RocketSTEM

Vol. 2 • No. 4 • July 2014 • Issue 8

Apollo 11: First humans on the Moon

Buzz Aldrin looks to Mars

Competition for a lunar rover

Red Planet living atop a volcano

Morpheus demonstrates new lander tech

Join us in this special supersize issue of RocketSTEM as we celebrate the 45th anniversary of the Apollo 11 Moon landing. We've got you covered with an expansive pictorial featuring many of the lesser known photos from the historic mission, as well as a number of anecdotes from those who were involved in the massive undertaking. Astronaut Buzz Aldrin shares his thoughts on the Moon landing and the events leading up to the mission, as well as his hopes to colonize Mars in the coming decades. We also speak to Jack King, the man known the world over as 'The Voice of Apollo.' We travel to Morehead Planetarium and learn how the early astronauts would travel there to learn to navigate by the stars. We take you behind the scenes of the Apollo space program and meet some of the unsung heroes of the race to the Moon.

But this issue is not all about Apollo. We bring you stories about the Morpheus test lander, the Google Lunar X Prize and one college team hoping to win the $20 million prize. We give you advice on observing and photographing the Earth's nearest neighbor, the Moon. We go high up on the slopes of a Hawaiian volcano to discover a group of adventurers who are simulating a four-month stay on the Red Planet. NASA Administrator Charles Bolden updates us on the future of America's space program, and we check out the latest progress on commercial crew efforts by Boeing and SpaceX.

We've been asked about purchasing printed copies of this magazine in the past, and we are happy to announce that a limited number of high-quality printed copies are available for this issue. If interested, please visit www.rocketstem.org/purchase to reserve your copy now. While there, also consider signing up to be notified should we begin offering an annual print subscription in the coming months.

Since founding RocketSTEM in late 2012, 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. Getting material from RocketSTEM used in classrooms is a top priority, therefore we have never sold advertising space in the magazine, as some schools would frown upon doing so. 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. Donations can be made online via PayPal to donations@rocketstem.org, or can be mailed to: RocketSTEM Media Foundation, P.O. Box 34409, Pensacola, FL 32507. Thank you for your support.

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

Chase Clark, Managing Editor

Contents

Also Inside:

Follow us online:

facebook.com/RocketSTEM

twitter.com/rocketstem

www.rocketstem.org

All of our issues are available via a full-screen online reader at:

www.issuu.com/rocketstem

Editorial Staff
Managing Editor: Chase Clark
Astronomy Editor: Mike Barrett
Photo Editor: J.L. Pickering

Contributing Writers
Mike Barrett • Lloyd Campbell
Skip Chauvin • Chase Clark
David Clow • Cameron Corrie
Dauna Coulter • Walter Dermody
Loretta Hall • Rich Holtzin
Mary Kanian • Mike Killian
Ken Kremer • Joe Maness
Christine Nobbe • Tony Rice
Nicole Solomon • Casey Stedman
Sherry Valare • Amjad Zaidi

Contributing Photographers
Mike Barrett • Joe Bibby
Mike Chambers • Chris Chamberland
Brenden Clark • Lauren Harnett
Bill Ingalls • Mary Kanian
Ken Kremer • Ross Lockwood
Frankie Martin • Tony Rice
Kim Shiflett • Nicole Solomon
Casey Stedman • Tiffany Swarmer
Tom Usciak • Sherry Valare
Alan Walters • Jack Weir

Contributing Graphic Artists
Victor Dang • Jonathan Mihaly
Orion 8 • Mark Wade

RocketSTEM Board of Directors
Chase Clark • Brenden Clark
Tim Brown • Nicole Solomon
Anthony Fitch

RocketSTEM • July 2014
Vol. 2 No. 4 Issue 8 (ISSN: 2326-0661)

RocketSTEM Media Foundation, Inc.
P.O. Box 304409
Pensacola, Florida 32507

email: ***info@rocketstem.org***

On the Cover: *Buzz Aldrin descends from the LM to the lunar surface.*
Credit: NASA via Retro Space Images

Project Morpheus

Credit: NASA/Kim Shiflett

Flying a test bed for future landers

By Lloyd Campbell

It's May 22, 2014, another bright sunny day at Kennedy Space Center in Florida where a shiny four legged vehicle, dubbed Morpheus, stands in a special area at the north end of the Shuttle Landing Facility awaiting the scheduled time to fly. This is the same facility where 78 of the 135 Space Shuttle missions landed.

At the end of the runway, a special area for takeoff and another for landing have been constructed. The landing area is not very forgiving as it has boulders and simulated craters that the lander will have to avoid in order to touchdown in a safe landing spot.

And one more thing, nobody is at the controls, the Morpheus Lander is going to attempt to do this autonomously, or all on its own.

RocketSTEM had the opportunity to visit with Morpheus Project Manager Jon Olansen and Morpheus Ops Lead, Ian Young at the project's home at Johnson Space Center in Houston, Texas prior to the May 22nd flight.

So what exactly is Morpheus? Morpheus is a reusable, autonomous Vertical Test Bed (VTB), a prototype lander capable of vertical takeoffs and landings. It provides a cost-efficient way to test and refine technologies developed in various NASA laboratories in an integrated flight system.

Morpheus is designed, developed, and tested by a small team at NASA's Johnson Space Center. From idea board to the first testing was accomplished in just eight months. Other segments of NASA provide their expertise to the project also; engine testing was done at the Stennis Space Center, the Marshall Space Flight Center provided assistance with the lander itself as well engine development, Goddard Space Flight Center (GSFC) provided core flight software development, and the Langley Research Center and the Jet Propulsion Laboratory assisted with ALHAT.

The Autonomous Landing and Hazard Avoidance Technology, or ALHAT, is what gives Morpheus the ability to fly autonomously.

The ALHAT system has three critical components, all using lasers as their ways of taking measurements. The trio consists of a flash lidar system, a laser altimeter, and a Doppler velocimeter. All of these instruments are essential to making a safe autonomous landing. The flash lidar uses imagery technology to detect anything bigger than the size of a basketball, under any lighting conditions.

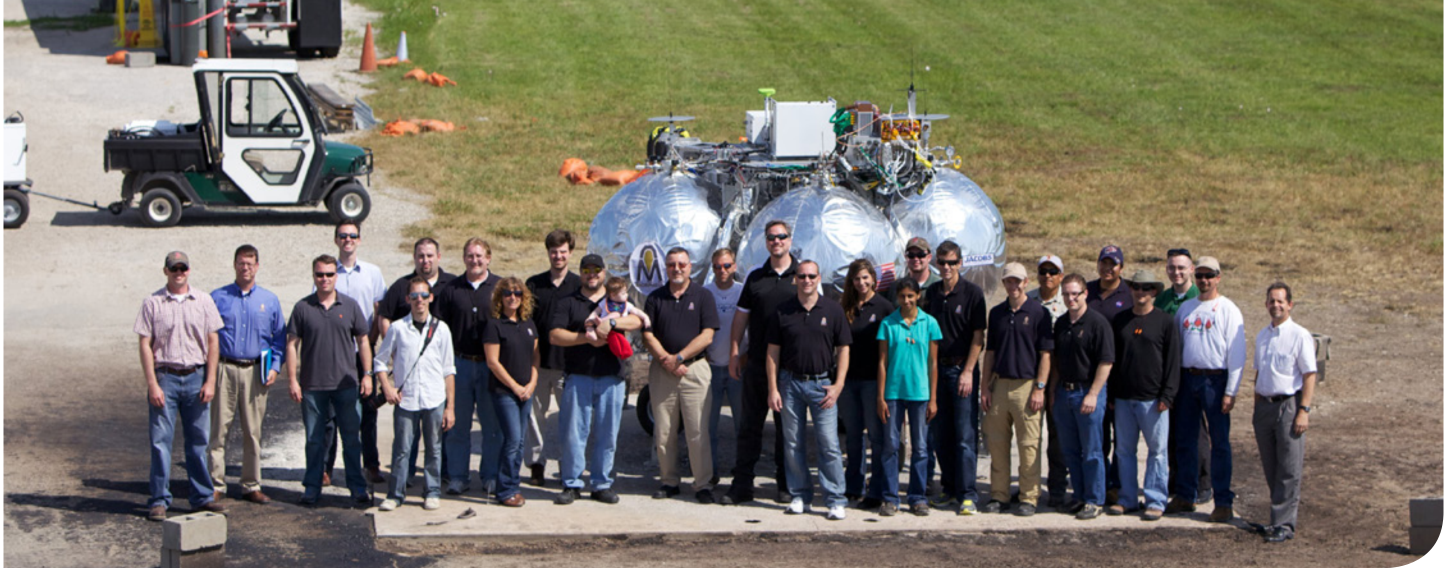
Flash lidar systems engineer Eric Roback described it as follows, "It's a flash lidar because the laser flashes and acts like a flash camera". The Doppler lidar measures the vehicle's altitude and velocity, allowing it to make a precision landing on the surface. And lastly, the high-altitude laser altimeter provides data enabling the vehicle to land in the chosen area.

As Morpheus Project Manager Jon Olansen told RocketSTEM, "Essentially you give the spacecraft the ability to control its own descent and landing. And that's what we will be attempting to demonstrate in our flight next week in Florida. Its initial target point in the landing field is right in the middle of the landing pad, irrespective of the rocks and everything.

"It goes and does a scan and identifies within that, what the best place to land is. We know what that should be. From a test perspective we can make sure it lands in the right place, the instruments themselves don't know we know that. They will be controlling the vehicle and if everything goes as anticipated, they will control the vehicle all the way to the ground and land where it should.

"That's just an indication of we can make the vehicle think for itself, and autonomously perform these functions that we expect it to do when we send it to the back side of the Moon, or near some crater, Mars, an asteroid, or even Europa. Where ever it is that we want to send a craft that you'll have the capability with

NASA's Project Morpheus prototype lander performs a free-flight test from a launch pad at the north end of the Shuttle Landing Facility at NASA's Kennedy Space Center in Florida.
Credit: NASA/Mike Chambers and Chris Chamberland



Members of the Project Morpheus team pose for a group photo during the 11th tether test of the prototype lander which took place in 2012 at the Johnson Space Center VTB Flight Complex. Credit: NASA/Joe Bibby

the suite of sensors to be able to find a good place and land precisely."

Lasers were required to perform in all types of lighting and environments. "To get the speed of return that they were looking at, to get the improved performance that they were looking at, and to meet the requirements to land at any time, they determined that the lasers provided the best performance," said Jon Olansen.

The velocimeter for example, the Doppler velocimeter, it's a set of three laser beams and that unit itself improves the ability to measure velocity on a spacecraft by almost an order of magnitude, so an almost 10 fold improvement in the ability to measure velocity, how fine you can measure changes in velocity. So it's a significant instrument improvement over what has existed to date.

There are a lot of people interested in just that instrument by itself. Just that instrument can make a big difference in how you fly, so that precision was one of the reasons."

Also the distances the instruments are required to operate from was a factor, "The altimeter, you're going to flying at significant altitudes, you are going to use that for Terrain Relevant Navigation when you are up 10, 20 or more kilometers from the surface."

This fuel used by the lander is a bit different than most space vehicles in that Morpheus is powered by Liquid Methane and Liquid Oxygen. This combination of fuel is relatively safe compared to other rocket fuels, it's a clean burning fuel mix, it is nontoxic, and it can provide up to 321 seconds of burn time during space flight using the current tanks on Morpheus.

The fuel also makes testing much easier since the hazard associated with the fuel mixture is minimal compared to most other rocket fuels. It's referred to as a "Green fuel" since it is not really hazardous outside of its combustibility.

From a storage standpoint, liquid methane does not boil off like liquid hydrogen (LH2). In order to store LH2 you need to keep it very cold, -253C (-423F) to prevent boiling off. The average temperature on Mars for example, is about -60C, so a lander going there would have to have equipment, and fuel to run it, to keep the LH2 chilled.

Using hypergols like the Space Shuttle used for its Reaction Control System (RSC) requires keeping those fuels very warm. Providing this heating or cooling for the propellants would require additional equipment on the lander which adds additional weight to the lander, which would have to be offset by decreasing the payload.

Using liquid methane however, you do not need that extra equipment. This would be useful in terms of a robotic sample return mission, or even a crewed landing. One lander carrying fuel as its payload could land well before the actual mission lander arrived. For example, in its current configuration, Morpheus would be capable of placing an 1,100 pound payload onto the Lunar surface.

ALHAT: Key Mission Facts

- The Autonomous Landing and Hazard Avoidance Technology project will provide a state-of-the-art automated descent and landing system for planetary lander craft.
- Precision landing will be based on a sophisticated, surface-tracking sensor suite with real-time hazard avoidance capabilities – assessing altitude and velocity of the descending vehicle and the topography of the landing site.
- ALHAT algorithms combined with sensor data will navigate the descending craft to the "pre-mission landing aim point," where it will quickly and autonomously identify safe landing areas and help guide the craft to touchdown.
- The technology provides an unprecedented procedure for safe planetary landing procedures – for future crewed as well as robotic missions.
- The technology works in any lighting conditions – from the harsh glare of an unshielded sun to the cloudy, gaseous murk of a distant solar system body.

Also Methane has been detected on Mars and is known to be on Saturn's moon Titan. If the technology to develop liquid Methane or liquid Oxygen, or better yet, both, on another world is invented, then once the equipment was in place to manufacture the fuels, no further precursor missions would be required.

The team behind all this is a small one. They are part of NASA's Advanced Exploration Systems (AES) program, which is pioneering new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond Earth orbit. AES activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle development.

According to Olansen, "It's a relatively small project, probably about 45 – 50 civil servants, and 10 – 12 support contractors. We have people from the Jet Propulsion Lab who are considered contractors that are tied in. We have folks from here at Johnson and at Langley Research Center that are considered contractors. We get a lot of support from a lot of different areas.

"Still a relatively small team, but with a wide variety of backgrounds, it's not one specific interest that drives a spacecraft like this. You could be interested in electronics or electrical engineering, you could be interested in propulsion, you could be interested in operations, you could be interested in the guidance, navigation, and controls aspects, or you could be interested in structures. If you have interest in any one of those areas, they all apply.

"A lot of different interests would have applicability in this, so we have a wide variety of personnel on the team, and they have done a great job of bringing their expertise to the team, as well as learning, because it's also a very diverse team from an experience level. We have some senior engineers who have been doing things for a long time, and they are sharing their experience and teaching folks. It's really a great environment for building the team."

