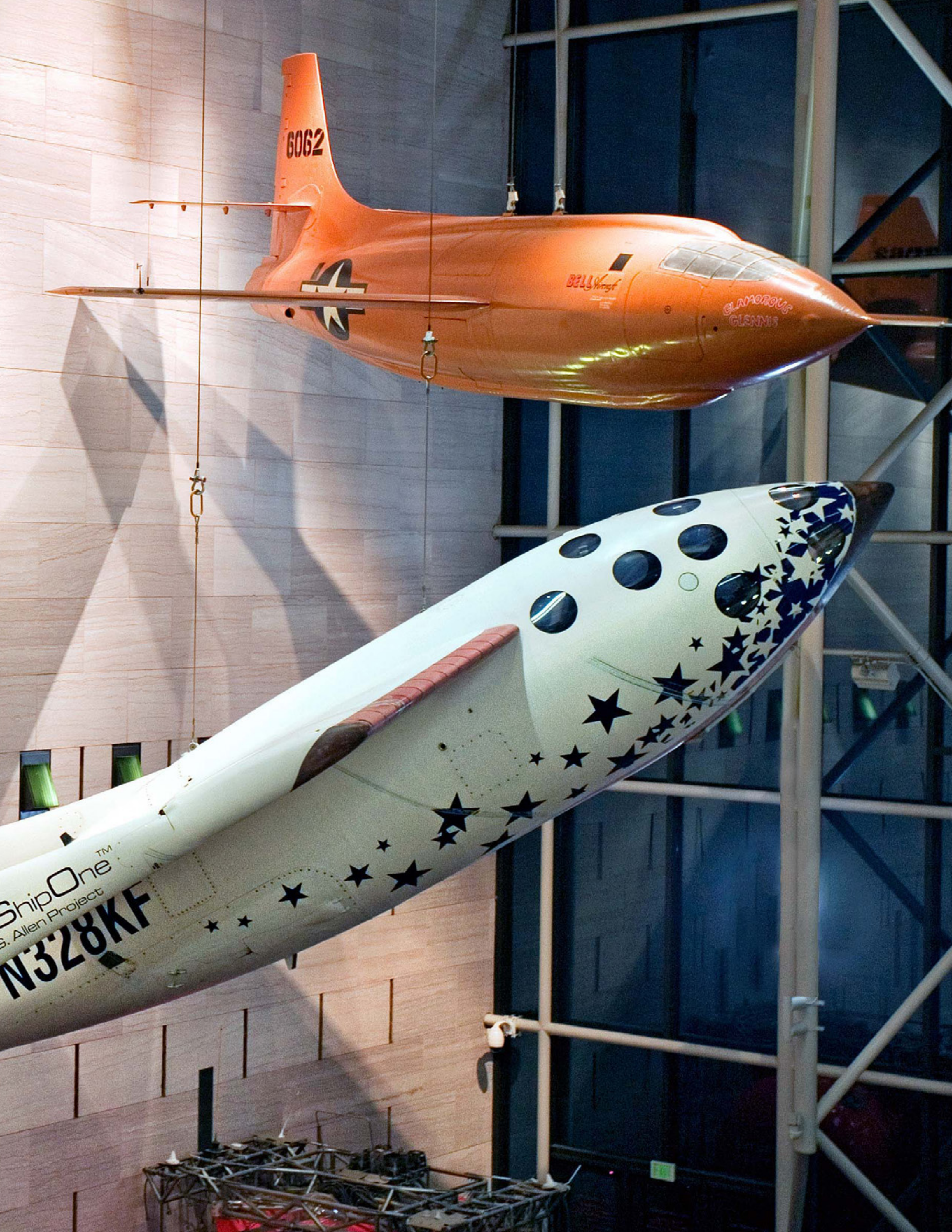
In addition to reading the texts for analysis, students can make a timeline of major events in the article using an online timeline maker (i.e. teach-nology.com).

The study of biographies and the writing of biographies and personal narratives) are important. Many famous people are mentioned in the SpaceShipOne retrospective and the Space and St. Louis webpage. Ask students to choose one famous person, research the person, and write a brief biography. One interesting variation is the six-word biography. See www.sixwordmemoirs.com for further information.

Aviation Treasures: Spirit of St. Louis, SpaceShipOne and the Bell X-1



Credit: Eric Long/NASM Smithsonian Institution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Apollo 17 astronaut Gene Cernan reflects on a life well lived in a new documentary film. Credit: Mark Stewart Productions

A look at 'The Last Man on the Moon'

By Amjad P. Zaidi

The Time: 19.30 GMT
Wednesday, June 4th 2014.

The Place: London's
Science Museum.

Silence and darkness is broken by the Houston skyline. At a livestock auction a white haired cowboy appraises the cattle stock before settling into a stadium seat at a Houston Rodeo Show. One by one the rodeo riders enter the stadium, holding on for dear life to stop being thrown by their bulls. The picture slows to a dream-like state. A rodeo rider moves in concert with his bull in slow motion. The white haired cowboy gazes on the scene, his mind's eye wandering over a lifetime of memories so long ago. Decades before he rode machines holding on for dear life, spinning around and experiencing untold g-forces but was never thrown off…

And so begins the documentary "The Last Man on the Moon". This is a new film produced by UK based Mark Stewart Productions and directed by Mark Craig describing the life of Gene Cernan. Between 1969 and 1972 twelve Apollo astronauts walked on the Moon; Gene Cernan was the last of them. This special preview screening at London's Science Museum celebrated those involved in producing and backing this remarkable film and the life of its subject, Gene Cernan.

Based on the biography of the same name written by Don Davis with Cernan's input, "The Last Man on the Moon" has a warm and simple narrative, putting the lives of people ahead of the technology and politics of the Space Race. In a very real sense this is storytelling in a traditional and relatable sense without the pretentiousness of some modern day productions.

The film looks upon Cernan's life as it is now with a mirror on the past. Settled and happy in his life as a rancher he is living a peaceful existence in the present, but occasionally his eyes wanders up to our constant companion in the night sky as he allows himself brief moments of reflection and memory. As he himself describes, the speed of thought transports him back to the surface of the Moon. After the noise and stress of landing the aftermath is the most peaceful, still and ultimately most quiet moment of his life. His life now echoes that pure serenity and the technical simplicity of his childhood growing up on his grandparents' farm. While he still flies and has a pilot's licence, he has achieved a balance, perhaps the best of both worlds.

Using newly found archival footage, Mark Craig's film weaves together a story; the history of Cernan's early days, growing up in a blue collar family during World War II and developing a fascination with planes and his life as a young naval aviator.

Memories and revisits. These are constant companions on the journey of this film sitting on the viewer's shoulders as Cernan visits San Diego's USS Midway recalling another earlier home, on the USS Shangri-La, one of his first postings. An air of invincibility and competitiveness pervades his earlier life as he jokes around with an old pilot buddy Fred “Baldy” Baldwin, but they both recognised the risks they took. As seen later on in the film, the constant danger of naval aviation was recognised by other Apollo astronauts who also rose up the aviator ranks with Cernan.

Although the film is largely told from Cernan’s point of view, other dramatis personae from his life play a large role in this tale. Naturally, key personnel from the Apollo era add to the recollections of that time, but somewhat differently to other retrospective NASA documentaries, people from Cernan’s personal life also have input giving a very fresh perspective. His first wife Barbara Butler candidly relates their early courtship and married life with daughter Tracy. Ordinary people’s lives take starring roles against the backdrop of the early Mercury and Gemini Program pioneers and JFK’s startlingly confident and ambitious “Moon” speech.

A stylised 60’s vignette gives a light hearted interpretation of Cernan receiving the call to become an astronaut and the subsequent testing. Both Cernan and Butler describe the constant media attention and pressure to achieve as an astronaut selectee. The toll of these pressures on family life is also telling throughout the film.

Cernan’s own spaceflight beginnings had a traumatic extended spacewalk. Expertly blending stock footage from Gemini 9 and CGI recreations, the viewer is placed into Cernan’s shoes experiencing his problems, an unsettling memory.

The closeness of the NASA astronauts and families during this era is shown as he takes us on a journey down memory lane looking back over the 50 year history of the small community of NASA families in Nassau Bay, Houston. The families’ support of each other is still evident as the devastating losses of Gemini 9’s prime crew and the crew of Apollo 1 are still keenly felt. The pain is still etched in Cernan’s face as if he lost his friends yesterday.

Apollo 17, the final landing on the Moon was the ultimate destination and moment of reckoning on his life’s trajectory. The film makers ably remind the viewers of the sacrifices made and the shoulders stood upon for these successes to be achieved.

As Cernan toiled in the surreal peacefulness of the Moon’s surface, Craig’s film highlights the introspection Cernan felt then, as he does now about this exceptional experience and the overview effect that happened to him. His need to communicate this profound awareness for the sake of those that would follow and those he has followed is clearly felt as an obligation and this film helps to support that message. Since that time, Cernan has sought to recapture that apex and gone on to great heights as a public speaker.

While his peers, family and friends have slowed down in their later years, he has pushed on out of a drive to relate his experiences, to communicate the importance of space exploration, STEM education and personal excellence but at some cost to himself.

Gene Kranz and Gene Cernan filming in Mission Control Houston. Credit: Mark Stewart Productions

Centering on the life of Gene Cernan, the film is not only a reminder of where we have gone, but also a source of inspiration for where we've yet to journey. Credit: Mark Stewart Productions

"You have to have a passion and a love for what you are doing, otherwise you shouldn't be doing it."
- Gene Cernan

Only now, in his 80's does Cernan entertain the notion of slowing down as he steps into his grandfather and family man role. Time with friends and family is as important as communicating his message. It seems like Cernan's experience is a life well lived and spent, yet with an eye on the future he wonders how future generations will appraise his life and that of his fellow astronauts who went to the Moon.

Speaking with director Mark Craig after the screening, he related his experiences during the making of this film. The lead time to build relationships and connections behind this documentary were key to its success. It took seven years from his first meeting with Gene Cernan to finishing the making of this film.

Recognising that the central theme is the story not the man, Craig was able to convince Cernan that this was a story that needed to be told so that the next generation of children know what they can do based on what Cernan accomplished in his lifetime. It is a testament to Craig's skill as a director that his original vision from seven years ago has not changed. The finished product has not detoured from this central theme.

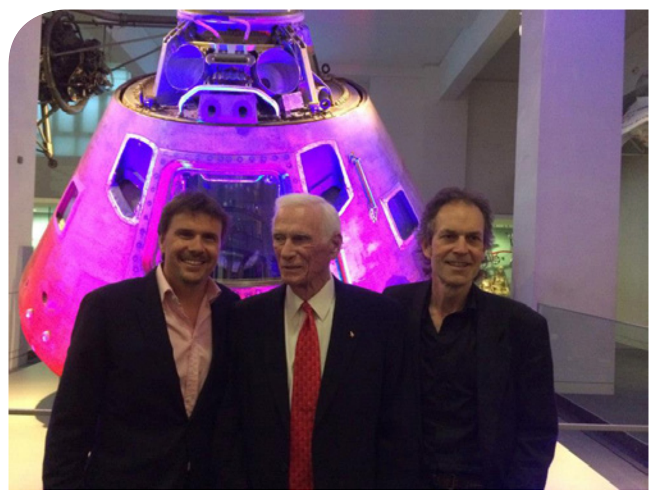
This documentary has surpassed its high ambitions and judging by the warm reception received by audiences so far, it is cutting across viewer demographics and gaining much acclaim from critics. Lorne Balfe's wistful soundtrack whispers across the screen like audio tumbleweeds as the camera lingers on NASA history of years gone by. Penny Holton's restricted but masterful computer generated visual effects also lend enhanced authenticity and truth to the space visuals on screen. Presented in the IMAX format at London's Science Museum, the film held up very well and was faultless in its presentation.

Self-belief, tenacity, professionalism, verisimilitude and a "right first time" approach are the hallmarks behind this production, which are also mirrored in Cernan's life. All of these qualities were later recognised by Cernan as he related how impressed he was with this film, which is a fitting legacy.

Craig's connection to the film and this event is a very personal one, as he remembers a childhood visit to see the Apollo 10 Command Module at London's Science Museum with his late father. To be working with and documenting the life of one of the men who flew in that spacecraft is an honour.

Producer Mark Stewart also reflected on the making of this film and recognising its unique story. A huge team effort, from the unseen archival footage, to the backing of investors and the space community, he also singled out his father, legendary racing driver Sir Jackie Stewart for his support in completing the film and telling this distinctive story.

As the curtain came down on this special preview screening, Gene Cernan stepped up to a standing ovation and was moved by the



L-R Executive Producer Mark Stewart, Gene Cernan and Director Mark Craig stand in front of Cernan's Apollo 10 Command Module "Charlie Brown" at London's Science Museum. Credit: Mark Stewart Productions

At the time of going to press, "The Last Man on the Moon" has received preview screenings in the UK and official release dates will be forthcoming. Stay tuned to the below links for further updates.

• The Last Man on The Moon: http://thelastmanonthemoon.com/

• Join their Mailing List: info@ms-productions.com

• Mark Stewart Productions: http://markstewartproductions.com/

• Facebook Page: https://www.facebook.com/thelastmanonthemoon

• Twitter: @LastManOnMoon

reception received. He reminded everyone in the audience that this is a story that counts for all. Those who voyaged to the Moon were the tip of the arrow; the strength behind the bow in meeting Kennedy's challenge was almost half a million people committed to do what most people thought wasn't possible and couldn't be done.

With steadfast belief he stated that we will return to the Moon and go on to Mars. And that this generation's children and grandchildren all over the world will take us back (to the Moon). We have one responsibility, to give them this opportunity.

His one wish is for this film to inspire those children to dream. As he speaks to his own grandchildren and many around the world his universal message resonates with everyone;

"Don't ever count yourself out. You'll never know how good you are until you try. Dream the impossible, go out and make it happen. I walked on the Moon. What can't you do?"

- Gene Cernan

Gene Cernan exploring Taurus Littrow on the Moon. Credit: NASA/Jack Schmitt

Artist's rendering of the Orion capsule as it separates from the Service Module during its upcoming test flight. Credit: NASA

Orion's December flight test critical for deep space human exploration plans

By Mike Killian

This December, after years of hard work from a team spanning across the United States, NASA will put America's future deep-space human exploration spacecraft to the test, flying it further than any human-rated spacecraft has been in over 40 years. The highly anticipated mission, known as Exploration Flight Test-1 (or EFT-1), will put the agency's unmanned Orion capsule into action to validate the spacecraft's design, with the data collected being used to further perfect Orion's capabilities before NASA puts astronauts onboard for deep-space crewed missions starting early next decade.

The upcoming 4.5 hour orbital flight test is currently scheduled to launch from Cape Canaveral Air Force Station in Fla. shortly after 8:00 a.m. EDT on December 4, thundering skyward atop one of the largest and most powerful launch vehicles in history; the mammoth United Launch Alliance (ULA) Delta-IV Heavy rocket. After its first orbit (two hours after liftoff) Orion will perform a burn to reach an altitude of more than 3,600 miles—15 times higher than the orbit of the International Space Station and 10 times higher than any human-rated spacecraft has been since 1972, when the crew of Apollo 17 visited the Moon.

Doing so will give engineers the opportunity to evaluate Orion's performance in a way only a real spaceflight can; computer simulations, scale model tests, and ground testing only goes so far. While NASA's iconic Space Shuttles carried out missions in low-Earth orbit, Orion is intended to fly astronauts on deep space missions, and so Orion will hit Earth's atmosphere on reentry much faster, and harder, than the Space Shuttle did.

The Shuttles hit the atmosphere on reentry at around 17,000 mph; when Orion returns on the EFT-1 mission it will hit the atmosphere at 20,000 mph, bringing hotter reentry temperatures of up to 4,000 degrees Fahrenheit to go with its faster velocity, simulating a return from a deep space mission and giving engineers the opportunity to evaluate its launch and high speed re-entry systems, avionics, attitude control, parachutes, computers, software, guidance and control, the separation events, and the performance of Orion's critical heat shield.

All of Orion's avionics components were installed earlier this summer, and engineers with Lockheed Martin (Orion's prime contractor) have completed functional testing on the crew module's 59 systems—methodically powering them up one by one. Performance testing, where all of the systems work together to operate Orion as a whole, was completed last spring prior to installation of the capsule's state-of-the-art ablative heat shield, which is outfitted with over 200 instrumentation sensors to provide engineers with data about the heat shield's ability to protect Orion.

A titanium skeleton and carbon-fiber skin gives the heat shield its shape, and will provide structural support during landing.

A fiberglass-phenolic honeycomb structure is installed on the skin, which holds 320,000 cells filled with Avcoat—a specific ablative heat shield material that will wear away as it heats up during Orion's violent 4-mile-per-second re-entry through Earth's atmosphere. The Avcoat will prevent heat from being transferred to the rest of the capsule, thus helping the spacecraft to survive its intense fall and splashdown in the Pacific Ocean.

One of the lesser known tests for the upcoming EFT-1 flight will demonstrate Orion's ability to operate after sustaining damage from a micrometeoroid hit, a very real threat to crews on any future deep space missions. Two of Orion's 970 protective space shuttle thermal tiles, which make up the space capsule's cone-shaped back shell, have holes in them to mimic damage from a micrometeoroid hit. Sensors on the vehicle will record how high temperatures climb inside the holes during Orion's return, which will inform future decisions about what kind of damage may warrant a repair in space when Orion flies humans next decade.

Currently, the spacecraft is inside the Launch Abort System Facility (LASF) at KSC, where the last piece of its flight hardware was recently installed, the emergency launch abort system (LAS). Orion is already fueled with ammonia and hyper-propellants for its EFT-1 mission as well, and will be transported to nearby Cape Canaveral Air Force Station Space Launch Complex 37B for stacking atop its Delta-IV Heavy rocket around Nov. 10.

The enormous ULA Delta-IV Heavy rocket Orion will leave Earth on is now vertical on the launch pad too, having moved there from its nearby Horizontal Integration Facility just a couple weeks ago after ULA's Delta launch team finished conducting the final horizontal processing of the triple-core booster.

The rocket's upper stage, which will fire after the initial launch to send Orion farther into space than any human spacecraft has gone in four decades, arrived at the Florida launch site by barge last May, along with the spacecraft adapter and 133-foot-long port booster. The two other common core boosters, each powered by a liquid-fueled RS-68 engine capable of producing over 660,000 pounds of thrust, arrived in Florida last March. When the rocket finally ignites its three RS-68 engines will throttle up to over two million pounds of total thrust to send Orion off on its important flight test.

Now that the rocket is at the pad ULA' Delta launch team is conducting extensive launch vehicle readiness testing, which will be followed by fueling the Delta-IV Heavy with liquid Hydrogen and liquid Oxygen to perform a Wet Dress Rehearsal, which is basically a practice countdown without actually firing the engines. Shortly after Wet Dress Rehearsal, Orion will be stacked on top of the Delta IV Heavy Launch vehicle, and a few weeks later will launch.

Orion's EFT-1 mission is very high profile, as it will pave the way for sending humans on the kind of deep-space missions that inspired so many during the glory days of NASA's Apollo program, which landed 12 men on the moon between 1969 and 1972. Orion is being designed to be reusable for up to 10 flights, capable of carrying four to six astronauts on missions to destinations deeper into space than any human spaceflight mission has ever been.