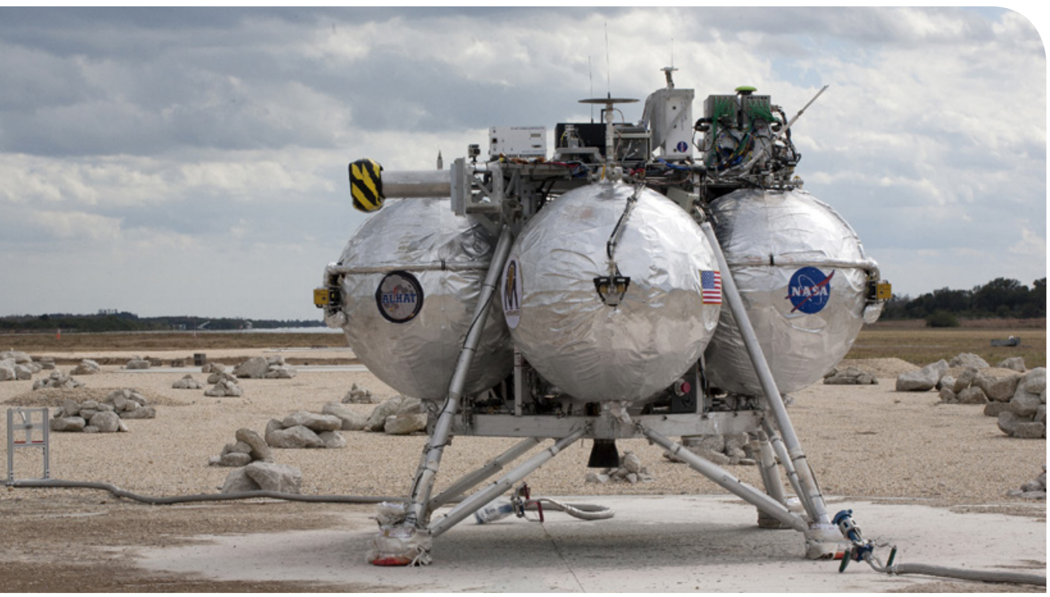
A successful hot fire test of the Morpheus engine in February 2012. *Credit: NASA/Lauren Harnett*

According to Morpheus Ops Lead Ian Young, "On a small project like this that requires all those things, the propulsion guys get a better feel and understanding of what the structures guys requires or what he needs and vice-versa. Versus if you are working on a bigger project, you've got a propulsion team that has probably 50 people on it by itself, so you don't get outside of the propulsion area to see how choices you make my impact somebody else. Where as in this, interacting on a daily basis with just about everyone, there are two or three propulsion guys and two or three structure guys, so if the propulsion guy has a problem, he'll go talk to the structure guy."

Olansen adds "One of the hardest things to grow in an agency like NASA is Systems Engineering. A lot of people come in with discipline specific interests, like Ian was talking about, propulsion engineering, you like rockets, you want to design and test rockets. But to have someone who understands across all of those different systems and how they have to integrate and helps integrate them is a difficult thing to grow. There aren't that many opportunities to experience that type of activity and so this is another thing that this project gives to all those people."

"The lean development was another aspect," says Jon Olansen. "To try and do it without spending a whole lot of money, to use assets that existed, because this is just a prototype. You don't want to build a craft that is too expensive to test. You want to make sure you get as much out of it as you can, but not have so much sunk into it that you are afraid of flying it. So that's a big part of making sure we actually get out there and fly, because we put the vehicle at risk every time we fly."

Another of the team's high level goals is education and outreach. Says Jon Olansen, "The fact that you have a RocketSTEM website, that's right up our alley with what we've been doing since we started the project. That's why all of our tests are streamed live as part of that goal.



The Project Morpheus prototype lander successfully navigated the hazard field and touched down safely after launching into the sky on its fourth free-flight test. *Credit: NASA/Kim Shiflett*

"We've had over 60 students involved in the project as co-ops or interns over the last three and a half years. We've had a couple of high school students as interns as well. We have partnerships with different universities on different aspects of the project. I just received an email from Perdue University, their students have actually built a rocket engine that would fit the Morpheus vehicle and test fired it yesterday. So that's something we will go advertise as well."

So how did we get to this test flight? The project itself started in June of 2010 and the first vehicle was ready to fly just eight months later. The first tests on the "Alpha" Morpheus lander were conducted in 2011, and things did not always go well.

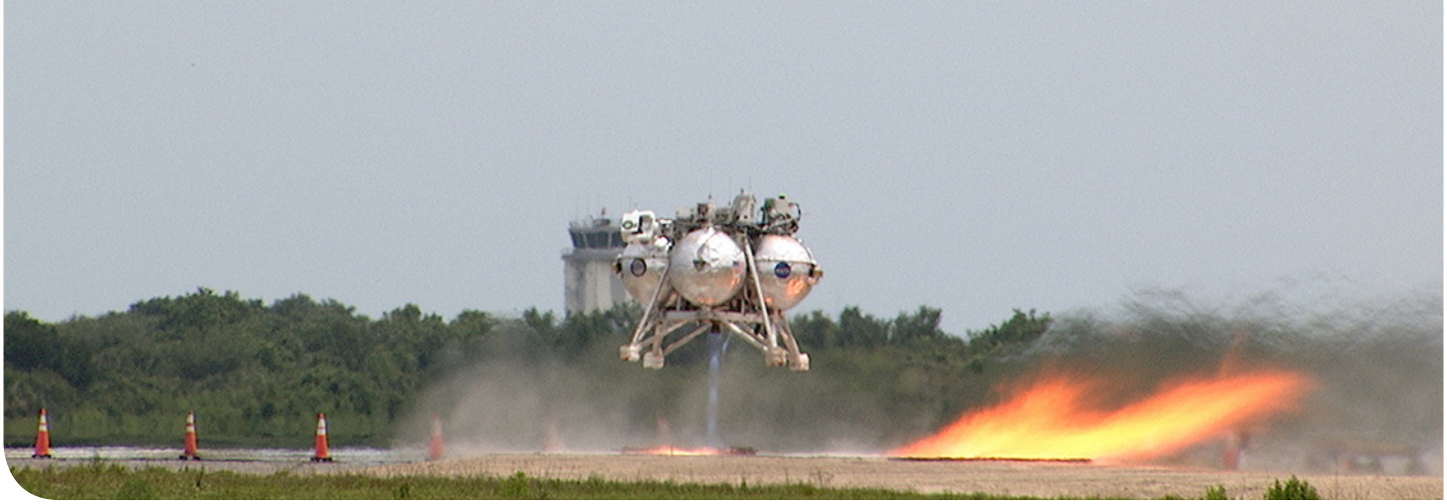
The first test, a tethered test where the lander is suspended from a crane and remains attached to the tether, was supposed to be a 40 second firing where the lander would hover about five feet above the end of the tether, only lasted a few seconds. The vehicle almost immediately pitched over and the thrust termination system ended the test.

Not deterred, the team analyzed the data, made changes and was ready to test again just six days later. A much better outcome resulted and they knew their modifications had them on the right track.

The very next day, another tethered flight gave them even better results. Much work was yet to be done, many more tethered tests and further development of the flight hardware and software would have to occur before any free flights could even be attempted. But the lander was beginning to perform. A total of seven tethered flights were performed before 2011 ended.

In March of 2012, the team rolled out what was essentially a new vehicle. While the structure and Methane / Liquid Oxygen tanks were the same, the vehicle itself was essentially a new vehicle. "The first series of tests gave us a basic understanding of our ability to control the vehicle and allowed us to initially characterize the performance of the subsystems on the vehicle," Olansen said. "With that information we were able to go back and design in upgrades to improve performance and reliability."

Morpheus at this time has a new engine, new avionics, and significant upgrades to the software in preparations for the addition of its Autonomous Landing and Hazard Avoidance Technology (ALHAT) system that will be added later. With all these changes, more tethered tests would need to be performed before any thoughts of free flight could be entertained. A total of 20 tethered tests flights would be conducted before the team would be ready to attempt the first free flight.



Morpheus lifts off on a 98-second, free-flight test on April 30, 2014. It ascended more than 800 feet at a speed of 36 mph, surveyed the hazard field, then flew forward and downward covering approximately 1300 feet while performing a 78-foot divert before coming to rest inside the hazard field. Credit: NASA/Frankie Martin

The first official free flight occurred on August 9, 2012 with Morpheus lifting off under full power, after just a few seconds the vehicle tumbled over and crashed to the ground in a spectacular fireball. The vehicle was virtually destroyed. Data coming from the Inertial Measurement Unit (IMU), which supplies data to the flight computer so it knows which way is up, down, and so forth stopped relaying. Without the data the vehicle was unable to maintain stable flight and crashed.

It is not unusual for failures to occur in testing new systems and the team went back to the drawing board with the data they had learned up through the failed free flight to build an even better lander.

As Olansen said to us, "When I give presentations, I don't shy away from problems we've had, we don't try to hide any of that stuff. Usually when I give presentations I start there. Especially to younger audiences, a lot of what we are trying to convey in that setting is that engineering is not a precise science that you always have to get right the first time. It is a learning process.

"Working through failures, and understanding them, advances learning significantly. Taking appropriate risk early enough in your development process allows you to end up with a much better design later on"

It took just eight months from the time of the crash till the debut of the "Bravo" Morpheus lander. Having learned many things from the previous vehicle's testing, this lander looked the same but 70 upgrades had been made to both the vehicle and the ground systems to improve reliability and operability.

The team had implemented improvements such as advanced engine performance capabilities (while recovering and reusing the primary engine components from the previous vehicle), enhanced communication protocols, redundant instrumentation where appropriate, increased structural margins, and mitigated launch vibroacoustic environments. It was time to test once again.

Starting back with the basics, the team conducted a 50-second static hot fire of the main engine in the vehicle at Johnson Space Center. Included in the test was simultaneous demonstration of thrust vector control (TVC) and integrated methane reaction control system (RCS) jet firings. Thrust vector control is used to balance and fly the vehicle, while the RCS jets are used to keep the vehicle pointed in the correct direction. All worked well and once again tethered flights soon followed, and finally a return to Kennedy Space Center for more testing up to the first free flight attempt of the Bravo vehicle.

Ian Young describes some of the other testing done at Kennedy other than the free flights, "We have a simulation capability, so that the operations team, the folks who sit at the consoles, will actually go up to the control center the day before and we'll run through eight to 10 runs of the flight we are planning to run the next day. We put in failures and react to those. It's good for the team to see the planned trajectory and to talk through any responses to failures. Those SIMS have brought about idea on how we could improve our current design.

We have done a number of tests that aren't flight tests out in Florida also. Sometimes the only way to get integrated data is too actually take the vehicle out and swing it on a crane so we get motion on the

The boulder-strewn hazard avoidance field built to test the Morpheus lander at KSC. Credit: Sherry Valare vehicle, so that the ALHAT sensors and the vehicle can see that motion, and make sure they are coming to the right solution without actually lighting the engine."

The Bravo vehicle roared to life at the north end of the Shuttle Landing Facility on December 10, 2013 to attempt its first free flight. It rose spectacularly on its single rocket engine's pillar of fire, like a ball balancing on the end of a straw. It flew almost flawlessly, rising to about 50 feet in altitude, hovering in place before moving to a landing spot approximately 23 feet from the takeoff spot, landing after about 50 seconds of powered flight. The team had done it; they had a vehicle that could fly. Less than a week later, Morpheus flew again, going higher, faster, and further in an 82 second free flight.

Ten more free flights would be conducted over the next four months, which brings us back to where this journey started, at Kennedy Space Center on May 22, 2014. This will be the 13th free flight for Morpheus, but this one is different than all of the prior 12 since all of those have been "open loop" tests where the team could jump in and take over if need be. This will be the first "closed loop" test, Morpheus will be in complete control of its flight for the first time. The training wheels are off, it's time to fly solo.

The first "closed loop" free flight begins as the engine of the lander ignites and the Bravo vehicle climbs to about 800 feet in altitude, there it hovers and does what is called its Terrain Relative Navigation to make sure the lander knows where it is in relation to the landing site. The lander then moves toward the designated landing area which is a quarter of a mile away from the takeoff spot. ALHAT is surveying the landing area making sure things look good.

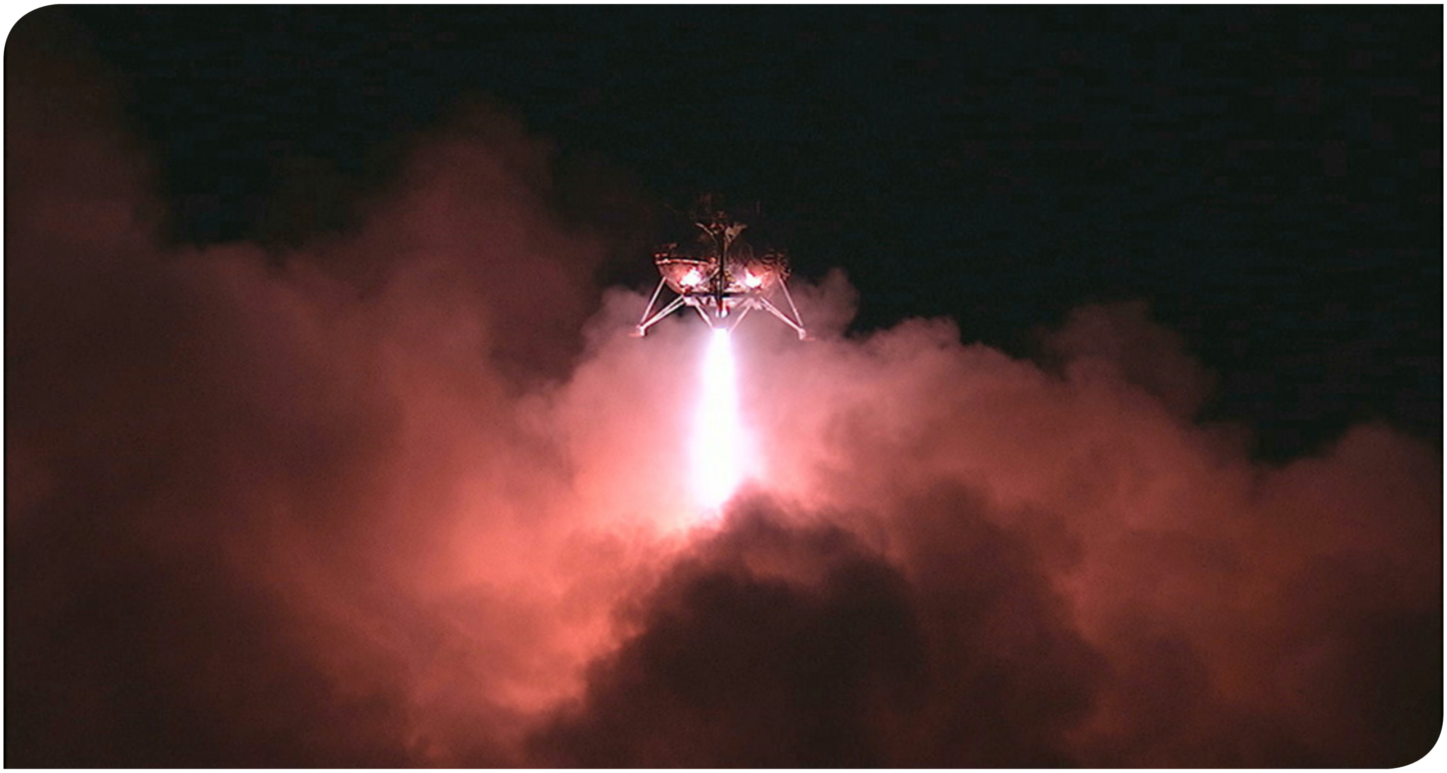
The night flight proved that the lander is capable of entering a completely dark crater and finding an appropriate landing spot, or landing on the dark side of a planet, moon, or an asteroid, where little to no light shines.

While the lander has a designated landing site in the landing field already programmed, that site is littered with boulders and Morpheus should decide that it is not a viable landing spot. Using the information from ALHAT, the lander finds the only appropriate area in the landing field, a concrete pad covered in simulated lunar soil. Its flight path is changed and it lands right where it is supposed to.

Morpheus made another "closed loop' free flight just six days later. This time though it occurred at night, proving that the lander will perform in any lighting conditions. The 98 second flight proved that the lander is capable of, if needed, entering a completely dark crater and finding an appropriate landing spot, or landing on the dark side of a planet, moon, or an asteroid, where little to no light shines.

So what comes after the testing at Kennedy is done? Jon Olansen speculated on that during our visit, "There are a lot of different things that we can do to continue to evolve the technologies. The ALHAT suite of sensors, we will have demonstrated what we call TR Level 6, Technology Readiness Level 6, really they are ready for a mission to pick them up and make them spaceflight ready.