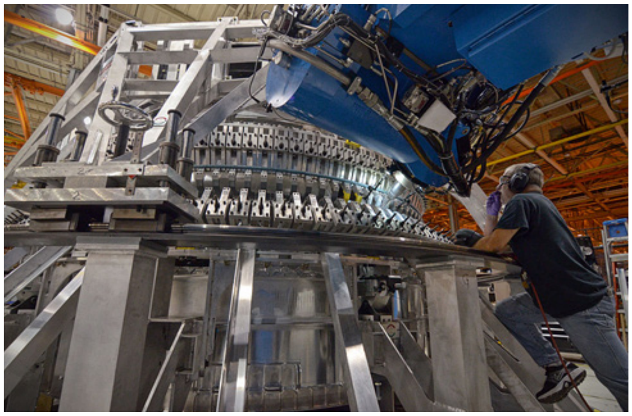
After the EFT-1 test flight, Orion will be put through its first integrated launch in 2018 on the first flight of NASA's Space Launch System (SLS) heavy-lift rocket, the largest and most powerful launch vehicle in history. The mission, Exploration Mission 1 (EM-1), will put the entire integrated system into action, sending Orion more than 40,000 miles beyond the Moon to a deep retrograde orbit where an asteroid could be relocated as early as 2021. The eventual goal, however, is landing humans on Mars, and Orion's EFT-1 mission will lay the foundation for a mission to Mars to become a reality by the 2030's.

Artist's rendering of the Orion capsule during its fiery ballistic reentry. Credit: NASA

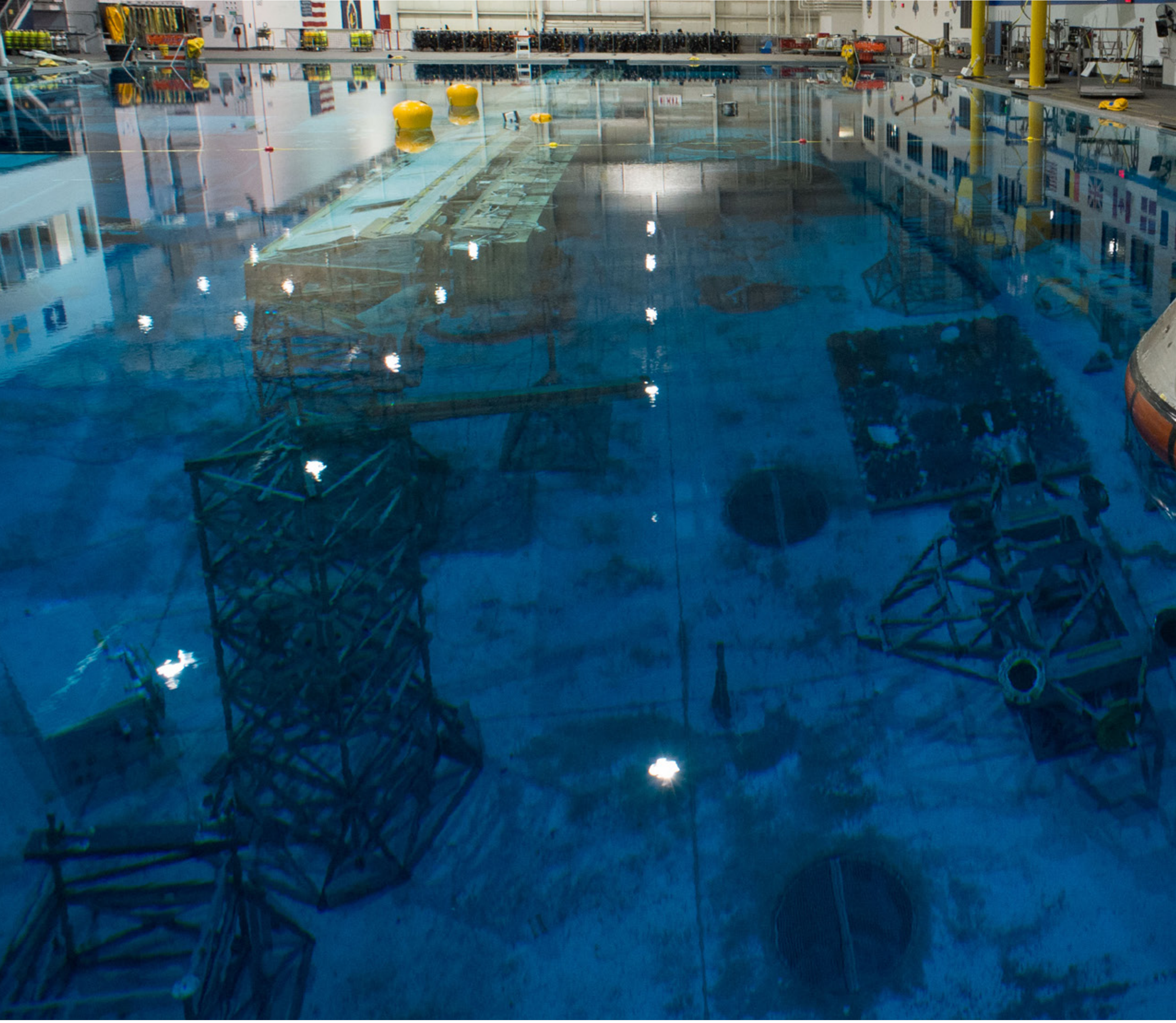
Building Orion

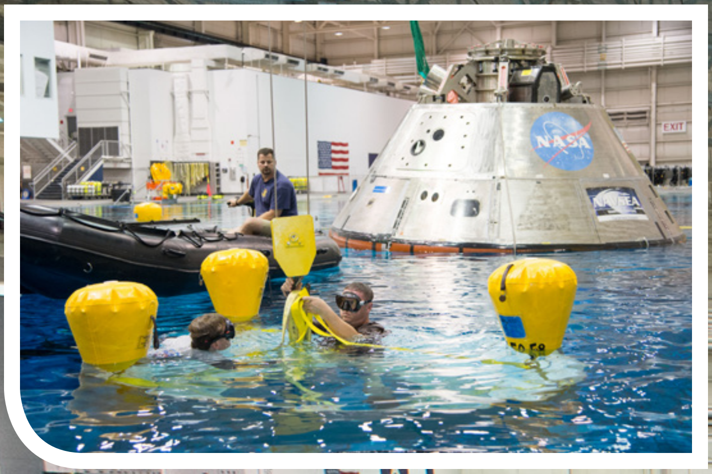
Construction on the first space-bound Orion spacecraft began at NASA's Michoud Assembly Facility in Louisiana. All photos NASA unless otherwise denoted

Construction of Orion continues in New Orleans.



Construction of Orion's heat shield began with Lockheed Martin in Colorado, then was shipped to Boston to have the protective coating applied by Textron Defense Systems.

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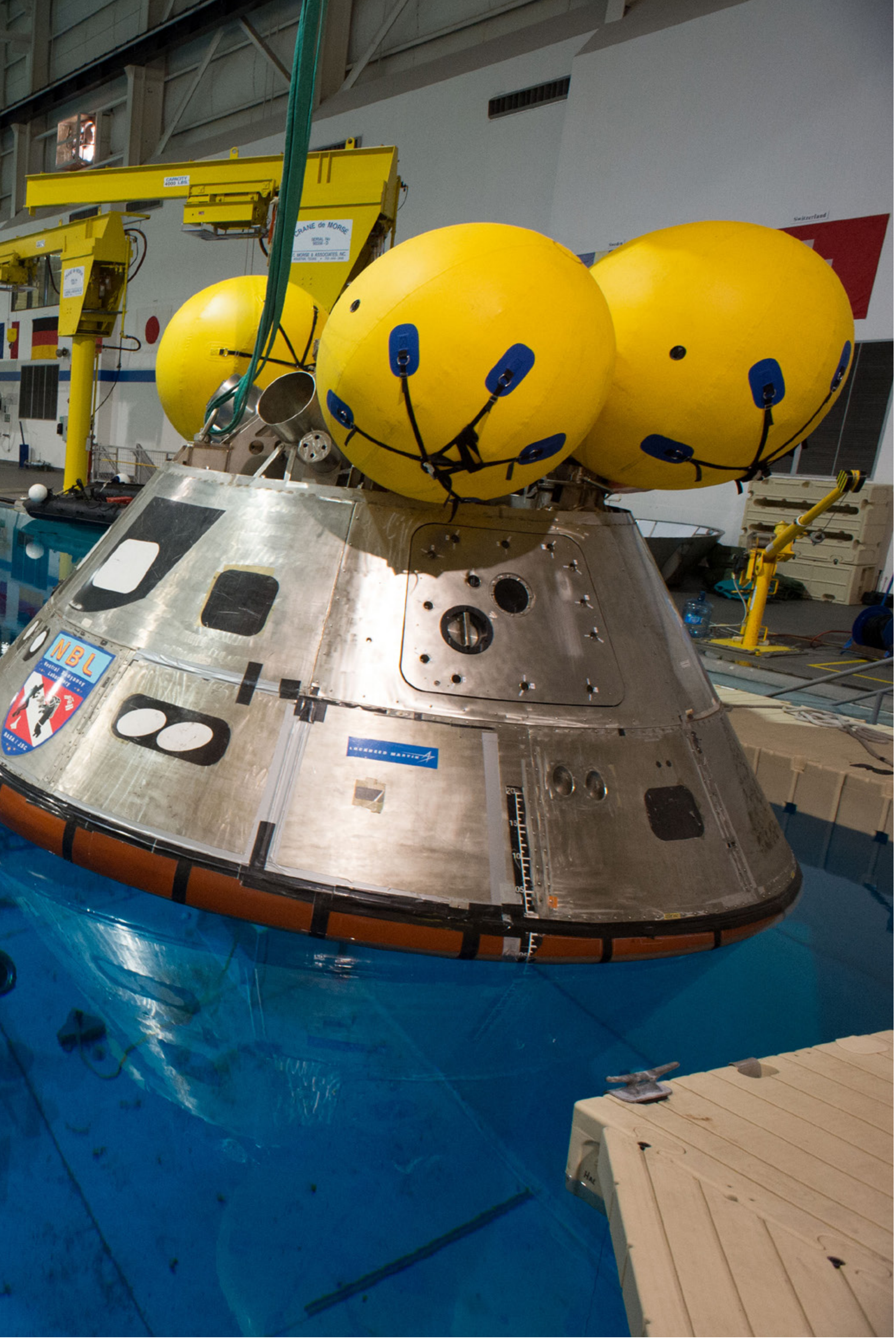
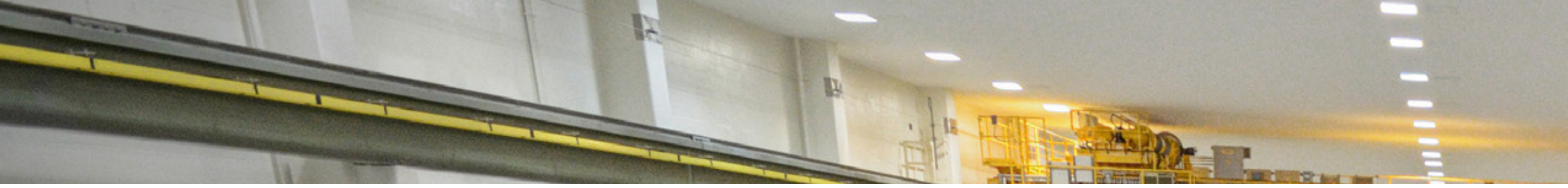
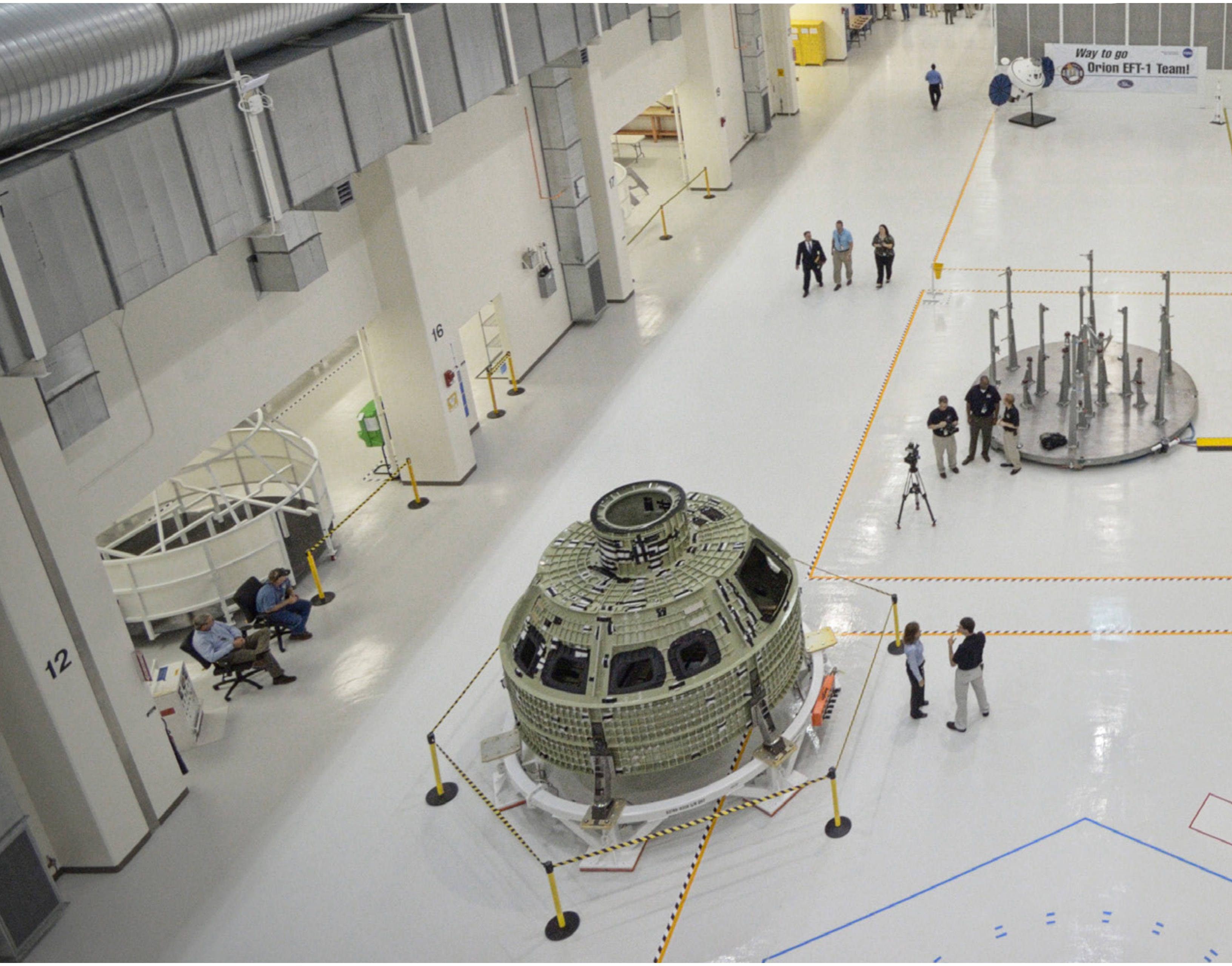
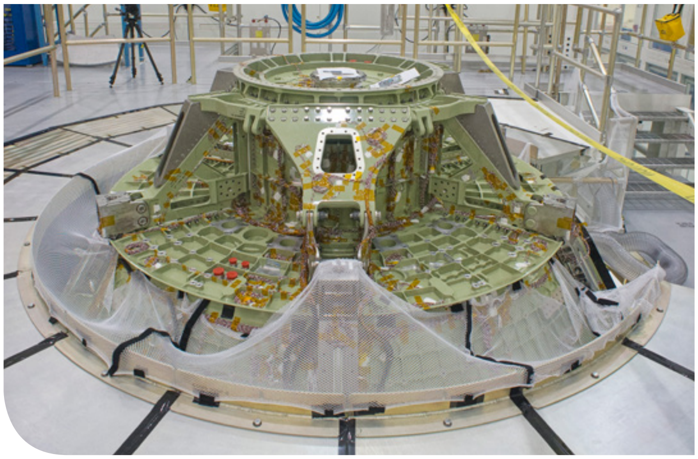


Recovery testing of the capsule and parachutes at NASA's Neutral Buoyancy Lab located at JSC.





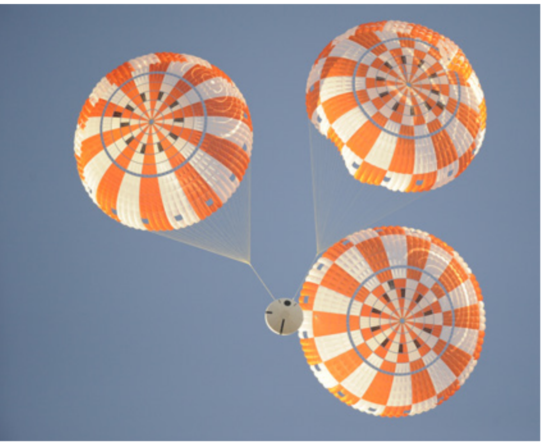
Orion construction continues within the Operations and Checkout Facility at Kennedy Space Center in Florida.



A model of Orion is used to perform a parachute drop test from a C-17 airplane 25,000 feet above the Arizon desert.

An Orion test article is used to conduct vertical drop tests into water at NASA's Langley Research Center.

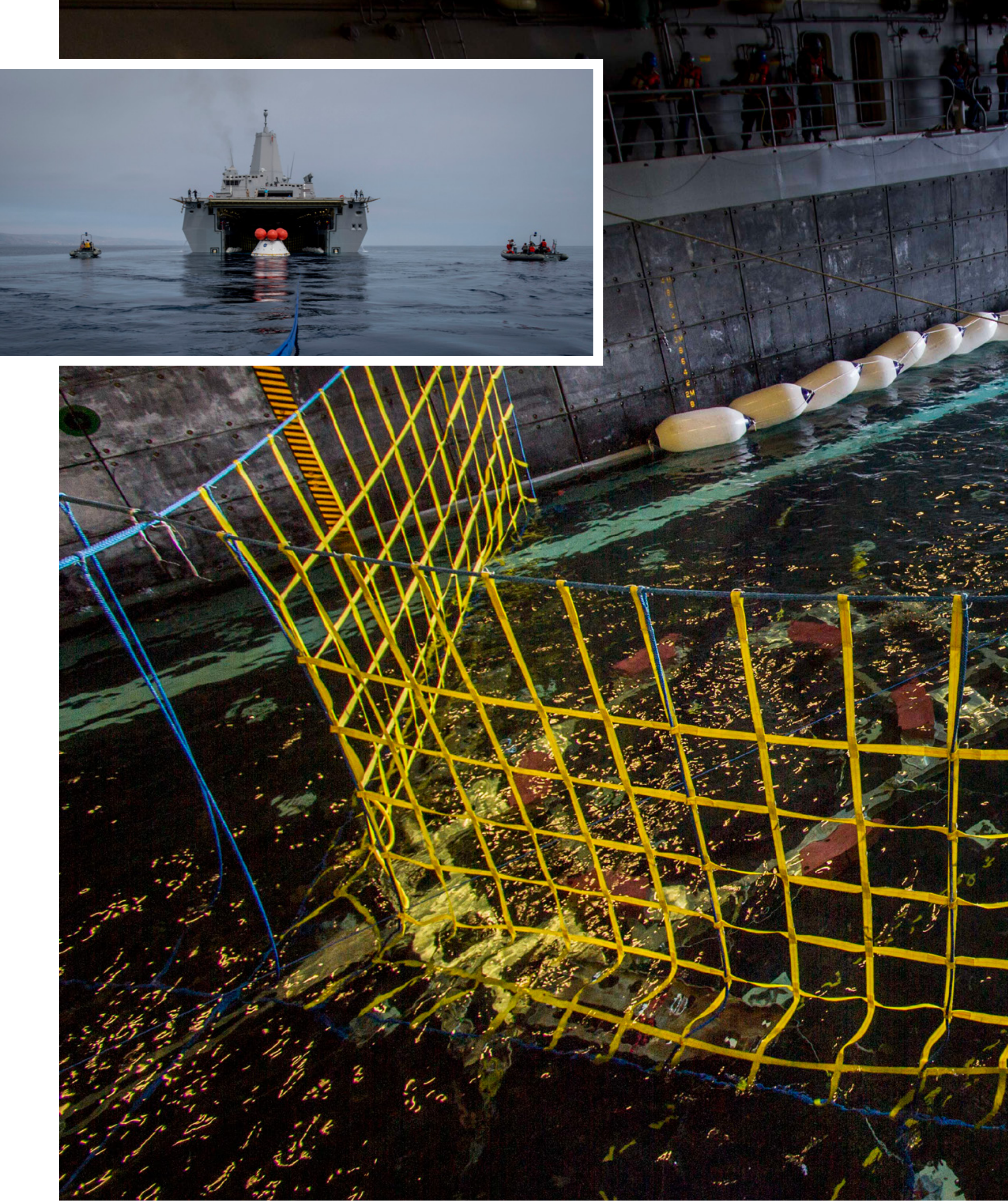
Test of the pad abort motor.