Engineers and technicians check the Project Morpheus prototype lander after it touched down on a dedicated landing pad inside the hazard field at the Shuttle Landing Facility at Kennedy Space Center. Morpheus launched on a free-flight test from a new launch pad at the north end of the facility. Credit: NASA/Kim Shiflett



NASA's Morpheus prototype lander proved it was quite capable of successfully navigating the ALHAT hazard field after finding a safe landing spot during a night-time, free-flight test conducted at Kennedy Space Center on May 28, 2014. *Photo credit: NASA/Mike Chambers*

They will have demonstrated that the capability exists, it's feasible, the algorithms work, and NASA just needs to package them appropriately for spaceflight. That would happen on a specific mission, a follow-on to Mars, the asteroid retrieval mission, or whatever that mission is, if they are looking for any of the sensors, or a combination of all three, that's where they'll pull it.

"We've pushed it to the point where it's ready, and other missions will pick it up and make it spaceflight ready.

"With the LOX and Methane, we need to advance the type of engine that is actually in the vehicle. We need to go to an engine that is actually ready for spaceflight. So, a regeneratively cooled engine where you are actually cooling the nozzle, not with film cooling like we use now, which we're actually flowing cold methane down the inside of the nozzle, but you actually having it flowing through the nozzle to keep it cool. It's more efficient that way and so you can get better performance out of the engine. Some of that development work has to happen in test stands, before you would put it on a vehicle.

"So there's some aspect where we reach a point with the vehicle, now we're going to have to step back off, make some advances outside the vehicle, and then look at when we have to test again in an integrated flight environment. Right now, we don't have specific tests laid out, beyond Kennedy testing for these vehicles, but they are available as we evolve."

Engineers in the Morpheus Control Room monitor the Morpheus lander as it lifts off on the first free flight test at night. *Credit: NASA/Kim Shiflett*

The night flight would be the 14th and last free flight for Morpheus, at least for now. The Morpheus project, while not done, is at least a stopping point as far as flying goes. What will come next for the lander, and its talented team is yet to be determined.

The ALHAT technology is apparently proven and hopefully will be used someday soon to land a rover, fuel, or even astronauts on a surface other than Earth's. Further development of the LOX / Methane propulsion system will hopefully see the Vertical Test Bed lander fly longer, higher, and further than ever before.

For more information about ALHAT, visit: http://alhat.jpl.nasa.gov/.

For more information about Project Morpheus, visit: http://morpheuslander.jsc.nasa.gov/.

For more information about NASA's Advanced Exploration Systems program, visit: http://www.nasa.gov/directorates/heo/aes/#.U5HcNvldXuQ.

Starting in astronomy

beginner's guide to stargazing

By Mike Barrett

All about the Earth's Moon

As this issue commemorates 45 years since the first human placed foot on the Moon it seems rather fitting to feature the Moon in this astronomy item. As we all know the Moon is our nearest astronomical body at about a quarter of a million miles or 405,000 Km away. Unlike other planets in our Solar System the Earth only has one natural body orbiting it, which we call the Moon.

Our moon is known by many names, but the most common are the Moon and lunar. Lunar is an anglicisation of the Latin for Moon which is Luna. Almost all space missions that go to the Moon are called lunar missions rather than Moon missions. The naming is used interchangeably, though lunar is more associated with scientific references and the Moon more with literary and artistic fields.

The Moon is, of course, very special to us. It frequently occurs in myths and mythology, but far more importantly it affects our physical world in the governance of the tides in the oceans and seas and in our calendars.

The gravitational influence of the Moon attracts the water on the Earth, which pulls it toward the Moon, thus creating the tides. The pull of the Moon creates two bulges in the seas on Earth which are pulled round with the Moon forming the twice daily high and low tides. The Sun also has some gravitational pull, albeit about 10 percent of the Moon's gravitational effect, which in combination with the Moon creates the extra high spring and extra low neap tides.

The Moon takes about 27.5 days to orbit the Earth forming a complete lunar cycle. The lunar cycle gave ancient civilisations a reference to mark time by, in addition to the rising and setting of the Sun on a daily basis, the Moon goes through its cycle in about 28 days. This gave rise to the calendars that use the lunar cycle as a basis for measuring longer time periods. Lunar calendars still are very important throughout the World with the Chinese New Year being determined by the Moon. The Islamic and Christian Calendars both are influenced by lunar events making the Moon a very important part of our culture.

We only ever see one side of the lunar surface. This is because the Moon is tidally locked to the Earth. Tidal locking is caused when one body (the Earth) creates a gravitational influence on another body (the Moon) changing its rotation rate to match its orbital period. This means that the Moon rotates about its axis once every time it orbits the Earth. This is the reason we only ever see one side of the Moon.

You would expect that as the Moon is tidally locked we would only see half of the surface. This is not quite true as there is an effect known as libration allowing us to see about 59 percent of the lunar surface. Libration occurs primarily due to the fact that the Moon's orbit is not perfect. The slight changes in the orbit combined with the changes in the Earth's orbit allow the Moon to either lead or follow us slightly. This in turn leads to more of the surface being exposed at the edges.

The Moon has, obviously, been visible throughout humanity, but one of the first serious attempts to map the visible surface was made by the legendary British astronomer Sir Patrick Moore. In fact, the quality and detail of Sir Patrick's maps formed the basis for the American Apollo lunar landings after having published "A Guide to the Moon" in 1953.

The Far Side of the Moon, often called The Dark Side of the Moon, is the half of the Moon that we cannot see due to the tidal locking. As mentioned above we can actually see 59 percent of the lunar surface so only 41 percent remains unseen from Earth. Indeed it was not until 1959, 55 years ago, when the Soviet probe Luna 3 took images of some of the far side that we started to get a clue as to what this looked like. Since this time many of the lunar missions have imaged the entire Moon and we have a complete picture of the entire surface. These images revealed a lunar landscape almost completely covered in craters.

The Moon's surface is interesting, particularly the contrast between the visible and the far sides. On the visible side of the Moon the surface has a good mix of 'seas' and craters, whilst the far side only has a single sea (visible during librations) with the remaining surface being pocked with craters. Although the Moon shows evidence of early volcanic activity it is widely accepted that the craters visible on the surface were created from impacts and are not volcanic in origin.

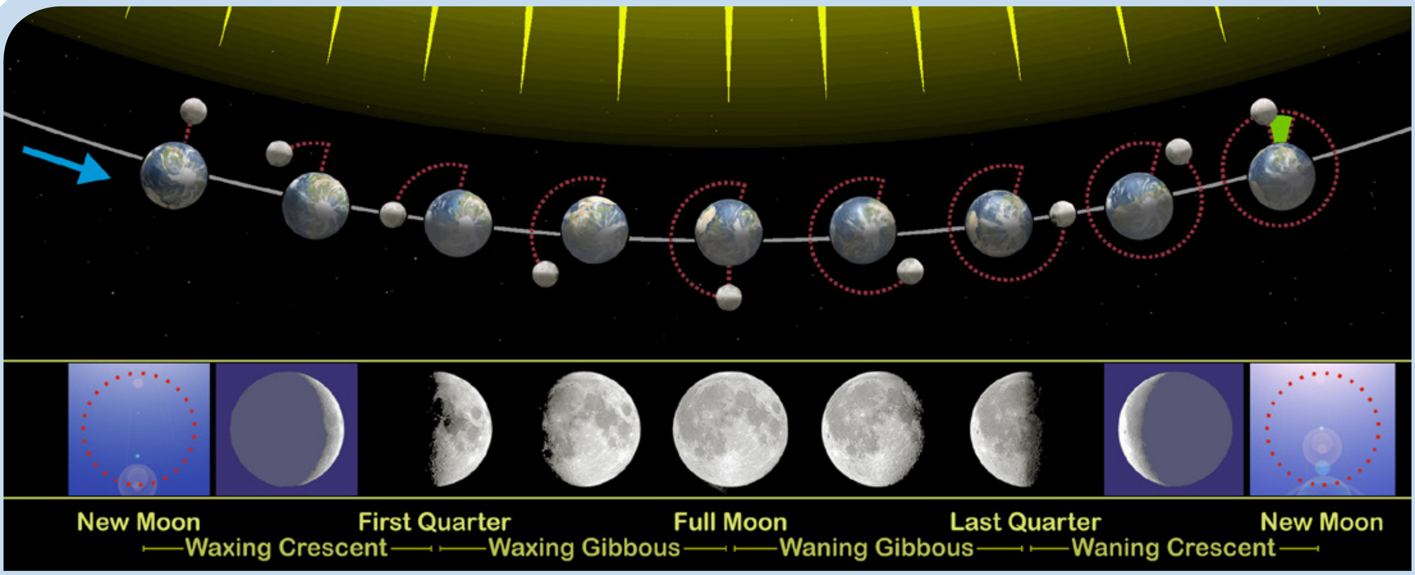
The lunar seas were created via volcanic eruptions with the resultant lava flooding the lower features of the lunar surface creating the huge expanses of relatively flat plains. Over the millennia these laval seas have been peppered by impacts from meteors and comets creating the impact craters seen on the surface. The most spectacular of these are Tycho and Copernicus both easily visible with binoculars.

On Earth our dense atmosphere provides a barrier to all but the largest impactors. The friction of entering our atmosphere causes the particles to heat up and burn providing us with the illuminated shooting stars in meteor showers. This means that only a very small number of meteorites make landfall.

As the Moon has very little atmosphere there is nothing to stop meteors crashing into the surface. With no protection from the objects flying through space the surface of the Moon is dotted with impact craters. One feature of these craters is the ejection of surface matter from the impact that can spread out for many miles from the crater. This can be seen as the lighter areas surrounding the crater, and often will form as rays emanating from the impact zone.

Of all the features of the Moon the most spectacular, easily visible, and obvious are its phases. This refers to the transition of the Moon from New Moon to Full Moon and back to New Moon again. The cycle starts at New Moon, with completely dark skies. The next seven days see the crescent moon gradually increase in size until the Moon is half illuminated. This is known as the first quarter. The illumination continues to cover more of the Moon until half way through the cycle when the entire surface is shining.

So we can see that the Moon exerts a strong influence on all of us, from the romantic to the scientific. Without the Moon we would have no tides, and our timekeeping would have evolved in a very different way.



The relation of the phases of the Moon with its revolution around Earth. The sizes of Earth and Moon, and their distance you see here are far from real. On this image the following also are depicted: the synchronous rotation of the Moon, the motion of the Earth around the common center of mass, the difference between the sidereal and synodical month (green mark), the Earth's axial tilt. *Credit: Orion 8 via wikipedia.com*

Moon phases: Past present and future

By Christine Nobbe

Take a look tonight at the Moon. What lunar phase do you observe? If you and your students want to learn more about the lunar phases before studying the night sky, we recommend: http://bit.ly/RShiwaay.

Observing the Moon night after night and either photographing the phase or drawing it, is a good way to understand the natural rhythm of the Moon, Sun, and Earth, but it doesn't explain why the phases occur. A simulation of the Moon traveling around Earth helps students of all ages understand the patterns. Two sites are suggested with the second the simplified version: http://astro.unl.edu/naap/lps/animations/lps.swf and http://bit.ly/RSmcgraw-hill.

With an online lunar phase calendar you and your students can discover the lunar phases for dates past, present, and future! Students love looking back in time and finding the phase of the Moon on their day of birth and looking forward in time to discover the phase of the Moon on a future birthday. There are many lunar phase calendars available but a good one to try is: http://bit.ly/RSalmanac.

The page opens to the current calendar; scroll down for past and future calendars.

Studying the Moon phases each night might awaken your curiosity about the Moon. One NASA website is devoted to Earth's Moon, http://moon.nasa.gov/home.cfm, where you can learn about the Moon, missions to the Moon, and how you can be involved in studying it as a citizen scientist. Take a look at the Moon tonight! Or as social media enthusiasts say, #WinkAtTheMoon.

An eclipse of the Sun at sunset over Monument Valley, Utah shows the Moon gradually moving off revealing the surface of the Sun. *Credit: Mike Barrett*

Take a closer look at the Moon

Observing the Moon

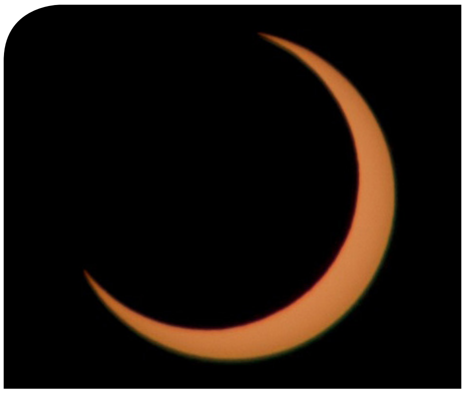
The object of the month this time is the closest celestial body to us: the Moon.

The Moon plays a big part in Astronomy for a number of reasons, the main one being light. Although the Moon does not generate light itself, it acts as a giant reflector for the sun. When the Moon is full it reflects enough sunlight to create shadows on the ground. It is even possible for the Moon to reflect sunlight that is itself reflected from the Earth. This is called earthshine.

Earthshine occurs during the new Moon lunar phase when a small amount of sunlight is reflected from the Moon creating a crescent Moon and sunlight reflected from the Earth illuminates the rest of the Moon. The earthshine is far fainter than the moonshine but it does let you see the entire Moon.

For astronomers the Moon can be quite inconvenient. The light it reflects has the effect of flooding the night skies and obliterating the faint stars, galaxies and nebula for all periods other than around new Moon. Of course this does give us at least one celestial body to observe, which is probably why the Moon is the most popular object for astronomers.

The phases of the Moon determine what an observer can see. At new Moon there is nothing visible of the moon and with clear dark skies the wonders of the Universe are opened up to us. As the nights progress a crescent Moon appears then fills out over the nights until seven days later the waxing Moon is at first quarter or half moon. During this period the Moon rises during the day and sets in the early evening, gradually rising later in the morning and setting later in the evening. A further seven days later there will be a full Moon when the moon rises at dusk and sets at dawn and is in the sky all night. During the period from first quarter to last quarter the skies will be washed out and little observing can take place. Finally as the waning Moon enters the last quarter it rises later in the evening and sets during the daytime. It is during this period that observing during the night can take place before the Moon exerts its influence on the night skies.



Using a solar filter this annular eclipse was shot using a Nikon camera with a 70-200mm zoom lens, the mountains of the Moon can be seen at the edges backlit by the Sun. *Credit: Mike Barrett*

To observe the Moon one might expect that the best time would be during the time around full Moon. To a certain extent that would be correct, but really the proper answer to the question is any time that the Moon is in the sky, even during the day.

Although at full Moon the entire surface of the Moon will be visible this is actually not the best time to look at it. The best details are observed during the waxing and waning of the Moon. It is at this time that the terminator can be seen. The area around the terminator shows a lot more detail of the surface of the Moon due to the angle that the sunlight hits it. This creates shadows revealing much more detail in the craters, which look completely different than when they are fully illuminated. As the days progress and the more of the Moon is revealed different parts of the surface are exposed at the terminator.

Viewing the Moon

Viewing the moon can be done without any optical equipment. The seas are clearly visible and, of course, the daily changes between crescent Moon and full Moon can be seen.

A small pair of binoculars will enable more of the detail of the Moon to be discovered, the major craters of Tycho and Copernicus are clearly visible along with more minor ones. The seas become more delineated with the boundaries being particularly visible.

Moving up to a telescope at low power the entire sphere of the Moon can be viewed in the eyepiece. Changing to a higher magnification allows you to zoom in on the detail of the lunar surface, and will reveal great delights along the line of the terminator. At these higher magnifications you are more subject to the turbulence of the atmosphere, which will make the view shimmer in the thermals, but on a steady night will allow intricate details to pop into focus. The trick is to keep looking and over time you will get some stunning views.

Imaging the Moon

Imaging the Moon can be quite a challenge, the main problem being getting the exposure correct. To achieve this you really need a camera with manual controls. When looking at the Moon it appears quite large in the sky, which it is compared to the stars, but through a camera lens it is quite small. Most cameras will average the exposure for an image which means that with the majority of the frame being dark the surface of the Moon will be vastly overexposed and no detail will be visible. When setting the exposure manually the effects of the background can be eradicated and the details of the Moon can be imaged.

An early phase of a lunar eclipse as the shade of the Earth slides over the Moon's surface. Note there is no sharp transition from light to dark. Credit: Mike Barrett

There are a multitude of ways that the Moon can be imaged. Firstly it can be captured as part of a landscape image, this will be very tricky with exposure settings as mentioned above. The best option for a landscape is to merge two images, one exposed for the landscape and one for the Moon.

A friend of mine takes an artistic approach to imaging the Moon. Using a long telephoto lens of about

Using a William Optics GTF-81 and a Canon T3i clearly shows the features of the Moon including the terminator to the left hand side. Credit: Mike Barrett

500mm he gets a nice large Moon but he focuses on something like a leaf or branch in front of the Moon. This throws the Moon out of focus acting as a circular light source with the subject in the foreground.

It is even possible to image the Moon and the Sun together in an eclipse without filters, but great care needs to be taken to avoid damage to your camera, and more importantly yourself. **Never look at the Sun directly or through a telescope without the correct filter to ensure that you do not damage your eyes. If in doubt do not do it.** The eclipse image here was taken using a special solar filter. The second landscape image of the partial eclipse was taken at sunset over Monument Valley when it was safe to take a photograph with no filters.

Two weeks after a full eclipse there will be a lunar eclipse. During the lunar eclipse you can safely take images of the moon as the Sun will not be in the sky. During the lunar eclipse, which always occurs during full Moon, the Moon passes through the shadow of the Earth. As it enters the shadow the Moon dims, but with no sharp delineation as with a solar eclipse, when it enters the Earth's shadow it turns red, which leads to the term "Blood Moon".

A more traditional image of the Moon can be taken with a medium telephoto lens on a DSLR camera. Using a tripod to steady the camera an image can be taken which will show good detail of the Moon. The image will only cover a very small part of the frame, but can be cropped to produce a reasonable sized picture with lots of detail. It is always good practice to take a number of images at different exposures to enable you to process and select the best ones on your computer. The example images were taken with a Canon T3i camera and a 200mm lens with an exposure of 1/125 second at f11 and ISO 100. This was for a full Moon, and can be used as a starting point. At other times of the month the Moon will reflect a lot less light so the exposure will need to be adjusted accordingly.

For even closer images then you need to start using a telescope with a DSLR attached to it. This setup is the type that was described in the previous issue. Telescopes have a focal length starting at around 450mm (in DSLR terms) and going right up to 1250mm and beyond. The same techniques apply as for shooting with a DSLR and normal lens with the exception that the f-stop is fixed so the ISO and shutter speed need to be adjusted to get the best exposure.

Using a cheap webcam the surface details of the moon can be seen clearly. Credit: Mike Barrett

To get really close images of the features of the Moon a Planetary or WebCam attached to a telescope is required. This will allow you to get incredibly close pictures of the lunar landscape. The problem with this is that the atmosphere of the Earth makes the images very distorted and unstable. To overcome this a technique has been developed that takes a video then processes the individual frames of the video dropping the bad ones and combining the good ones to create some stunning images of the features of the Moon.

Next issue I will cover the basics of this imaging and processing which applies to planets as well as the Moon.

Cash prizes have often spurred advances in humanity and technology, and the same is hoped will happen by the foundation behind the Google Lunar X Prize.

Teams vie for $20 million lunar prize

By Sherry Valare

The race to the Moon is on. However, this race isn't a pride-filled competition between nations. Now it is several teams consisting of engineers, entrepreneurs, and anyone with a vision, racing to build a moon roving robot – to the tune of $30 million in prizes. The Google Lunar X Prize is a next-generation competition that will have self-funded teams create cost-effective rovers that can land, roam and complete tasks on the moon. There are even some big brand names on board - such as SpaceX and the SETI Institute – working as allies in providing services to assist the competitors.

The X Prize Foundation is a non-profit who is on a mission to better humanity with breakthroughs that inspire growth and new formation of industries, and provides a nudge to markets currently stuck in a pessimistic rut. It creates high stakes prize competitions, where the winner's solution far outweighs the price of the award value. These competitions push great minds to think outside of the box in solving the grand challenges of the world. Incentives create drive. Motivation and inspiration are born from incentive based awards - and offering a $30 million dollar prize bounty demonstrates the difficulty it takes to achieve landing a lunar rover – in practice, and in cost.

Here is how this works. The privately funded competitors will build a robot and successfully land it on the Moon. Once it lands, it must move a minimum of 1/3 of a mile (500 meters), and send high definition video and imagery back to Earth. The team to finish the mission requirements prior to the end of 2015 will win a grand prize of $20 million. The second place finishing team will win $5 million. Additionally, another $4 million is allotted as bonus prizes for completing other specific incentives, and $1 million is awarded to the team that most strongly attempts to encourage diversity in the space exploration field.

X Prize and Google announced in 2013, a set of Milestone Prizes – additional prizes that allow more teams to win a part of the purse – as recognition for the technological achievements, as well as financial walls the teams had to deal with. Some Milestone Prizes categories include development of space hardware, launching the vehicle, or reaching certain distance away from the surface of the Moon.

The global aspect of the competition allows for fresh ideas and players with an array of knowledge that contribute to the creation of each team's spacecraft. The X Prize Foundation believes that diversity in nationality, gender, age group, and profession is necessary and therefore opens up its competitions with almost no exclusions as to who can participate. Their hope is that their contests will open up the opportunity to form an assorted pool of participants that is typically very limited.

Now, to meet the teams! Here are the 18 remaining competitors:

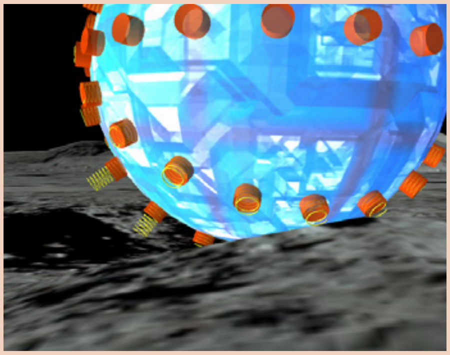
Barcelona Moon Team

Barcelona Moon Team is a multidisciplinary joint venture bringing together Spanish entrepreneurial, industrial and academic capabilities.

Headquartered in Barcelona, we are the first Spain-based team to enter the competition and through our official participation in the GLXP, we want to promote collaboration between the Spanish Aerospace industry, academia and the whole of society, for the GLXP is an amazing project that poses new challenges and fosters enthusiasm in a growing industry such as the Catalan and Spanish aerospace sector.

The price must be considered a stimulus, for the budget can be even higher than those $30M, but the real goal, for us, is to develop steps and synergies for longer term plans for an appropriate exploitation of space.

SpaceMETA



The SpaceMETA team is formed by several people with good experience in startups and new ideas and trends in the market.

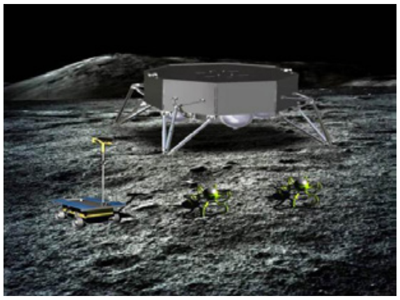
Founded by Mr. Sergio Cabral Cavalcanti, from IdeaValley in the Petropolis City in Rio de Janeiro, born in Natal in the north of Brasil, Mr. Sergio has a real passion for rupture innovation and near impossible challenges.

After brainstorming with friends on the beaches of Rio de Janeiro, the group decided to go ahead with the dream to land on the Moon, and after that, several ideas on how to do it on an innovative and uncommon way was born in their minds -- which became SpaceMETA.

Due the super cooperation by the XPF Team, the SpaceMETA crew feel couraged to move ahead and to start their incentive for the entire community in Brasil.

Now, each day, the SpaceMETA team is growing and receiving collaborators from all parts of the world.

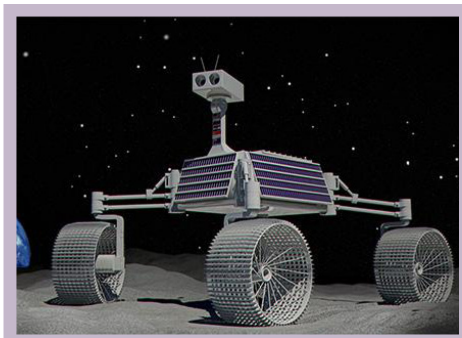
Team Italia



Team Italia proposes reliability and costs as driving criteria for the mission design. Therefore high TRL equipments will be preferred to contain the costs, still taking into account advanced solutions – typically technologically refined - to reduce the overall mass. It should be underlined that the goal of the mission is the success; scientific objectives should be read as secondary. A soft landing, achievable thanks to a cluster of dedicated thrusters is preferred. The landing will occur after few days orbiting around the Moon to finalize commissioning operations.

Team SpaceIL

SpaceIL is an Israeli nonprofit organization working to land the first Israeli spacecraft on the moon. The organization was founded in 2011, when three young Israeli engineers undertook upon themselves to enter the international GLXP competition. Today, SpaceIL is led by CEO Eran Privman (PhD) together with the three co-founders: Yariv Bash, Kfir Damari and Yonatan Winetraub. SpaceIL has nearly 20 full-time staff and more than 250 volunteers. SpaceIL is the only Israeli team in the competition.



STELLAR

The Moon has always been inaccessible to individuals and private businesses due to high costs of space travel and explorations. Team Stellar's mission is to develop a new business approach to exploration of space and creation of new technologies.

Synergy Moon

InterPlanetary Ventures, the Human Synergy Project, and Interorbital Systems have joined forces to become Synergy Moon, the newest team to enter the Google Lunar X Prize race to the Moon. With working groups in 15 countries, the Synergy Moon team actively promotes international cooperation in space exploration and development. Synergy Moon will use a lunar-direct launch of an Interorbital Systems' modular NEPTUNE rocket to carry a lunar lander and at least one rover to the surface of the Moon before the end of 2012. That rover will, at a minimum, travel 500 meters across the lunar surface, and transmit video, images, and data back to Earth. Synergy Moon will prove that an international, private-sector team can do what has never been done before: move private enterprise into space beyond Earth orbit.

California Space Authority Board Member Celeste Volz Ford commented on the link between science and the humanities, "For the space enterprise community to maintain its edge in the global space market, our future workforce is going to consist of engineers who think like artists and artists who think like engineers." Speaking on the future of space exploration, Nicolas Peter, a research fellow at the European Space Policy Institute, commented "This adventure will be driven primarily by a quest for knowledge, involving not only the hard sciences, but arts and humanities as well." The Synergy Moon team is unique in that its members personify an eccentric, electrifying merge of the arts and sciences.

Plan B

"Team B" is an initiative from privately funded Canadian company Adobri Solutions Ltd. Our mission is to utilize existing technologies to produce small weight vehicle capable of traveling to and transmitting data to/from the Moon surface.

Delivery of a vehicle to lunar surface planned by a probe/craft with fixed impulses engines. Main weight target on low-earth orbit for a probe and vehicle total is 100-150 kg. Flight schema will include two orbit correction impulses, one main and one brake impulse with direct arrival to the moon surface and soft landing with air-bags assistance.

Two launches are planned to succeed in winning the Google Lunar X Prize. Results, mistakes in design, errors in calculation, and bugs in software on first mission will give valuable input for the second craft/probe re-design and second launch planned nine months later.

Our Canadian "Team B" is considering to deliver to the lunar surface a hockey ice puck to make a symbolic face-off on the Moon.

Team Indus

Team Indus is a non-conformist, unconventional alliance of dreamers and explorers who will not stop short of asking for the moon.

Team Indus is India's only entry for the Google Lunar X Prize.

Team Indus' founding team is eclectic to say the least – it features a former Air Force pilot, a management guru, a branding expert who is also a turnaround honcho, a serial entrepreneur and an aerospace engineer with a passion for space. As disparate they may be on paper, they are all bound by their sheer passion and determination for this project, and by their unshakeable conviction in the Indian Entrepreneurial Spirit.

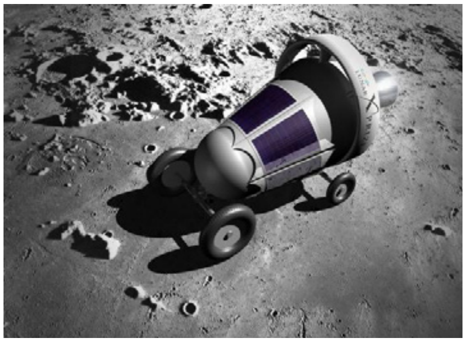
The team's Advisory Board features some of India's revered thought leaders from various industries, who truly believe in the the ability of this team to succeed.

Team Indus is on a mission to lead India into the next generation of space exploration and aviation technology. And while they are at it, they intend to redraw the boundaries of private initiative, inspire an entire generation of dreamers, and unforgettably impact entire communities.

And they mean to do it…It's just rocket science, after all.

Hakuto

Hakuto is currently active and working on its currently unnamed spacecraft. This Japanese team is led by Takeshi Hakamada.



Euroluna

The European Lunar Exploration Association (Euroluna) team is a group of friends and relatives with engineering backgrounds who have gathered to compete for the Google Lunar X Prize.

The team, whose ages span from 16-60, is headquartered in Denmark, with members in Switzerland and Italy. The background of the team spans most of the necessary technical disciplines, from software, through chemical and mechanical engineering, over risk assessment to business administration. According to the team, the members have been discussing moon rovers and lunar bases for at least 10 years now.

The team is led by Palle Haastrup, President of Euroluna. Haastrup has a Master of Science in Chemical Engineering, a Ph.D. in Risk Assessment, supplemented by a MBA from the Harriot Watt University in Edinburgh, UK. He has been active in research in the fields of risk and environmental assessment with associated information technology tools for the last 25 years. In his career, he has held various positions as team leader in universities, consultancy companies and research centers. He continues to hold a position as action leader at the Joint Research Centre in Ispra.

Independence-X

Independence-X is currently active and working on its spacecraft, "Independence Lunar Rover – 1 (ILR-1)". This Malasian team is led by Mohd Izmir Yamin.

Team Puli

Team Puli is a dedicated team of young Hungarian professionals and space enthusiasts, named after the Puli, a dog-breed long used by shepherds for the protection and guidance of livestock in Hungary. Pulis are revered for their extraordinary intelligence, obedience and playful temperament. Pulis' unique appearance and capabilities easily distinguish them from other dogs, just as Team Puli aims to be different from any other GLXP Team.

Through the Google Lunar X Prize, we will show that we can invent and apply new technologies to develop a lunar lander rover which is conceptually novel, and send it to the Moon.

We are an innovative engineering team, which, over a longer term, aims to become a prominent player in the growing space industry. A top priority for us is to promote scientific thinking through our quest, especially in Hungary, and make science more popular among students. Building on Hungary's previous major scientific achievements, we hope that the success of Team Puli will offer another fantastic example that nothing is impossible for Hungarian engineers and scientists, and we can compete with anyone anywhere in the world.

Omega Envoy

Earthrise Space Foundation (ESF) is a non-profit corporation dedicated to developing space technology in collaboration with industry and academic institutions. ESF seeks to leverage experience gained through its Omega Envoy project to create the first viable commercial lunar delivery service to support future space transportation infrastructure.