Orion Capsule Parachute Assembly System (above) drop test using the Parachute Test Vehicle (PTV) at the Yuma Army proving grounds in Arizona.

Ground teams practice stacking test versions of Orion and its launch abort system.

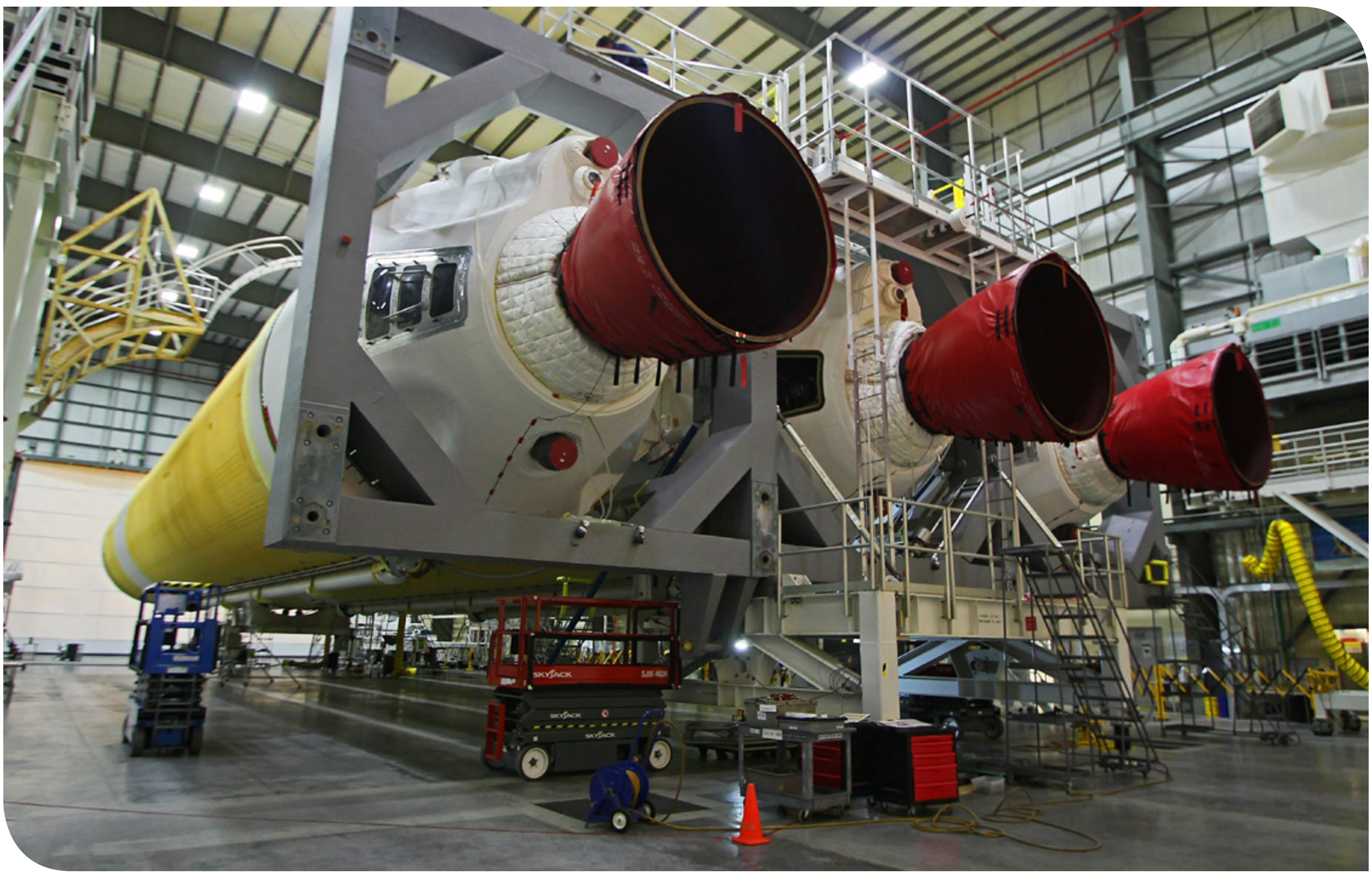
The Orion launch abort system (far right) lifts off during the Pad Abort 1 flight test at the White Sands Missile Range in New Mexico.



The U.S.S. Anchorage was used during recovery tests of a model of Orion off the coast of California. Credit: U.S. Navy & NASA

Work progresses on the Orion Service Module.

United Launch Alliance prepares the Delta IV heavy boosters slated for the EFT-1 launch from SLC-37 on Cape Canaveral Air Force Station. Credit: Mike Killian



Outer panels to shield the launch abort system are being prepared.

Orion's heat shield is installed.

Orion is mated to the Service Module and nearly ready to meet the Delta IV Heavy rocket that will lift it into space in early December.

Taking a peek inside Boeing's new high-tech CST-100 mock up test article. Credit: Mike Killian

Boeing, SpaceX garner NASA contracts to launch astronauts from American soil

By Mike Killian

In 2010, with the retirement of NASA's iconic 30-year space shuttle program, the space agency began the Commercial Crew Program to stimulate development of privately built and operated American-made spacecraft for transporting astronauts to and from low-Earth orbit (LEO) and the International Space Station (ISS). Since the final shuttle landed in 2011, America has been forced to buy seats to and from the orbiting outpost on the Russian Soyuz capsule, at a cost of over $70 million, per seat. Now, after over four years of testing, development, and waiting, NASA has selected Boeing's CST-100 space capsule and SpaceX's Dragon V2 space capsule to replace the agency's now-retired space shuttle fleet for flying astronauts to and from LEO and the ISS no later than 2017.

"Turning over LEO transportation to private industry will allow NASA to focus on an even more ambitious mission – sending humans to Mars," said NASA Administrator Charlie Bolden. "We don't know who is going to get to command the first mission to carry humans into LEO on a spacecraft built by an American private company, but we know it will be a seminal moment in NASA history and a major achievement for our nation. We now know, however, who will build it."

The total award value of their Commercial Crew Transportation Capability (CCtCap) contracts are worth up to $6.8 billion, with $4.2 billion for Boeing and $2.6 billion for SpaceX, and in order to achieve final NASA certification by 2017 both Boeing and SpaceX must meet the same rigorous safety standards that were required for the space shuttle. NASA has stated that Boeing is the agency's primary transport vehicle of choice, with SpaceX's Dragon V2 awarded as a backup. There's the old saying, "money talks," and NASA potentially awarding Boeing $1.6 billion more than SpaceX shows the agency has more confidence in Boeing's experience and the CST-100's design, despite the fact that some might not like to hear it. Not only that, but off the record several anonymous sources within NASA have expressed the same.

Additionally, the awards are dependent on Congressional funding; if Congress does not make the requested funds available, then the actual awards will be less, so NASA wants to make sure that if that does happen the CST-100 will still have adequate funds available to become a reality and start carrying crews to and from the ISS from American soil sooner rather than later.

Per the terms of the contract, each company must fly at least one crewed flight test, with at least one NASA astronaut aboard to verify the fully integrated rocket and spacecraft system can launch, maneuver in orbit, and dock to the ISS, as well as validate that all its systems operate as expected throughout the mission. Once Boeing and SpaceX have completed their test programs successfully and earned NASA certification, they will conduct at least two, and as many as six, crewed missions to the ISS for NASA. Both vehicles will also serve as lifeboats for crew living on station in case of an emergency, as well as serving other potential customers besides NASA.