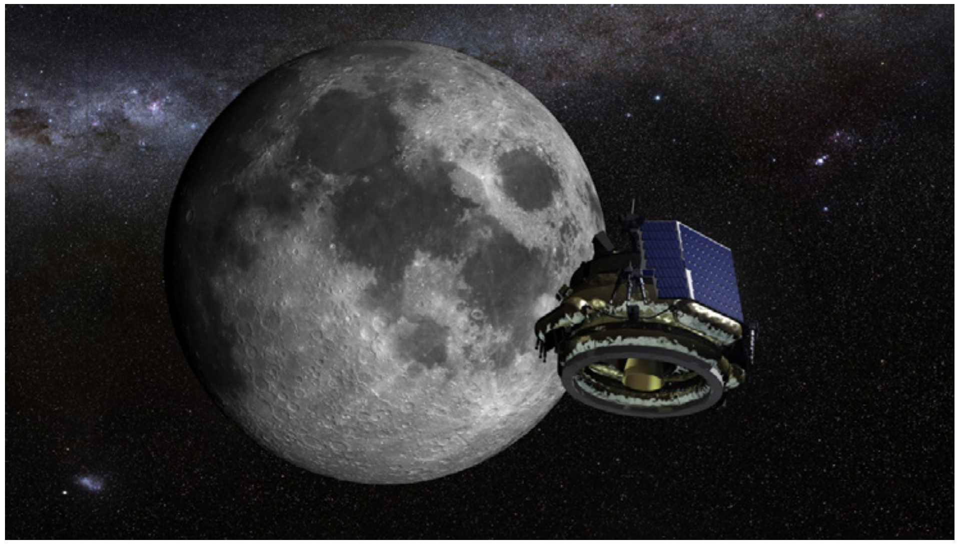
ESF provides services to private companies, government agencies, and educational institutions that have the resources to explore space and are looking for low cost products to meet their mission requirements.

Through the Google Lunar X Prize and government contracts such as the Innovative Lunar Demonstrations Data Contract from NASA, ESF's initiatives enable the creation of new technology and systems to support lunar exploration while increasing the Technology Readiness Level (TRL) of innovative, commercial space systems.

Moon Express

Moon Express was selected by Forbes as one of the 'Names You Should Know' in 2011. Moon Express is a privately funded lunar transportation and data services company based at the NASA Research Park in Silicon Valley.

The company plans to send a series of robotic spacecraft to the Moon for ongoing exploration and commercial development focused on benefits to Earth and has signed a partnership agreement with NASA for the development of its lunar lander system.



Moon Express was founded in 2010 by Dr. Robert Richards, a founder of International Space University, who serves as President and CEO; Naveen Jain, a philanthropist, entrepreneur and technology pioneer who founded Intelius and InfoSpace and serves as Chairman; and Dr. Barney Pell, a former NASA manager and active parallel entrepreneur who founded Powerset and serves as Vice Chairman and Chief Technology Officer. The Moon Express founders also work together as Trustees of Singularity University. Moon Express has been selected by NASA for a lunar data services contract worth up to $10M. It is also one of only three U.S. companies to receive the first $500K delivery order under NASA's Innovative Lunar Demonstrations Data (ILDD) program.

Part-Time-Scientists

The Part-Time-Scientists team is the first Google Lunar X Prize participant based primarily in Germany. The PTS team consists of dozens of scientists, engineers, and entrepreneurs from several countries around the world.

The efforts of team members are coordinated over the Internet from their headquarters in Berlin. The team is funded in part by donations from individuals, as well as monetary and technical support from key sponsors. The PTS team is perhaps the youngest team in the GLXP, and draws on members from a number of technical disciplines including physics, information technology, electrical, mechanical, and software engineering.

Astrobotic

Astrobotic is currently active and working on its spacecraft, "Red Rover". This American team is led by Dr. William "Red" Whittaker.

Penn State Lunar Lion Team

Featured in this month's issue of RocketSTEM (see article on page 20), the Penn State Lunar Lion Team is a combination of Penn State students and faculty combined with engineers from Penn State's Applied Research Laboratory aimed at fulfilling the requirements of the Google Lunar X Prize. The team draws on Penn State's extensive expertise in electrical, mechanical and aerospace engineering which includes experience in drafting, fabrication, assembly and testing. The team is pursuing partnerships with companies throughout the aerospace industry to strengthen the project.

AngelicvM

The leader of Team AngelicvM, Gerardo Rocha Haardt, a former airline pilot in the United Arab Emirates, subscribed to the Foundation X Prize Newsletter, which, after his return to Chile to assume as President of Santo Tomas Chile, inspired him to seek out Chileans with expertise in the field of space in order to register the national team as participants in the lunar competition.

Today Team AngelicvM had featured in meetings organized by Google Lunar X Prize, with an outstanding participation at the Team Summit in May of 2012 in Washington, D.C., where it won the prize for the most surprising presentation, given the comparative progress with the other teams who had the advantage of several years in competition. Members of Team AngelicvM are invited by NASA and other institutions around the world to expose on their development.

AngelicvM participated as sponsor of the "Global Aerospace Summit 2012 in Abu Dhabi, capital of the United Arab Emirates that attracted the maximum exponents of the world in the field of space, such as Boeing, Virgin Galactic, Arianespace, EADS, Airbus, among others." AngelicvM was also recently accepted as the sponsor of the "Global Aerospace Summit 2014".

Team AngelicvM is preparing to meet the launch date of its Rover within the time period stipulated by the contest, and thus place Chile on the Moon for the first time, incorporating Chile into the international space community in the private sphere.

MoonBots Challenge inspiring kids

The MoonBots Challenge is an interactive competition that emulates the real Google Lunar X Prize and increases students' interests in STEM (Science, Technology, Engineering and Math). The challenge is considered a "game of skill" and is designed to help youth teams learn how to produce videos, create digital platforms, design playfields, program Lego Mindstorms robots, and inspire their generation through a variety interactive STEM outreach projects. At the end of the two phase competition, a grand prize winner is awarded to an once-in-a-lifetime science based experiential prize.

Who can participate? The challenge is geared for a youth audience between the ages of 9 years to 17 years and is open to children all over the world. The mean age for this contest is 12 years old; however, much younger and older students do participate and perform equally well. Youth form teams of 3-5 members with one adult captain 18+ years old acting as the mentor of the team. Teams can be made up of friends at a local public/private/home school, or kids from an afterschool program like Scouts, 4-H, or a robotics clubs. The most important asset a MoonBots Team can bring to the competition is their willingness to want to learn about lunar exploration.

Why did the Google Lunar X Prize create this competition? There are many reasons for creating this competition. We want to reach youth from all over the world and create a youth based community that wants to learn about the Google Lunar X Prize, lunar exploration and all of the cool things that you can do in space. This Challenge is innovative, exciting and free. Teams get to showcase their work to people in their local community and all over the globe. Students get to work with their friends on a project and use social media platforms to interact with one another. We want every student that participates in the MoonBots Challenge to have a great experience and get a taste of what it is like to be a part of the Google Lunar X Prize.

Where can I learn more about the yearly competition? You may visit www.moonbots.org for more information.

What is Moonbots-in-a-Box? MoonBots-in-a-Box is a spin-off educational project of the MoonBots Challenge. This project has been specially created for Science Centers to use with audiences all over the world. Participants will get an opportunity to show off their robotics skills by maneuvering a one-of-a-kind Google Lunar X Prize Lego Mindstorms robot on a specially designed moonscape playfield.

To see if your science center is offering MoonBots-in-a-Box please visit www.googlelunarxprize.org/education/moonbots-in-a-box.

Penn State students aim for the Moon

By Cameron Corrie

The Lunar Lion spacecraft depicted as it leaves Earth's orbit.

Landing a spacecraft on the Moon is an audacious undertaking, one that has only been accomplished by three nations of the world, the United States, Soviet Russia, and most recently, China. However, in December 2015, that will all change as the Pennsylvania State University's Lunar Lion team will attempt to go to the Moon and win the much sought-after Google Lunar X Prize and earn a place in history as the first ever university to actually land a spacecraft on the Moon.

The Lunar Lion team is relatively new to the Google Lunar X Prize competition, officially announcing its intent to go to the Moon just this past year. They join a group of 17 other participating teams from around the world, some of which have been preparing since the inception of the prize back in 2007.

Despite the late start, the Lunar Lion team has quickly risen to the challenge, under the leadership of Michael Paul of Penn State's Applied Research Laboratory. Paul holds the title of Director of Space Systems Initiatives. Prior to his work at Penn State University in 2009, he held a position at Johns Hopkins Applied Physics Laboratory and was the Spacecraft Systems Engineer for NASA's MESSENGER spacecraft that was sent to study the planet Mercury. In addition, Paul was active in the development of the twin STEREO spacecraft currently observing the Sun.

His educational background includes an M.S. in Applied Physics from Johns Hopkins and a B.S. in Aerospace Engineering from the University of Notre Dame. Paul leads a multidisciplinary team of roughly 100 members, spanning almost every imaginable major, from aerospace engineering to theatre. There is a role for anyone who is interested and committed to the project.

Simplicity is the main factor in Penn State's approach to winning the Google Lunar X Prize.

While many other teams are developing multiple vehicles such as a rover and lander for exploring the Moon, Penn State's Lunar Lion is the spacecraft, lander, and rover all rolled into one convenient package that will minimize points of failure and reduce weight. To further cut costs, they avoid the creation of new parts and materials wherever possible. Instead, they rely heavily on existing surplus materials and designs that are all tried and true - a technique heavily employed by the big players in space exploration. Fellow competitors are designing their components from the ground up which is a major hindrance in terms of cost and reliability.

As of fall 2013, the Penn State Lunar Lion team has completed 'Phase 0', which is an entirely student-developed process, that included putting together its rocket testing guidelines and procedures as well as contingency and safety plans. Following this, the team was finally able to begin testing a rudimentary liquid rocket engine, using atmospheric oxygen and methane gas, through a full series of 'hot fire' tests to validate their new testing procedures.

With the completion of Phase 0, the team has moved forward to the first phase of actual development using a 'pencil-thruster' fueled by super cooled liquid oxygen (LOX) as an oxidizer and liquid ethanol (like what's found in gasoline). Alongside the thruster, the team developed a functioning engine test stand fully integrated with propellant delivery systems and sensors. With the team currently running tests on a regular basis, students are analyzing the effectiveness of these thrusters and even making improvements to the design in order to increase their efficiency.

The pencil thruster was designed and provided to the Lunar Lion team by NASA through Penn State's Space Act Agreement. This agreement is a formal means of NASA entering into a partnership with an outside entity, such as Pennsylvania State University in order to further the missions of NASA and the missions of their partners. The agreement is a two way street, Penn State will provide NASA with research and development concepts from the mission, and NASA will aid the team by providing consultation with their many scientists and engineers for the duration of the project.

Such an agreement has an interesting implication for the way space is explored, deviating from both "old space" and "new space" models. Throwing an educational institution into the mix pulls the best aspects from both of these models. The Lunar Lion team utilizes Penn State students as team members who are working on the project as part of their learning, instead of treating it as an extracurricular activity or club. Industry taught Penn State faculty members guide these students using their own time, providing the much needed expertise highly sought after by private industries such as SpaceX and Orbital Sciences.

Penn State hopes to land on the Moon in 2015, which will put them into a unique position to secure even more potential contracts from

NASA and other private companies, guided by the experience they will acquire from learning to manage their own space program. If they win the $20 million grand prize, program director Michael Paul stated that he would like to put this money towards the building of infrastructure that would allow for future University-led space exploration missions out of Pennsylvania State University.

The major obstacle the team faces is the lack of funding. To remedy this, the Penn State Lunar Lion Team has been actively using internet crowd funding through a website called RocketHub. In February 2014, they finished their first major fundraising campaign round, raising a total of $133,768 of their $406,536 goal. The money earned in this round is going towards the construction of a working prototype which will be used for testing in the Mojave Desert later this year.

Beginning in 2015, the team will start final systems tests and send the vehicle to be processed for launch, while the team sets up a functioning mission control center in State College.

Another hurdle to be cleared is the development of the spacecraft's avionics and control subsystems. Which Paul states as "being built from the ground up as with all spacecraft". This particular subsystem helps to orient the Lunar Lion while in space and during it's descent to the surface of the Moon. To accomplish this, the team has taken a novel approach by constructing a remote control quadcopter coupled with autonomous flight capabilities receiving the same commands as if it were the Lunar Lion spacecraft.

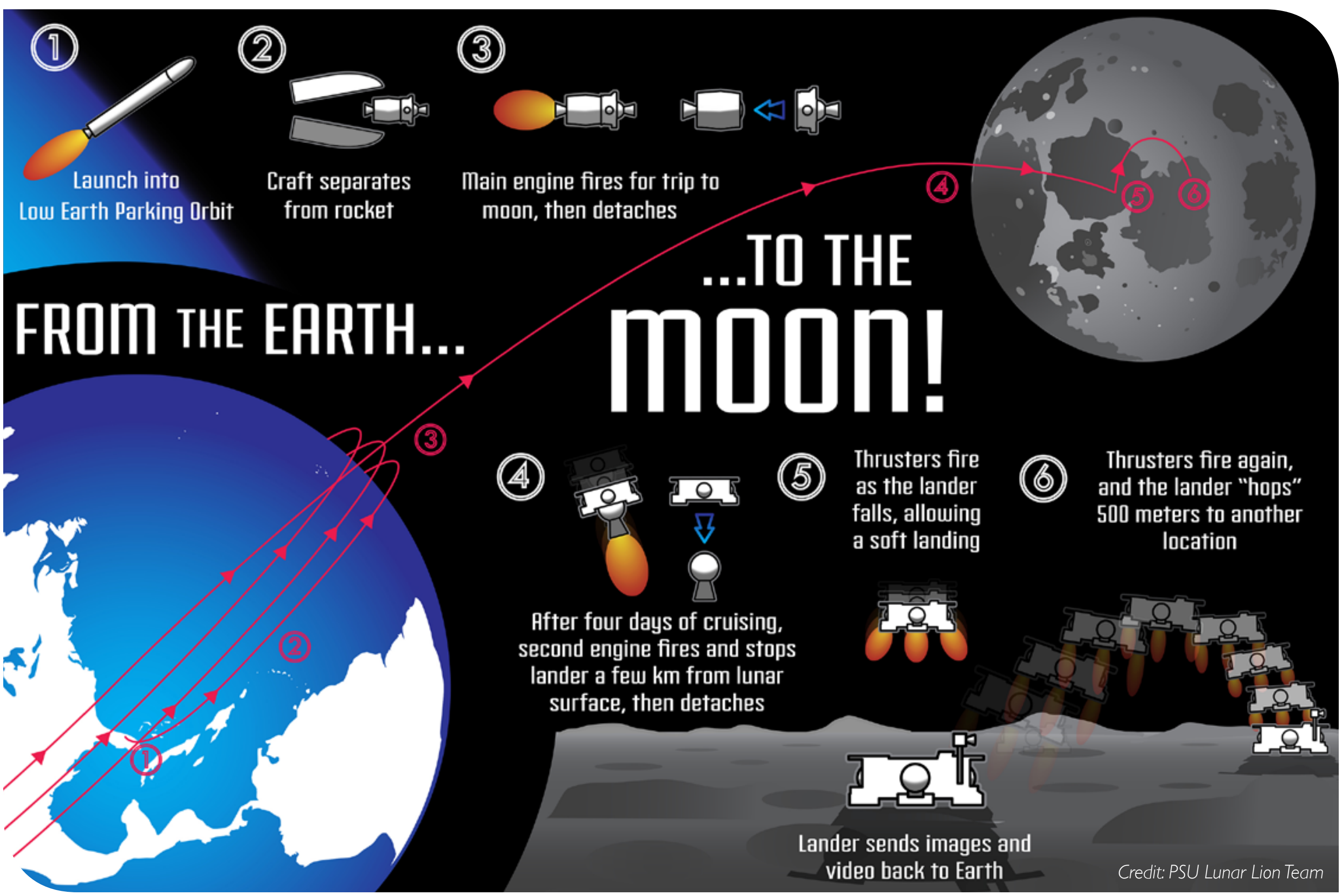
Autonomous control of a spacecraft is absolutely imperative because commands to the Lunar Lion will take approximately 1.3 seconds to be received and executed.

Late last year, the Lunar Lion team put a $100,000 deposit down on a commercial launch vehicle through a former Google Lunar X Prize competitor, Team Phoenicia LLC, which now focuses its assets on securing room on commercial launch vehicles as secondary payloads in an attempt to maximize cost effectiveness. Simply procuring the ride to space aboard a rocket has been the reason most teams have dropped out of the competition and it is because Penn State has made it this far that they are considered a viable candidate to win the prize.

"The hardest part of the mission is the two minutes between when we fire our rockets to slow our descent and when we touch down." Paul said. "It all comes down to that."

The team's intended landing spot is The Sea of Tranquility, located just 30 km north of the site where Apollo 11's lunar lander, "Eagle", touched down on July 20th, 1969. With the landing site so close to this landmark, the Lunar Lion team hopes to take images of the landing site in order to acquire some of the additional $4 million that exists for teams going above and beyond the requirements.

To learn more about the Penn State Lunar Lion Team and how you can help them land on the Moon, visit www.lunarlion.psu.edu.



Credit: PSU Lunar Lion Team

The new Eagle has landed

Vocabulary

- **Landing Kit:** Includes the lunar landing legs, infrastructure, landing radar, etc.
- **Lunar Investment:** The amount of money needed to fully fund a mission to the Moon
- **Lunar Material:** A certain substance that can *only* be found on the Moon
- **Powered Ascent Initiation (PAI):** The lunar liftoff ΔV requirements equal to 1,890 mps
- **Powered Descent Initiation (PDI):** The lunar landing ΔV requirements equal to 2,181 mps
- **Return On Investment (ROI):** The percent increase of a profitable investment

Narrative

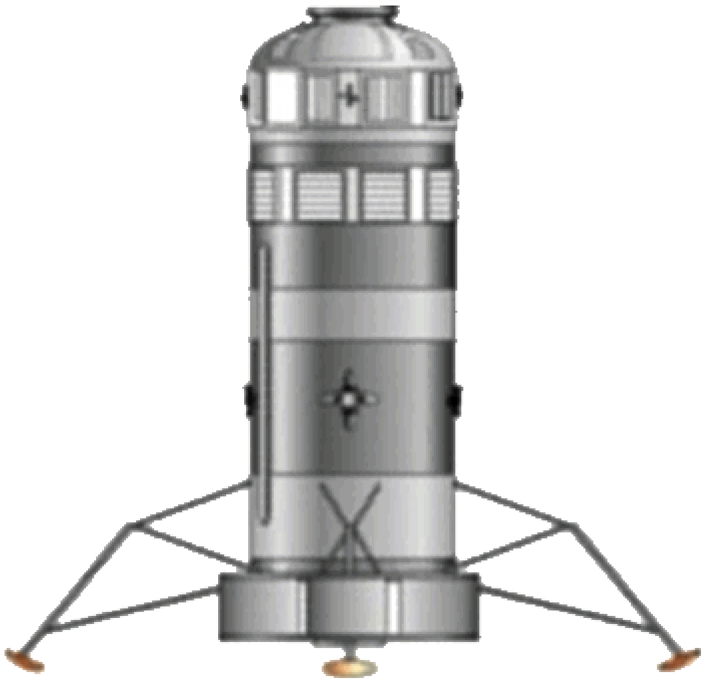
Going into space is an expensive proposition; there really is no way around this important fact. The old adage "No bucks, no Buck Rogers" certainly encapsulates this sentiment. This (probably) is why only nations so far have attempted this feat. But there is a sea change underway.

Private industry has been getting into the act recently, albeit with a little help from their friends, the US government. So far, however, the Return On Investment (ROI) has been woefully inadequate. There has to be a way to not only finance everything that is needed for a trip to, say, the Moon, but to also make a reasonable ROI (we define a "reasonable" ROI as anything greater than 10.0%).

Enter the Boeing Space Tug Study (circa 1971). This reusable spaceship included a design for a Crew Module (CM) and an Engine Module (EM) that were connected together, Apollo-style.

***Note:** For a detailed treatment of this spacecraft and the equation that follows, please see the previous issue of RocketSTEM (May 2014).*

The Boeing ship also held one last surprise: a lander kit designed to be attached to the spacecraft to form a reusable lunar lander! The lander kit included the landing legs, a landing radar, extra batteries, etc., and weighed 890 lbs. Additionally, a donut-shaped Payload Tray was attached to the bottom of the lander to allow crews on the lunar surface easy access to the cargo brought down. Boeing had truly outdid themselves back then.



Credit: Mark Wade/Boeing

Despite how formidable the Boeing space tug was, it was never funded, which is to say, it was never built. But what if it had? Would there have been a way to pay for not only the development and engineering cost, but the day-to-day operating costs as well?

Analysis

We estimate a lunar investment of no more than $25B USD total to build and fly the reusable Boeing Space Tug Lunar Lander and all associated equipment and other spacecraft. This includes flying the lander into lunar orbit and back, as well as replenishing the EM propellant tanks and refurbishing the CMs.

There exists on the Moon a commodity that is relatively easy to mine and at one time sold for $442,500 per carat. But let's not use that figure. Instead, let's use the

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

price of lunar meteorite, since that is close enough to our mysterious lunar material. A 0.08 gram chunk of the famous lunar meteorite NWA 4881 is selling for around $200. Dividing $200 by 0.08 grams equals $2,500 per gram, which is the price of an average quality diamond. But let's not use that figure either. Let's instead set the average selling price at $1,500/gram for this lunar commodity.

The Boeing Space Tug with a Lunar Lander Kit attached could have easily brought back this lunar material. But how much of it? To the ideal Rocket Equation, derived by the awesome Russian rocket pioneer Konstantin Tsiolkovsky.

Example

A Payload Tray weighs 1,500 lbs, and the science equipment we will deposit on the lunar surface weighs in at 8,250 lbs. To make the math easier, we will replace the science equipment with the same amount of lunar material. We will continue to use the CM (with a crew of ten) and the EM from the previous RocketSTEM article.

$$\begin{aligned} M_1 &= Weight_{EM} + Weight_{KIT} + Weight_{TRAY} \\ &\quad + Weight_{SCIENCE} + Weight_{CM} \\ &= 5610 + 890 + 1500 + 8250 + 9540 \\ &= 25{,}790 \text{ lbs} \end{aligned}$$

$$\begin{aligned} M_0 &= M_1 + Weight_{PROPELLANT} \\ &= 25790 + 39800 \\ &= 65{,}590 \text{ lbs} \end{aligned}$$

The mass ratio ($Ratio_{MASS}$) of this rocket configuration therefore becomes:

$$\begin{aligned} Ratio_{MASS} &= M_0 / M_1 \\ &= 65590 / 25790 \\ &= 2.54323{:}1 \end{aligned}$$

Since the rocket engine nozzle has to be retracted to make room for the landing, there is a 3 second loss in the rocket engine's specific impulse. Thus the exhaust velocity (v_{EXH}) of the rocket is 4,482 mps, and the delta V (ΔV) that the lander is capable of producing is:

$$\begin{aligned} \Delta V &= \text{Tsiolkovsky Rocket Equation} \\ &= V_{EXH} * \ln(Ratio_{MASS}) \\ &= 4482 * \ln(2.54323) \\ &= 4482 * 0.933 \\ &= 4{,}184 \text{ mps} \end{aligned}$$

Looking up the total ΔV requirements (ΔV_{BUDGET}) for a lunar landing and liftoff, we get:

$$\begin{aligned} \Delta V_{BUDGET} &= \text{Lunar Landing } \Delta V + \text{Lunar Liftoff } \Delta V \\ &= PDI + PAI \\ &= 2{,}181 + 1890 \\ &= 4{,}071 \text{ mps} \end{aligned}$$

Since the lunar lander is capable of producing more ΔV than is required (that is, since 4,184 mps is greater than 4,071 mps), we can therefore conclude that this spacecraft lander configuration is sound. This means that we can safely bring back 8,250 lbs (3,742 kg) of lunar material.

Using the $1,500 per carat price calculated earlier, and multiplying by 5,000 carats per kilogram, our average selling price is $7,500,000/kg. So our Gross Income becomes:

$$\begin{aligned} \text{Gross Income} &= \text{Average Selling Price} \\ &\quad * \text{Weight of lunar material} \\ &= 7500000 * 3742 \\ &= \$28{,}065{,}000{,}000 \text{ USD} \end{aligned}$$

Subtracting the lunar investment from the Gross Income equals $3,065,000,000. That's over three billion U.S. dollars in profit!

Conclusion

As every high school math student knows, just like the students at The Learning Community Charter School (http://www.tlcnm.net), the percent increase is defined as new minus old divided by old times 100:

$$\begin{aligned} ROI &= \% \text{ Increase} \\ &= (New-Old) / Old * 100 \\ &= 3065000000 / 25000000000 * 100 \\ &= 12.26\% \end{aligned}$$

So we get to have ten people walk on the Moon, we get to reuse the lander, we get all of our money back, and with a tidy profit. Even more incredible is the fact that this lunar landing mission uses a spaceship that was designed way back in 1971.

Now, what can this very mysterious lunar material possibly be? The answer is: why, lunar material of course; better known as Moon rocks!

References

- http://moonpans.com/meteorites
- http://www.adiamondbuyingguide.com/diamondpriceguide.html
- http://www.lpi.usra.edu/lunar/samples

Jack King

The voice of Apollo

Interview by Nicole Solomon

Most people have crushes on astronauts, but I'm smitten by a voice. Jack King has never been to the Moon. He has never had a ticker tape parade. You wouldn't recognize him if you passed him on the street. But the moment he begins speaking, chances are you'd want a front row seat, because Jack King has seen it all.

King is best known for his work as the NASA Chief of Public Information during the Mercury, Gemini and Apollo missions. It was his voice that was heard as Apollo 11 lifted off for the Moon, earning him the nickname, "The Voice of Apollo." A 15-year NASA veteran, King is now retired, but still volunteers his time as a public affairs officer for the agency with which he is so associated.

I recently had the privilege of sitting down with King for a generous interview that spanned some of NASA's greatest accomplishments and his most cherished memories. 3…2…1…LIFTOFF.

RocketSTEM: How did you make a name for yourself in the world of Journalism?

Jack KING: "I was born and raised in Boston, Massachusetts. I lived there for 25 years. My dad was a sports writer for the Associated Press. I wanted to follow in my dad's footsteps as a newsman. That's how it all came about really. I worked as an office boy for the Associated Press every summer from high school all the way through college.

"I started off as the low man on the totem pole. As a rookie newsman, I worked with some great people, some really talented people and I was fortunate enough to take advantage of their guidance.

"One night I was all alone in the office and a ship had crashed, the SS Andrea Doria. It was in a collision with the Stockholm off the coast of Nantucket. I grabbed the almanac and looked up the passenger list. It was 5,632 or something like that. I saw and I jumped on the wire with a bulletin and was the first to report it. In the wire service the great competition was between Associated Press, United Press and International News Service. There was always the rush to be first and accurate with the news and that particular night I was first, which went down to my credit."

RS: When did you start covering launches?

KING: "The early era of space exploration was driven by a race between the Soviet Union and the United States. In 1957 I covered the launch of Sputnik, followed by the explosion of Vanguard and a month later Explorer 1.

"What happened was after Sputnick, Associated Press saw what was going on down in Florida. We were developing our own big rockets, at the time the Atlas and the Titan. They decided that they should have a full time news chief down at the Cape. So my bureau chief recommended me and the next thing I knew I was down there covering all the stories.

"I remember there were two major motels in Cocoa Beach at the time, one was the Vanguard and one was the Starlight. I had two floors in the Vanguard, the Associated Press did. It was a beautiful set up. I had a bedroom upstairs and a printer and a whole newsroom downstairs. I had a telescope looking out at the Cape. Whenever there was launch a big red ball would drop notifying the ships."

RS: How did you become a permanent part of America's beloved space agency?

KING: "NASA was established in 1958, the same year I came to the Cape. The agency didn't have anything set up at that time. They had just been established and named the Mercury 7 astronauts who were stationed up at Langley. NASA had its first actual presence in 1960 when the Wernher von Braun team came over to NASA.

Jack King speaks about the Apollo program to a group at the Saturn V Center located at Kennedy Space Center in Florida. Credit: Alan Walters

At that time I was offered the job to be director of public information."

RS: Did you ever meet President Kennedy?

KING: "I'm from Boston and we grew up with the Kennedys. I had great respect for President Kennedy. I don't think he was particularly a tremendous champion of the space program but he was in is a position where he had to use it and that is what lead him to give us a mandate to land a man on the Moon before the end of the decade.

"In those days everything we were doing was for the first time which was quite a challenge in itself. As a result of Kennedy we had the nation behind us.

"NASA started out with the Mercury program and that was to show that man could work in space. The first mission was with Alan Shephard and anybody who was there never forgets. I must admit it was the only launch I got misty eyed on, the first American to go into space.

"We were just a small group at that time we hadn't become the Kennedy Space Center or anything else. There were a handful of us working down there and we were still doing basic things with small rockets, and here was Kennedy coming out and saying land astronauts on the Moon. We were just dazzled."

RS: When did you start during launch commentary?

KING: "I had done about 25 unmanned launches before I started doing the countdowns for Apollo. Those were the weather satellites, communications satellites, lunar and planetary probes. Those were all in the early days. I had been during launch countdowns for years and just fell into the Apollo launches."

RS: How did you get the nickname the Voice of the Apollo?

KING: "I don't know how I got that nickname. I did the commentary on all the Apollo launches so I guess if came from that. I also did the countdowns for Gemini 4 through Gemini 12. It's very humbling to be told that your voice has been heard by more than a billion people."

RS: Where were you during the Apollo 1 fire?

KING: "I was in a block house when the fire happened. I used to sit in for all the prelaunch tests to get the experience and that was something I will never forget.

"There was a 155 pound escape rocket sitting on top of the spacecraft and when it burst into flames and the call came in fire in the spacecraft… fire in the spacecraft, we were all stunned. It was a spark that was created under Gus Grissom's boot. The fire occurred at 6:31 p.m. and I didn't get out of the block house at about 3 o'clock in the morning. That actually put the spacecraft down. We went from January 1967 until November of 1967 without another launch."

Jack King, KSC Public Affairs Apollo Launch Commentator, follows proceedings of the wet portion of the Countdown Demonstration Test for Apollo 12 from his console within Firing Room 2 of the Launch Control Center.
Credit: NASA via Retro Space Images

RS: What do you remember about the launch of Apollo 4?

KING: "The sound! The sound hit on launch, and the windows were starting to rattle and the ceiling was coming down, and I thought the whole building was going to come down. It knocked Walter Cronkite right out of his seat. Saturn V was amazing to me. We launched it 13 times and it worked everytime. Twelve times with Apollo and once with Skylab."

RS: How intense was the press back in the early days?

KING: "The biggest group we ever had was more than 3,000 reporters for Apollo 11 and that included media from all over the world. The dedication of the general public just amazed me. Back then people would come out and watch the launch from any place they could. They were excited and focused and paying attention to the launch. Nobody had cell phones so people weren't looking down and trying to post online or do social media stuff like they do today. All eyes were on the launch. It was a different time."

RS: How did the media get launch information?

KING: "Back in the beginning we were operating on a military facility and information was very limited. Nobody would tell you anything. When the Vanguard blew up the press wasn't allowed to go out there at all. So what I did was make sure I was available to the press with as much information as possible.