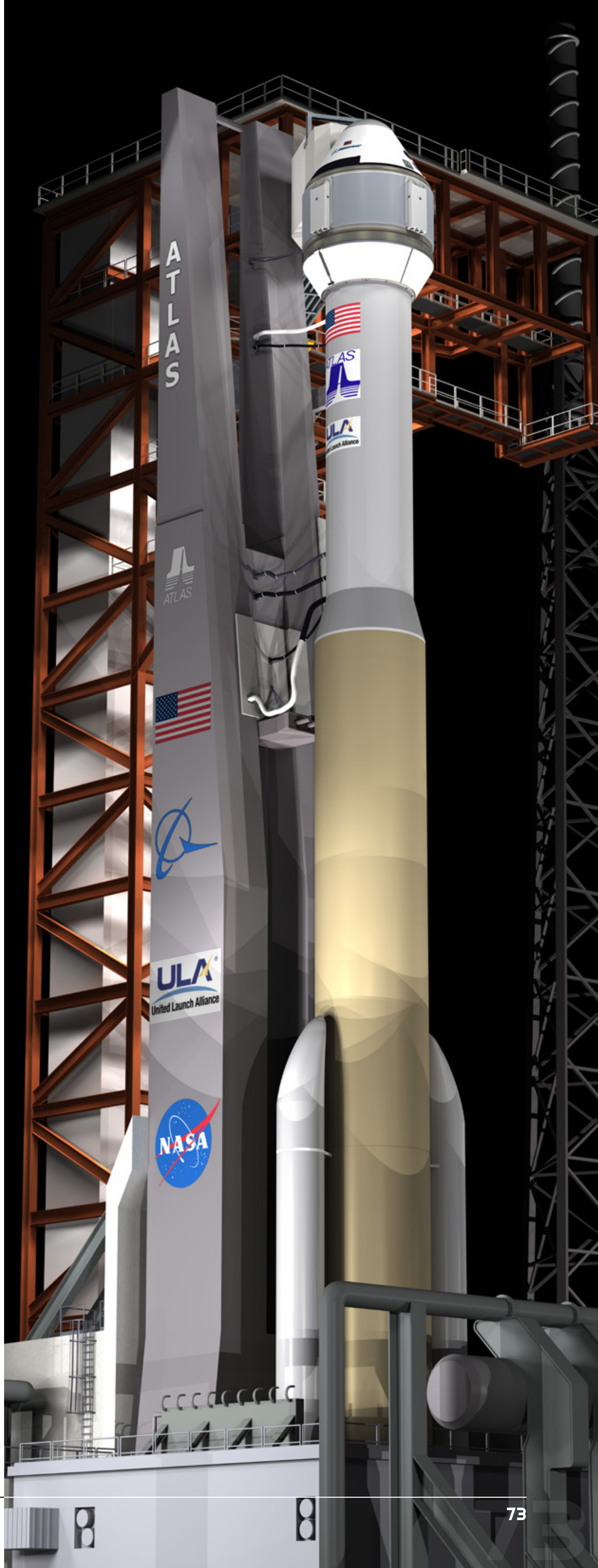
The Boeing CST-100 crew space transportation system

"It feels great to be building this, not only for Boeing but for the entire country," said Boeing CST-100 engineer Tony Castilleja in a telephone conversation we had hours after NASA announced their award decision. "I grew up inspired by space shuttle, and this will inspire a whole new generation. Seeing where we are headed, it's a testament to the hard work of our team, I haven't seen a passion like this ever, there's a passion to the work that each and everyone does on this program, and I think that's shown in the past with our ability to meet our milestones on time, as promised, and it's going to show at the launch pad come 2017."

With their award now secured, Boeing is picking up the pace with building three flight articles, each capable of 10 orbital flights each, and each flight article will serve to fulfill NASA's CCtCap requirements for certification and regular crew transportation flights.

"The CST-100 is a cheap, cost effective vehicle that does not need to be luxurious because it only needs to hold people for 48 hours. It's a simple ride up to and back from space," said former astronaut and commander of the last space shuttle mission Chris Ferguson, who now serves as Director of Crew and Mission Operations for Boeing. "Our focus right now is making sure we build the vehicle the right way."

CST-100 will launch initially atop ULA's Atlas V rocket and be capable of ferrying a crew of up to seven astronauts to and from the ISS. NASA only requires seating for four, but Ferguson has said he expects crews



An artist's rendering of the Boeing CST-100 sitting atop an Atlas V rocket at the launch pad. Credit: ULA of at least five to fly. The vehicle will launch from Cape Canaveral Air Force Station, just a few miles from its processing facility, and will cruise autonomously on a six to eight hour trip to the $100 billion orbiting ISS. The astronauts will not need to fly the vehicle themselves at all, and will literally be along for the ride in all aspects of the flight. They will, however, be able to take manual control of the CST-100 at any time, just in case.

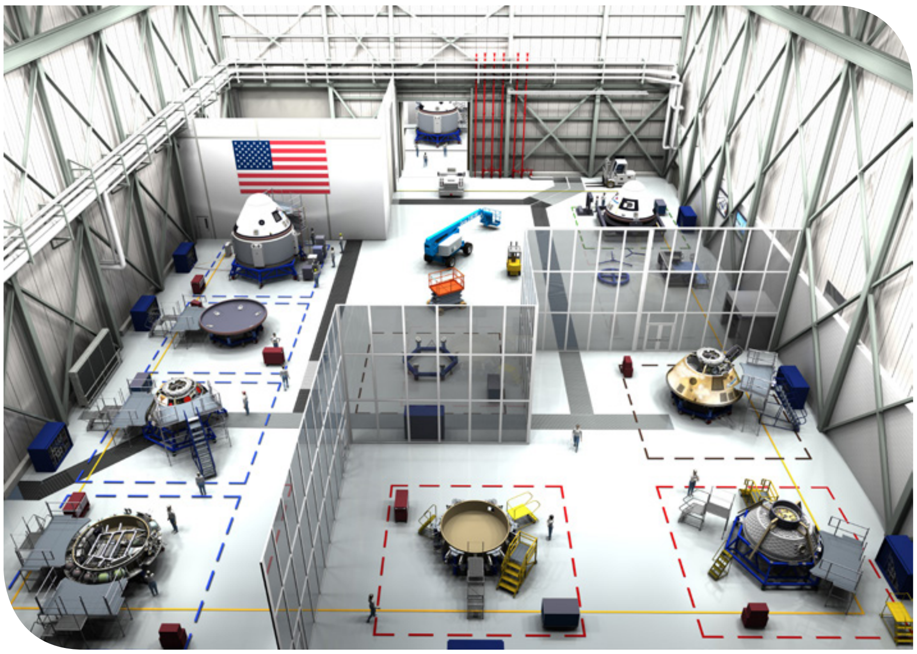
"We have a basic level of training we provide that will give the operator, a pilot, the knowledge that they need to operate the spaceship, which is mostly autonomous," added Ferguson. "They will have the ability to get to the ISS and back, as well as the ability to deal with failures and the ability to take manual control if necessary. NASA wants a single piloted vehicle, so we will train the pilot to whatever level of proficiency they need, and if NASA wants us to train someone else to a pilot level of proficiency then we will be happy to do that. That being said we have factored into our design the ability for a copilot, and train them perhaps to the same level of proficiency as the pilot. They would sit beside the pilot and do all of those types of crew resource management (CRM) types of things that NASA instilled in us shuttle astronauts over the years."

"When astronauts go up in the CST-100 their primary mission is not to fly the spacecraft, their primary mission is to go to the space station for 6 months, so we don't want to burden them with an inordinate amount of training to fly our vehicle," added Ferguson.

The spacecraft interior is much more user-friendly than vehicles that came before, no more hundreds (if not thousands) of switches on nearly every wall; CST-100's control panel spans not more than three feet wide. Its look and feel is very user-focused, featuring therapeutic Boeing LED Sky Lighting technology similar to that found in the company's 787 Dreamliner. A blue hue creates a sky effect and makes the capsule appear and feel roomier, something any astronaut will agree is always desired (spaceflight is not for the claustrophobic). The interior also boasts tablet technology for crew interfaces, which completely eliminates any need for bulky manuals, while wireless internet will support communications and ISS docking operations.

"One of the great things with the technology we have at Boeing is the ability to rapid prototype the interior, and as designs get updated we're able to bring in new design concepts," said Castilleja while we sat together onboard his CST-100 mock up last June at Boeing's CST-100 processing facility at KSC. "We get the engineers in here and get the astronauts in here every six months to provide that reach and visibility. Do they feel comfortable? Is there anything we need to tweak as we move forward? It really builds trust with them. It's almost like buying a car, but you're a part of the design process in that vehicle."

"We brought our commercial airliner feel into the CST-100, and so you see this merging … it's almost like history repeating itself, from commercial airlines to commercial spaceflight," added Castilleja. "We're bringing that Boeing element into spaceflight and wanted to create an interior that makes the spacecraft feel a little bit bigger."



An artist's rendering of the processing facility for the Boeing CST-100 being constructed at Kennedy Space Center. Credit: Boeing

Now that Boeing has secured their award with NASA, operations will immediately move to the Kennedy Space Center (KSC) to manufacture, assemble, and test the actual CST-100 flight articles. Boeing, in partnership with Space Florida, is already leasing the former space shuttle Orbiter Processing Facility Bay-3 at KSC to do this, modernizing the facility (now known as the Commercial Crew and Cargo Processing Facility, or C3PF for short) to provide an environment for efficient production, testing, and operations for the CST-100 similar to Boeing's satellite, space launch vehicle, and commercial airplane production programs.

"We're transitioning this facility into a world class manufacturing facility," said Mulholland. "With a 50,000 square foot processing facility it's going to allow us to process up to six CST-100's at a time."

The hangar facility has more than enough room to support processing of multiple CST-100s simultaneously, and the adjoining sections of the building are well-suited to process other systems such as engines and thrusters before they are integrated into the main spacecraft.

Elon Musk reveals the Dragon V2 (above) that will serve as the first SpaceX spacecraft to be human rated. The capsule will feature eight SuperDraco engines (right) for both launch aborts and for controlled powered landings. Credit: SpaceX

Boeing will also bring 300, and eventually 500, new jobs to Florida's "Space Coast," whose economy was hit particularly hard at the end the shuttle program.

"This facility will become point and center, we'll be developing the test articles here and then starting the manufacturing for full services in 2017," added Castilleja. "This is where all the pieces and parts will come in, and we'll then build everything right here. One side of the building is for processing the service modules, and the other side of the facility is for processing the crew modules. We'll then ship out to the Atlas launch pad integration facility and off we go."