"One thing NASA did at the start was hiring four really good newsmen. I came from the Associated Press and obviously I had to be a pretty good writer. Paul Haney and Al Alabrando came from the Washington Star. These were good solid news guys who could really write. A guy named Julian Spears came from a newspaper in North Carolina and he got things very organized.

"Jim Webb was the NASA administrator at the time and he did a fantastic job. He would pound his feet on Capitol Hill and really got the NASA public affairs program going.

"We were the only ones screaming you've got to have a camera in the Apollo spacecraft. The astronauts

The Apollo and Space Shuttle programs are long retired, but Jack King can still be found sitting within the bullpen of the press center at Kennedy Space Center answering the phone and helping out members of the media. *Credit: Nicole Solomon*

didn't want a camera. They were worried about the weight. Every ounce of payload weight was looked at very closely. But in the end we won that battle and when people saw that footage they were blown away. All those guys are gone now. God bless them. I'm kind of the end of an era here I think. There aren't many of us around."

RS: How has NASA changed over the years?

KING: "When you consider the Apollo era and all these things that took place the 1960s it was one of the most dramatic decades of the 20th century without any question. We had three major assassinations. We had the cold war with the Russians and the hot war with Vietnam. We had the protests about the war. You had racial unrest all across the country. You had the rise of the hippie and drug movement. All of these things were taking place while we were trying to develop our capabilities to go to the Moon, which we did.

"There were a lot of negative things in that decade and what NASA was able to accomplish was just incredible.

"Back then we had a tremendous management team. You had General Sam Phillips, who was the program manager for Apollo. In Houston, Bob Gilruth and Chris Kraft were great leaders. You had Kurt Devise here at the Cape and a marvelous guy named Rocco Petrone who was the launch director. You had of course von Braun in Huntsville, and you had some top people in Washington. The management team to me was the key to our success. The last 25 years have been very different."

RS: Back then five cents from every dollar went to NASA, and now in 2014 a half of penny goes to the agency. How are we suppose to get to Mars with that kind of money?

KING: "One of the few space movies that is truly outstanding is Apollo 13. There is one scene where Marilyn Lovell is taking her kids into Mission Control, and the Apollo 13 crew, before the incident occurred were showing weightlessness and stuff. And the news wasn't airing it. That was the first sign that the public interest was starting to lag. It took 22 billion dollars to get those guys to the Moon. Who knows how much money it will take to get to Mars!"

RS: Do you think the International Space Station slowed us down?

KING: "We could have spent the last 30 years building hydrogen rockets. Shuttle slowed us down. I wanted to be on Mars 20 years ago. Shuttle did a good job, but it cost a lot of money and a lot of time."

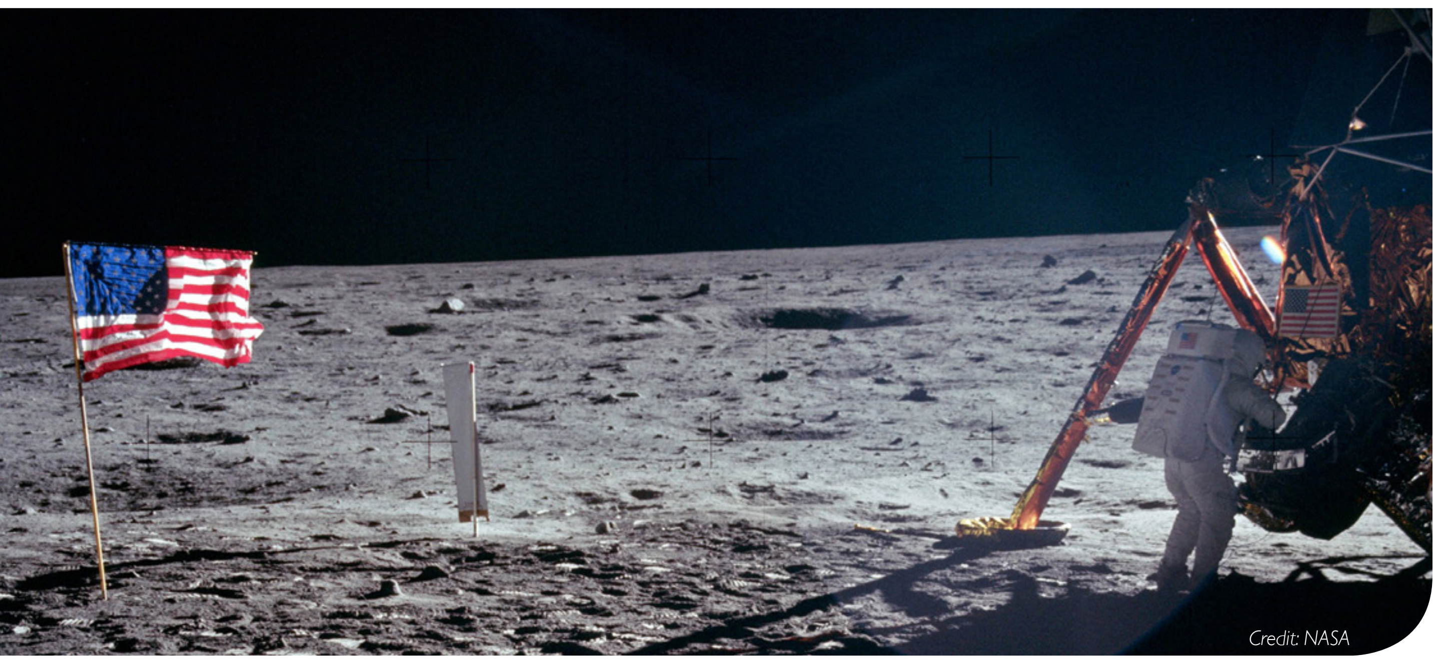
RS: How would you like people to remember you?

KING: As a good father, a family man, as somebody who enjoyed the heck out of his job, all the way through. As somebody who loved what he did and enjoyed everyday going to work, all the way to the end.

A few of the many

UNSUNG HEROES

of the Apollo program



Credit: NASA

For years history has celebrated the crews of elite astronauts who rode fire to the Moon and the unique twelve who walked on its surface. To a lesser degree, the senior mission specialists working in Houston and in Florida were also lauded. But at its height during the Apollo program 400,000 people were involved in the Moon effort at NASA, its various contractors and sub-contractors. The story of these thousands is seldom heard, but their tales are just as heroic in terms of the dedication and personal sacrifices they made for landing a man on the Moon and returning him safely to the Earth. This is the story of some of those unsung heroes of Apollo.

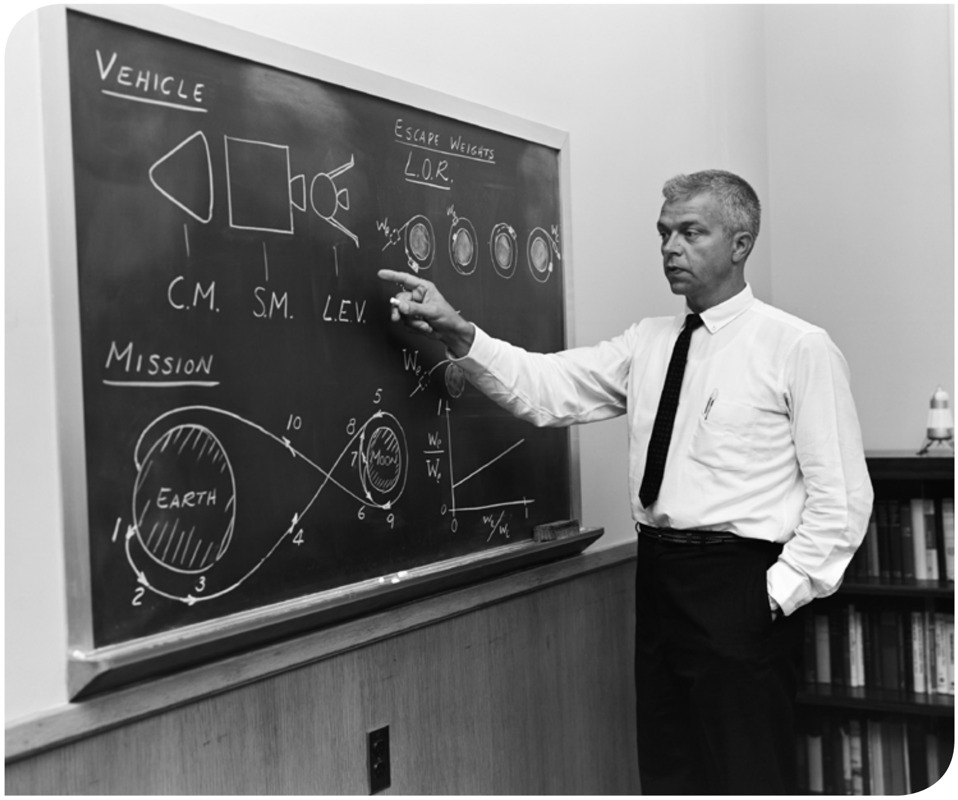
Story by Amjad P. Zaidi

John C. Houbolt: *Visions can be realised*

Named as TIME magazine's unsung hero of the Space Program and Apollo 11, Houbolt was responsible for transforming the strategy to get to the Moon from the Werner Von Braun favoured Direct Ascent and landing to the untried and risky Lunar Orbit Rendezvous.

A native of Altoona, Iowa, the young John Houbolt always had dreams of flight, at one time jumping from a hay loft with an umbrella and a glider built with wings attached to a baby carriage. But these were hopeful starts, as he soon graduated to winning airplane competitions, became a pilot himself, gained a Masters in Civil Engineering from the University of Illinois and eventually a PhD in Technical Sciences from ETH Zurich in 1957. As a self-reliant learner, Houbolt continued his self-tutelage through the '50s and '60s on space travel principles and Lunar Orbit Rendezvous. However, well before gaining his PhD, Houbolt became a member of the National Advisory Committee for Aeronautics (NACA). NACA later become NASA in 1958, taking Houbolt's career on an unexpected trajectory.

The climate of fear during the Cold War found a productive and technical purpose in the Space Race. Vast teams of engineers and scientists were assembled on both sides of the Iron Curtain to study various methods of getting to the Moon; the Buck Rogers style "Direct Ascent", Earth-Orbit Rendezvous and Lunar-Orbit Rendezvous (LOR). The idea that bigger was better and faster appeared to be winning the minds of NASA program managers and Werner Von Braun himself, until Houbolt deduced that weight would be the deciding factor in winning the race to the Moon. Smaller, modular spacecraft would be essential, more cost effective and faster to develop. LOR required astronauts to leave Earth orbit in a large rocket carrying with them the modular spacecraft needed for a journey to the Moon. Only a small lander was needed to land and launch from the Moon requiring a lunar orbit rendezvous with the mother ship.



John Houbolt, the populariser of Lunar Orbit Rendezvous. *Credit: NASA*

LOR was first devised by rocket pioneers Yuri Kondratyuk and Hermann Oberth, but had been buried in development hell. Remembering his education and seeing true genius in LOR, Houbolt prepared presentations, lectures and reports proving the value of LOR over other options. Despite his populist methods being ignored for over a year, Houbolt was convinced LOR was the road to the Moon and persevered, at risk to his own reputation. He eventually circumvented the management chain of command by writing directly to NASA Associate Administrator Robert Seamans in a passionate and forceful letter. This letter brought LOR into serious consideration by NASA management and eventually found a supporter in none other than Werner Von Braun, who saw the genius of this idea. Shortly after, LOR was selected as the way to get to the Moon.

Houbolt was present at the launch of Apollo 11 and fittingly saw the principle of LOR proved in practice when the Lunar Module "Eagle" touched down and returned to the Command Module "Columbia" in lunar orbit. The recipient of NASA's medal for Exceptional Scientific Achievement, his story is that of an individual with tenacity and vision who championed an idea at great personal cost because it was right. An individual who did not let obstacles stand in his way. His perceptive vision allowed Apollo to become reality and changed history forever.

Tom Kelly: *Father of the Lunar Module*

Scattered on the surface of the Moon are the remains of 6 spidery spacecraft that took 12 men there and back, and remain the only manned spacecraft to have landed on another world. Notably among them is the fifth Lunar "Excursion" Module (LM) to roll off the production line called "Eagle". And it was an unknown, young, Long Island engineer who "brought up his children" in 7 years that took us there.

Kelly, a Brooklyn native, earned a Bachelor's degree in Mechanical Engineering from Cornell University before gaining a Master's from Columbia University in 1956. Following his time at Cornell he worked as a propulsion engineer at Grumman Aircraft Corporation. After a brief stint as a Lockheed space propulsion engineer he returned to Grumman to independently study and form methods to get people to the Moon with a study group of like-minded engineers before Kennedy issued the challenge with his famous "We Choose to Go to The Moon" speech. Amongst the methods researched was Lunar Orbit Rendezvous (LOR).

Tom Kelly (front) works in one of the 'back rooms' of Mission Control during the Apollo 11 mission.
Credit: NASA via Retro Space Images

Gaining valuable experience sub-contracting under General Electric for Apollo, Kelly also assisted in the rationalisation of the LOR concept. When NASA selected LOR as the road to the Moon, Kelly and his team were miles ahead of the competition. In 1962 Grumman were contracted by NASA to build the LM. Kelly led the engineering team to design and develop a machine in 7 years to land on the Moon in conditions unlike anything experienced on Earth. Under his leadership the 3000 engineers and 4000 technicians at Grumman conceived, designed the critical manufacturing techniques, constructed, integrated materials, parts, systems and tested the LM.

Transforming designs into functioning hardware, his growing team quickly and frequently ran into unforeseen problems and repeatedly made radical refinements to the design of this two-stage fully throttle-able spacecraft. Kelly faced incredible pressure from both NASA and the administration who were disappointed with the lack of progress against Kennedy's end of the decade deadline.

Steering an ever evolving company to simultaneously create the LM, construction methods, acceptance tests and procedures, Kelly and his team were already behind from day one. However, his mantra of never giving up on a problem and seeking engineering excellence echoed well with the NASA mind-set of the time and eventually won the day. Kelly recognised that "we were all part of a majestic endeavour and that we were making history happen". Given how deeply involved Kelly was with each LM's development and maturation, he very much saw the LMs as his "children" and was personally invested in their delivery.

To gain pace in the testing phase and completion of the LM, Kelly fostered a culture of transparent inclusivity, bringing the Apollo astronauts and technicians in to help provide input and advice on the test performances of the new spacecraft. This partnership finessed each hand made LM, on target for each mission. LM-3 dubbed "Spider" was successfully manned and flight tested In Earth orbit by the Apollo 9 crew, Jim McDivitt and Rusty Schweickart, later docking with David Scott piloting the Command Module "Gumdrop". Apollo 10 expanded the LM's operational envelope as Tom Stafford and Gene Cernan painted a white line for later missions, piloting LM-4 "Snoopy" down to 8.4 nautical miles above the Moon, before separating from the descent stage and returning to the Command Module "Charlie Brown".

As LM-5 "Eagle" settled into the lunar dust on July 20th 1969, Tom Kelly's dedicated hard work and that of the thousands working under him, finally paid off. His pride in saving the lives of the Apollo 13 crew using the LM as a lifeboat is also well deserved.

Without his leadership this unique spacecraft would not have been completed on time, let alone flown successfully before Kennedy's pledge to land a man on the Moon and return him safely to the Earth expired in 1970.

Tom Kelly himself recognised that the crucible of Apollo focused goal orientated teamwork, raised abilities, ambitions and aspirations of a nation to exceed its wildest dreams. In doing so, the rich technological returns have also revealed the finest possibilities of human achievement. The legacy of this man's accomplishments cannot be understated.