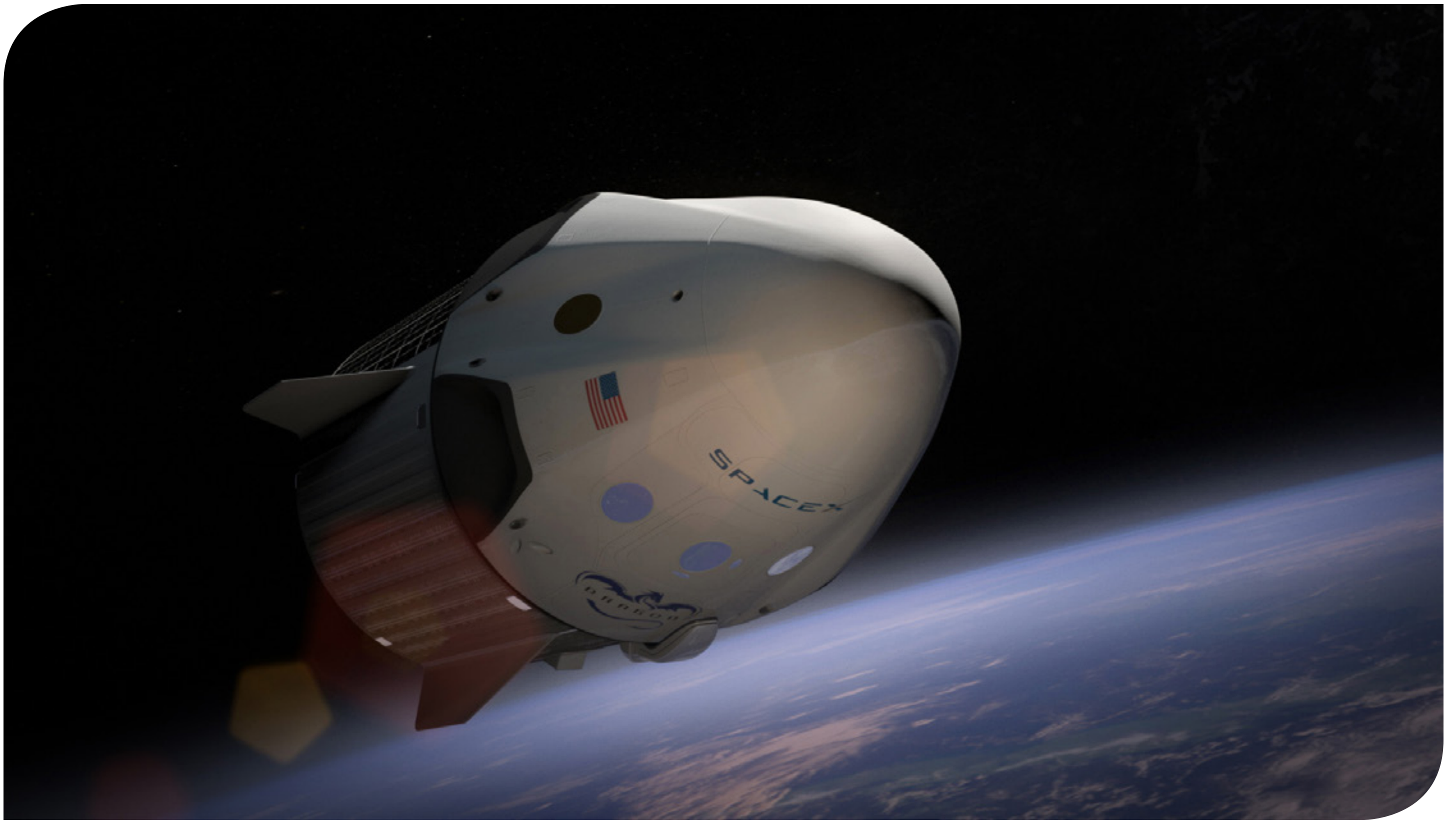
The SpaceX Dragon V2 crewed space capsule

"SpaceX is deeply honored by the trust NASA has placed in us," said SpaceX CEO Elon Musk in a statement this afternoon. "We welcome today's decision and the mission it advances with gratitude and seriousness of purpose. It is a vital step in a journey that will ultimately take us to the stars and make humanity a multi-planet species."

Musk unveiled his Hawthorne, Calif.-based company's new Dragon spacecraft, the Dragon V2, at SpaceX Headquarters in southern California last May.

"When we first created Dragon V1 we didn't really know how to create a spacecraft, we never designed a spacecraft before, so, while there are a lot of interesting technologies in Dragon V1 it does have a relatively conventional landing approach by throwing off parachutes and landing in water off the coast of CA after it comes back from the ISS," said Musk, moments before dropping the curtain on Dragon V2. "It's a great spacecraft and a great proof of concept, it showed us what it took to bring something back from orbit, which is a very difficult thing to do, but going from V1 we wanted to take a big step in technology."

SpaceX currently flies their Dragon V1 to carry out a $1.6 billion Commercial Resupply Services (CRS) contract with NASA, signed in late 2008, to conduct 12



An artist's rendering of the SpaceX Dragon V2 capsule and service module in orbit and heading to the International Space Station. Credit: SpaceX

dedicated Dragon resupply missions to the ISS by 2016, missions which promise to haul a total of 44,000 pounds of equipment and supplies to the orbiting outpost. Dragon V1 was the first commercial spacecraft to visit the ISS, and the first commercial spacecraft to return to Earth from orbit. It has flown to, and from, the ISS four times, starting with the inaugural Commercial Orbital Transportation Services (COTS) Demo mission in May 2012 and followed by the dedicated CRS-1 and CRS-2 missions in October 2012 and March 2013, the CRS-3 mission last April, and most recently the CRS-4 mission just last month.

However, Elon Musk has always said he wants to bring American human spaceflight capability back to the nation and give humanity the means to become a multi-planet species, at much cheaper than any government can do, and even though the Dragon V1 does have a life-support system it's not one that can last for a long time or carry a lot of people. That's where the Dragon V2 comes in, and its landing method will be quite different, too.

"Dragon V2 still retains the parachutes of Dragon V1, but V2 will be able to land anywhere on land propulsively, and do so anywhere on Earth with the accuracy of a helicopter, which is something I think a modern spaceship should be able to do," said Musk. "When Dragon V2 reaches a particular altitude a few miles before landing it will test the engines and verify that all the engines are working before proceeding to a propulsive landing, and if there is any anomaly detected with the engines or propulsion system it will then deploy the parachutes to ensure a safe landing, even in the event that the propulsion system is not working. All around I think it's really a big leap forward in technology, it really takes things to the next level."

"Even after starting the propulsion system it can afford to lose up to two engines and still land safely," added Musk. "After the engines are started it will then deploy the landing legs for a soft landing. This is really important, apart from the convenience of the landing location, because it enable rapid reusability of the spacecraft, you can just reload propellants and fly again. This is extremely important for evolutionizing access to space because as long as we continue to throw away rockets and spacecraft we will never truly have access to space, it will always be incredibly expensive."

Musk offered the following scenario for comparison:

"If aircraft were thrown away after each flight then nobody would be able to fly, or very few, maybe a small number of customers. The same is true of rockets and spacecraft, so that's really why it's so important to be able to land propulsively, land on land and be able to reload propellants and take off again."

The biggest upgrade, at least from a propulsion standpoint, is the addition of the SuperDraco engines, a "superpowered" version of the Dragon V1 Draco engines used to maneuver in space and control the spacecraft's trajectory during reentry. Dragon V2 will still use the original Draco thrusters for maneuvering in space, but the V2's SuperDraco thrusters will serve both as part of the vehicle's launch escape system and enable propulsive landing on land. A total of eight SuperDraco's are built into the side walls of the Dragon V2 and will produce up to 120,000 pounds of axial thrust (16,000 pounds of thrust each, compared to 100 pounds of thrust each with the original Draco thrusters). The engines also come in pairs, so if one engine fails the other can increase its thrust to compensate for the engine that is not firing.

The SuperDraco engines on the Dragon V2 are also the first fully 3-D printed engines intended for space. The chamber is regeneratively cooled and printed in Inconel, a high-performance superalloy that offers both high strength and toughness for increased reliability; they will become the first printed rocket engines ever used in spaceflight. It was only a couple days ago that SpaceX completed qualification testing for the SuperDraco thruster at the company's Rocket Development Facility in McGregor, Texas, which included testing across a variety of conditions including multiple starts, extended firing durations, and extreme off-nominal propellant flow and temperatures.

"Through 3-D printing, robust and high-performing engine parts can be created at a fraction of the cost and time of traditional manufacturing methods," said Musk. "SpaceX is pushing the boundaries of what additive manufacturing can do in the 21st century, ultimately making our vehicles more efficient, reliable and robust than ever before."

An artist's rendering of Sierra Nevada's Dream Chaser spacecraft alongside Space Shuttle Atlantis at the Shuttle Landing Facility in Florida. Credit: SNC

Where does this leave Sierra Nevada's Dream Chaser?

As with any competition, there must be a loser. Sierra Nevada's Dream Chaser "mini space shuttle" did not secure a CCtCap award from NASA. However, that does not mean we will never see a Dream Chaser fly, it just means we won't see NASA giving them extra money to continue development to serve the space agency's agenda for contracting with private companies for crew transport to and from the ISS.

However, soon after the award decision was announced Sierra Nevada Corporation (SNC) filed a "legal challenge" with the Government Accountability Office (GAO) protesting NASA's selection of Boeing and SpaceX, stating that, "NASA's own Source Selection Statement and debrief indicate that there are serious questions and inconsistencies in the source selection process."

Pursuant to the GAO protest filed by SNC on Sept. 26 NASA was forced to issue a "stop work order" instructing both Boeing and SpaceX to stop performance of their newly awarded Commercial Crew contracts. However, a couple weeks later NASA decided to exercise their "statutory authority" and press on with Boeing and SpaceX contracts despite SNC's protest with the GAO.

"The agency recognizes that failure to provide the CCtCap transportation service as soon as possible poses risks to the ISS crew, jeopardizes continued operation of the ISS, would delay meeting critical crew size requirements, and may result in the U.S. failing to perform the commitments it made in its international agreements. These considerations compelled NASA to use its statutory authority to avoid significant adverse consequences where contract performance remained suspended. NASA has determined that it best serves the United States to continue performance of the CCtCap contracts that will enable safe and reliable travel to and from the ISS from the United States on American spacecraft and end the nation's sole reliance on Russia for such transportation."

Regardless of the outcome between SNC and NASA, SNC Space Systems VP Mark Sirangelo has made it loud and clear that the company is ready to move forward with development of the Dream Chaser without NASA, as long as there is a business case for it, and that business case may come in the form of international cooperation with the European Space Agency (ESA) and the Japan Aerospace Exploration Agency (JAXA).

Sierra Nevada has already begun to build their first Dream Chaser for an inaugural orbital flight test atop a ULA Atlas-V rocket in late 2016, and they have already purchased the Atlas-V for that flight. Whether that flight actually occurs though we will have to wait and see.

"Our destiny is set. Our course is laid out before us. And we are following it," added Bolden after announcing NASA's decision. "We hope the American people will be inspired to join us on this next great, ambitious leg of humanity's journey farther into our solar system than ever before."

"I can't put into words what it will feel like to see years of hard work payoff when that first CST-100 launches," added Boeing's Tony Castilleja at the end of our most recent conversation. "When we launch the CST-100 on that Atlas-V rocket I can't wait to look to the left of me, to the right of me, and see the friends and the passion that each and everyone put together to launch this off, and I can't wait to see our astronauts return home on our vehicle safely."

Students from some of the participating SSEP schools stand with program founder, Dr. Jeff Goldstein, the morning of the Antares Orb-2 launch. The students watched their experiments soar into space that same day with much anticipation. Credit: Lloyd Campbell

SSEP: Sending student experiments to the ISS

By Lloyd Campbell

On the morning of July 12, 2014, the Orbital Science Antares rocket sits on Pad 0A at NASA's Wallops Island facility awaiting to be hopefully be launched at 12:52 p.m. that afternoon. On top of the rocket is Orbital's Cygnus ORB-2 spacecraft packed with cargo bound for the International Space Station. The spacecraft has been christened the "SS Janice Voss", in honor of the late Janice Voss who flew on the space shuttle five times as a NASA Astronaut and was also an Orbital Sciences employee.

The ORB-2 mission is also carrying 16 experiments to the station, experiments with titles like; "Mold Reproduction rate in Microgravity", "Affected Efficacy of Sprayed Enamel Coating as a Corrosion Inhibitor", "Core-Shell Micro/Nanodisks: Microencapsulation in Two Dimensions under Microgravity", "Polyhydroxyalkanoate Production in Zero Gravity", and "Triops as a Protein Source", just to name a few. These are some impressive experiments that are flying on this mission designed by researchers here on Earth.

While preparations continue towards the scheduled launch, a media event is occurring inside of the Wallops Island Visitors Center newsroom. The researchers behind the 16 experiments on board the Cygnus spacecraft are giving presentations to the media on their experiments and what they hope to learn from them.

While this may seem like any other pre-launch media presentation, it is quite different in that the researchers who designed and submitted these experiments are not from NASA or any other government agency, nor are they from a private corporation; they are instead from schools just like yours. They are regular students just like you, ranging from the 5th through 12th grades.

So just how did these students get their experiments on this spaceflight? It's through a program called the Student Spaceflight Experiments Program, or SSEP. Today's launch will be the seventh time that SSEP participants have had their experiments sent into low Earth orbit.

The program is designed to show the students how real science is done. Much like their adult counterparts in private industry who have to have their proposals reviewed and approved, these students must submit their proposal to SSEP for review and hopefully be selected to participate. Due to the extremely limited resources in both available cargo room on the spacecraft, and the astronauts' time aboard the ISS to conduct the experiments, the selection process sends what are hopefully the most beneficial experiments into orbit. Their experiments must also pass all of NASA's requirements for spaceflight just like any other cargo.

But I jumped ahead a bit; first each community that participates in SSEP has to conduct their own local Flight Experiment Design Competition. Student teams from across the community will be competing against other teams to have their experiment fly in low earth orbit using a real research mini-laboratory reserved for their community.

The teams from across the community must submit formal research proposals which will go through a two-step review process to select the flight experiment for the community which will in turn be submitted to SSEP for evaluation. The local design competition from the program start, through experiment design, and finally ending in their proposal submission, runs at least nine weeks.

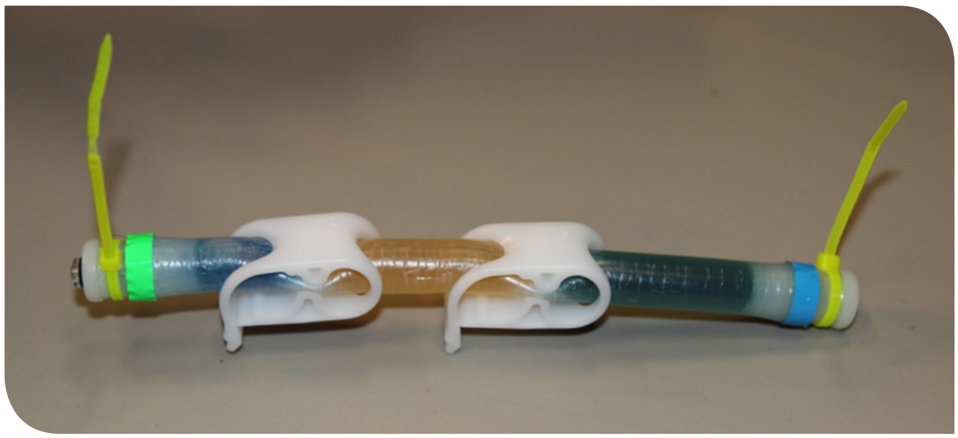
Each community is competing to fly their experiment in low earth orbit using a mini-laboratory (pictured) aboard the ISS. Astronauts will conduct the experiment in orbit, usually within days of the departure of the latest SpaceX Dragon cargo capsule which will return the executed experiments back to earth so the teams can analyze their results. The astronauts truly enjoy working with these student experiments and after returning to Earth, many of them have followed up with the design teams of the experiment they performed to see what knowledge was gained from the experiment.

Since its inception in June of 2010, eight SSEP flight opportunities have been offered with a total of 84 communities having participated in the program. The communities have submitted, to date, a total of 7,922 flight experiment proposals. A total of 96 experiments will have flown so far with today's launch, including 27 that flew aboard the last two flights of the Space Shuttle. If you are doing the math, you will see that some communities have actually had experiments on more than one flight! Another 19 experiments are slated to fly aboard the ORB-3 flight that, as of this writing, is currently scheduled to launch just after midnight on October 14th of this year from the Mid-Atlantic Regional Spaceport on Wallops Island, VA. More than 35,000 students, ranging from grades 5-15 have participated in experiment design and proposal writing so far.

And there is even a way for the more arts oriented student to participate. Each mission sends a number of patch designs into orbit also. If an experiment from your community is selected, up to two patches (printed on paper) from your community can also fly with the experiment. Once again, the community would conduct its own competition for patch designs and select one or two to be sent to SSEP. The patch images are returned after the flight so they can be displayed by the community.

To learn more about SSEP and how your community could have an experiment fly to the space station, visit http://ssep.ncesse.org/.

Now let's go back to some of those experiments mentioned above. Even with their detailed scientific names, they are not all as complex as you might believe. For example, the "Affected Efficacy of Sprayed Enamel Coating as a Corrosion Inhibitor" experiment is comparing the effectiveness of Rust-Oleum paint in microgravity as compared to its performance here on earth. Using Coca-Cola as a corrosive agent, they will expose an iron disk that was previously coated with Rust-Oleum, and another that is not coated, to the corrosive agent for 72 hours and then stop the corrosive process by absorbing the Coca-Cola with a polymer.



A duplicate example of the "Affected Efficacy of Sprayed Enamel Coating as a Corrision Inhibitor" student experiment which was transported to the International Space Station. Credit: Lloyd Campbell

After retrieval of their experiments from Earth orbit they will examine the discs under a microscope.

Another experiment is studying mold growth on white bread in microgravity, yet another is analyzing Lettuce growth in microgravity and how long it takes to germinate. So as you can see, while they're looking for results to prove or disprove a theory, or to determine if something is viable (such as growing lettuce in microgravity), the experiment itself can be quite simple, it's the science behind it that is important.

As you may already know, the Antares rocket did take flight that glorious July afternoon and the experiments are now onboard the ISS. The completed experiments are currently scheduled to return to Earth aboard the next SpaceX cargo mission.

SpaceX CRS-4 launch: A SpaceX Falcon 9 rocket with a Dragon cargo spacecraft on top launched from Cape Canaveral Air Force Station's Space Launch Complex-40 in Florida at 1:52 a.m. EDT, Sept. 21, 2014. In this four-image composite, the launch, second stage burn to orbit and the Falcon-9 vertical soft landing test are all visible. The Dragon carried more than 5,000 pounds of supplies, science experiments, and technology demonstrations to support 255 science and research investigations aboard the ISS. *Credit: Mike Killian*

JAXA launches Himawari-8 weather satellite

Mitsubishi Heavy Industries, Ltd. and the Japan Aerospace Exploration Agency (JAXA) launched the H-IIA Launch Vehicle No. 25 (H-IIA F25) with the Geostationary Meteorological Satellite “Himawari-8” onboard at 2:16:00 p.m. on October 7, 2014 (Japan Standard Time, JST) from the Tanegashima Space Center.

The launch vehicle flew as planned, and, at about 27 minutes and 57 seconds after liftoff, the separation of the Himawari-8 was confirmed.

Credit: MHI/JAXA

Astronaut Reid Wiseman on the first spacewalk of Expedition 41

On Oct. 7, NASA astronaut Reid Wiseman (pictured here) and European Space Agency astronaut Alexander Gerst completed the first of three spacewalks for the Expedition 41 crew aboard the International Space Station. The spacewalkers worked outside the space station's Quest airlock for 6 hours and 13 minutes, relocating a failed cooling pump to external stowage and installing gear that provides back up power to external robotics equipment. Flight Engineer Barry Wilmore of NASA operated the Canadian robotic arm, maneuvered Gerst during the course of the spacewalk and served as the spacewalk coordinator.

A few days later, Reid posted to twitter (@astro_reid) that "While #spacewalking I realized something: I used to think I was scared of heights but now I know I was just scared of gravity."

Credit: NASA/ESA/Alexander Gerst