Eleanor 'Ellie' Foraker: *Cross your heart while walking on the Moon*

Who was Ellie Foraker? Her name is certainly not up there in lights with Neil Armstrong, Buzz Aldrin, Gene Kranz, John F. Kennedy or their ilk. How did she come to be connected with the Apollo Program and its high flying astronauts?

Before Kennedy's pledge to have a man actually walk on the Moon high altitude pressure suits had been designed purely for emergencies. The cockpits of high altitude aircraft or early spacecraft were the first line of defence to the vacuum of space. Apollo required something more robust altogether, but NASA had no knowledge of how to build a flexible yet protective space (and Moon) suit which was literally another mini spacecraft around an astronaut.

The astronauts of Apollo and beyond owe ILC Seamstress Manager Ellie Foraker (above) and those like her their lives. *Credit: CNN and MIT Press*

In 1962 NASA invited tenders from contractors to build the new Apollo Spacesuit, a huge leap forward from the Mercury and Gemini programs suits. Many were well known names in the aviation and engineering industries with vast experience, but none had solved the problem of how to build a flexible and portable spacesuit for walking on the Moon.

An outsider, the International Latex Corporation (ILC), known for Playtex undergarments won the contract to build the Apollo spacesuit. ILC had one huge advantage; they knew how to make personalised, form fitting, flexible rubber garments that were perfect for the Apollo spacesuits' needs. However ILC had no experience with huge government contracts and so Hamilton Standard, an engineering company with this requisite experience was given oversight on the project.

At the time Ellie Foraker was a seamstress manager working on the floor making baby clothing at ILC. Along with many talented seamstress employees she was transferred to the ILC arm now contracted to produce the Apollo spacesuits. This work was long and arduous with a high degree of unprecedented engineering standard precision required to produce each personalised suit. Usual sewing tools were discouraged for safety reasons. For example, seamstresses had to sew together the spacesuit's outer Thermal Micrometeoroid Garment's 17 layers with seams over hundreds of yards using their fingers. Quality and tolerance control was a priority; each stitch was counted and measured to within a pinhead. Anything less than perfection was unacceptable.

Occasionally sewing pins were needed. However the constant danger of losing sewing pins within a spacesuit could lead to a fatality on the Moon, so Foraker was tasked with pin management and tracking all pins to each seamstress in her team. The life of each astronaut wearing these suits was very much in the hands of Foraker and her team. One wrong stitch, one lost pin, could mean disaster later down the road.

Simultaneously, Hamilton Standard produced the life support backpack and the internal cooling system for the new spacesuit. By 1964 fully completed spacesuits were being delivered to NASA but they fell well short of NASA's acceptance criteria. Longstanding differences between ILC and Hamilton Standard erupted and NASA, with no confidence in receiving a suitable spacesuit on time, terminated the contract.

Re-launching the Apollo spacesuit competition in 1965, both Hamilton Standard and ILC submitted their own independent designs for spacesuits. With the clock ticking, seamstresses like Foraker worked harder than ever to improve their designs and produce a final suit for NASA. Powered by dreams of success ILC staff pushed on and free of Hamilton Standard's constrictions re-designed a newer form fitting spacesuit that was far more flexible and beat out the competition.

As a result, NASA used the best ideas from both contractors. The final A7L spacesuit contained ILC's inner cooling garment, and on top of that a flexible air pressure suit. The final protective layer was a tough external nylon / non-flammable beta-cloth layer. Hamilton Standard provided the life support backpack.

As the spacesuit was put through its paces on the Apollo missions, the ultimate test came on July 21, 1969. The world rejoiced as Neil Armstrong took humanity's first steps on the Moon, but for Foraker and her ILC co-workers this momentous day was filled with fear. Armstrong's and Aldrin's slips and low gravity bounces caused high stress and concern over accidental damage to the spacesuit, but of course there were none. This is a testament to the huge dedication and talent of Foraker and those who worked with her in producing a high quality, flexible and tough spacesuit.

Over the coming months and years, men would return to the Moon in these remarkable spacesuits to explore, experiment, work and even play golf on an alien and hostile world. And each one returned home, thanks to the likes of Ellie Foraker.

Joseph F. Shea: *A brilliant engineer with heart and the hopes of a nation*

Joe Shea (far right) at a press conference in 1962 to announce to decision to go with the LOR concept.
Credit: NASA via Retro Space Images

In an era of macho pilots, politically bruising management and buttoned down engineers, Joe Shea brought a no nonsense Bronx attitude with a calm but assertive and unifying authority to the Apollo Program overseeing the development of the Apollo spacecraft. A maths whiz, he received an engineering education at the University of Michigan before gaining an engineering doctorate via Dartmouth and MIT. His technical aptitude and managerial savvy were becoming well known and sought after by firms such as Bell Labs and General Motors.

After delivering the Titan 2 ICBM missile guidance system on time within budget for Bell Labs, NASA invited him to help them answer Kennedy's clarion call to land a man on the Moon. Shea believed in Kennedy's mission and stepped up for the cause despite a huge pay cut, joining the Office of Manned Spaceflight in 1961 to share his systems engineering expertise.

With his ability to win a strong consensus between various, culturally different and independent NASA centres, Shea greatly assisted in smoothing the waters for acceptance of the LOR concept throughout NASA. In 1963 he became the new head of the Apollo Spacecraft Program Office (ASPO), with the same consensus building mandate between NASA and its contractor North American Aviation.

At the time warring factions within NASA and North American had been unable to reach agreements on how to build the Apollo Command Module (CM), burning out two of Shea's predecessors and seriously impacting the ability to build a Moon ship before the end of the 1960's. Even though Shea also met resistance, he reached an accommodation with North American Aviation manager Harrison Storms to stem the flood of change requests, disagreements and find a way forward. With a sense of engineering discipline and renewed cooperative purpose, the CM was finally being built and tested.

Joe Shea demonstrating the docking between the Apollo Lunar and Command Modules. *Credit: NASA*

Naturally being in the spotlight Shea was a target for hostile criticism but even his enemies acknowledged his considerable engineering nous and managerial style that had finally given forward momentum to the ASPO. TIME Magazine was even planning to have Shea grace their cover in February 1967. And then tragedy struck.

On January 27, 1967, the complicated and by now widely known to be problematic Apollo 1 CM underwent a routine "plugs out" test with the crew of Gus Grissom, Ed White and Roger Chaffee on board. A spark from frayed wiring inside the CM ignited flammable Velcro in the high pressure pure oxygen environment starting a flash fire, killing all three astronauts in seconds.

As recriminations and reviews began in the aftermath, Shea became part of the advisory group on the investigation. Feeling a sense of personal responsibility to the program and especially to the lost crew who were his friends, he began working eighty hour weeks.

Shea and Storms, the pair most responsible for the advances made to date were side lined so that the program could continue. Shea in particular suffered a heavy and personal toll. Following the loss of the crew and overwork he suffered a breakdown. Eventually following his recovery but still in a fragile state, Shea was moved to NASA HQ in Washington but left shortly after for a renewed career first at Polaroid, then at Raytheon and eventually as a professor at MIT.

His story shows the intense personal responsibility and costs carried by some of those working within the program. Were it not for Joe Shea's skill as an engineering leader and a fair diplomat within and without NASA, the program could easily have ground to a halt.

In the glare of astronaut publicity, contributions such as Shea's must not be forgotten or else we would never have been able to make the voyage from the Earth to the Moon.

Professor Lee Silver: *The original rock star teacher*

How do you get a group of test pilot/engineers interested in a bunch of rocks? How can you teach these hard-nosed astronauts to be geologist detectives around rocks and soil, especially on the surface of the Moon? For some time the Apollo astronauts (and would-be geology students) had been bombarded with jargon filled classroom geology lectures that did not excite them. This had been a nagging problem for NASA as they prepared for the Moon landings. After all, one cannot spend billions of dollars going to our nearest planetary neighbour just for pretty pictures.

Lee Silver points out some geological observations to his astro-geologists in training, Charlie Duke and John Young.
Credit: NASA/U.S. Geological Survey via Retro Space Images

Neil Armstrong himself broke the mission parameters, exploring beyond the Apollo 11 landing camera's field of view to collect 80 kilograms of interesting lunar rock samples. He began the "meat part" of the Apollo missions, but not seeing where he had collected the rocks from, there was no detailed context to their story.

Enter Caltech Professor of Geology Lee Silver. As an Apollo lunar sample investigator, Silver had been invited by his old student Harrison "Jack" Schmitt to meet with James Lovell and Fred Haise (assigned to Apollo 13) to discuss teaching the astronauts some basic field geology.

Given the chance to spend a week proving his teaching methods and the absolute need for good planetary science on Apollo, Silver took a party of astronauts on a camping field trip into the Californian Orocopia Mountains.

With the beautiful Orocopias at their feet, Silver's students including James Lovell, Fred Haise, John Young, Charlie Duke and Jack Schmitt, entered a new and beautiful world of geological discovery. Silver began organising further cross country field trips with a hungry enthusiasm, investigative acumen and sharpness akin to a test pilot's that spoke the same language and spread among his Apollo apprentices.

Soon after, further astronauts joined the field trips including David Scott and James Irwin whose geological findings from Apollo 15 are attributable to Professor Silver's teachings.

Using the Earth's natural environment as a stand in for the Moon's was a masterstroke. The new geology students practiced dress rehearsals of their missions, standing by Lunar Module substitutes (trees) and describing the 360 degree landscape views as a geologist would.

Interpreting each other's detailed descriptions each of the astronauts became quick students in geological observation. Under Silver's tutelage, their innate curiosity ran wild, collecting a variety (or a "suite") of rock samples each one telling a line in the story about the evolution of the Orocopia Mountains. Silver imposed time and sample limits on collecting these rock suites, just as the astronauts would face on the Moon and their rock collections became more refined, much to the later benefit of the actual missions.

Observing and sampling within the exposed strata of geological time on the Earth, the Apollo astronauts, now armed with the tools of scientific observation, were prepared to tell the story of the Moon.

When the true scientific "J" missions began on Apollo, Silver himself was in the back-room of Mission Control steering the geology ground teams and acting as a back seat driver for the lunar roving astro-geologists on the Moon.

Dave Scott and Jim Irwin had been trained to find anorthosite during their Apollo 15 mission, a piece of the primordial lunar crust that would prove the Moon's age. On August 1, 1971 on Hadley Delta, Scott radioed back to the ground that he and Irwin had found just that. The "Genesis" rock would later prove to be 4.5 billion years old giving rise to the widely accepted theory that a Mars sized body had collided with the Earth spinning off matter that later formed the Moon.

Silver himself described this find as "hitting a home run" which validated his supreme teaching efforts to embed science within the Apollo missions.

Were it not for Lee Silver, the Moon's story and relationship with the Earth would still be relatively unknown. His unique and exciting teaching methods imbued a sense of urgent exploration, not just of the Moon but of science, always looking to push the boundaries of knowledge and follow the observational evidence wherever it leads.

Dorothy ‘Dottie’ Lee: *Blazing a trail back home*

The men returning home from the Moon at an incredible 25,000 miles per hour faced a blistering re-entry into the Earth’s atmosphere encountering soaring temperatures of 5,000 degrees Fahrenheit. Death was but feet away were it not for an ablative heat shield installed on the base of the Command Module (CM) that melted and eroded away as the heat of atmospheric friction built up. Many engineers were involved in designing the heat shield and other systems that would bring each crew home safely. Dorothy Lee was one such engineer specialising in ablative heat shield technology.

Dottie Lee’s childhood interest in astrophysics led her to believe early on that humanity was destined to reach the Moon. As an alumnus of Randolph-Macon Women’s College in Virginia, Lee proved she was a natural at mathematics and upon graduation was soon recruited in 1948 to work for NACA (National Advisory Committee for Aeronautics). Placed in their PARD (Pilotless Aircraft Research Division) under the direction of Langley Research Centre, she was a “human computer with a calculator” testing different configurations of launch vehicles from Wallops Island. She explored the characteristics of blunt nosed and cone shaped vehicles, trajectory and spacecraft stability all of which informed her later work.

Lee was soon invited to work for the director of engineering and development Dr Max Faget, the famous designer of the Mercury capsule and who later contributed to the designs of the Gemini, Apollo and Space Shuttle spacecraft. As the only lady working with a team of male engineers under Faget, the “human computer with a calculator” was adopted into this exclusive engineering club and soon excelled as an astute project engineer responsible for her own teams. Then, on October 4th 1957, Sputnik orbited the world and everything changed. NACA was re-tasked from an advisory body into NASA and funding soon began to flow into new projects.

Dorothy Lee, the “human computer with a calculator” hard at work developing re-entry predictions for Apollo.
Credit: NASA Johnson Space Center

Lee moved to Houston and the principles developed on Mercury were translated onto the Apollo Program. The earlier work Lee had done at the PARD on trajectories, spacecraft stability and blunt/ cone shaped spacecraft properties became essential in predicting the performance of the ablative Apollo heat shield, or Thermal Protection System (TPS) as it was known. Given the predicted orbital and super-orbital velocities Apollo spacecraft would encounter, she and her team made a series of calculations to measure the aero-thermodynamic characteristics of an Apollo Command Module (CM) at re-entry. Wind tunnel tests gathered pressure and heating rate data at varying angles of attack with the atmosphere. Along with previous data gathered from the orbital flights of the Mercury and Gemini programs, Lee was then able to collate the data, punch their values into a series of cards, and feed the cards into a floor filling computer for analysis. This was a difficult and slow process as computers at the time were in their infancy. They were huge, slow and had only a fraction of the power and portability of an average phone today. Despite this, Lee was able to calculate predictions of the extreme temperatures and pressure generated from a super-orbital speed re-entry. However these were all still theoretical.

Based on Lee’s predictions, incremental work began to refine the ablative heat shield technology previously used on Mercury and Gemini spacecraft. This required significant upgrading of the tools, materials and techniques as the Apollo Command Module (CM) heat shield was much bigger than its predecessors and would encounter far greater stresses. Materials such as Teflon were explored, but finally, a new Avcoat epoxy resin was used. This epoxy novalic resin was created with additives in a special fibreglass honeycomb matrix injected into a brazed steel structure. This matrix was bonded to the shell of the CM, where each honeycomb was painstakingly filled by the mixture, cured and inspected. Any defects meant the resin had to be removed and the whole process restarted from scratch. It had to be perfect as any anomalies in the resin could cost the lives of an Apollo crew.

Following Lee’s theoretical predictions and the production of a satisfactory heat shield, four unmanned heat shield qualification flight tests were done at orbital (up to approximately 18,000 mph) and super-orbital (up to approximately 24,000 mph) re-entry speeds with Block-1 Apollo CMs. Each CM included pressure transducers, radiometers and surface mounted calorimeters to capture data during re-entry. The flight data was compared with Lee's theoretical predictions to confirm her calculations and the design of the heat shield was correct. The results proved that the use of Lee's pre-flight theoretical predictions and the use of wind tunnel test data were essential in the design of the Apollo spacecraft, and especially so for its extreme re-entry conditions.

The legacy of Dottie Lee's work are clear; four unmanned Apollo and subsequent manned Apollo flights protected the spacecraft and carried its crews across the fiery last obstacle of re-entry before returning home. Such is the trust in her work that NASA continued to promote Lee and retain her experience where she directed large project teams in the design of the thermal protection system for the Space Shuttle. Her vast experience with cone shaped spacecraft was incorporated into the design of the Shuttle's nose cone which was nicknamed "Dottie's Nose". Now the legacy of her early work back on Wallops Island and since has been continued once again. On June 5th 2014 engineers at NASA's Johnson Space Center in Houston installed the largest heat shield ever made to the new Orion spacecraft. The heat shield is made from Avcoat (the same material used on Apollo CMs) and is built on the same theoretical predictions made by Lee so many decades before. In an echo of the 1960's Apollo heat shield tests, in December 2014, Orion will undergo its own super-orbital velocity tests with a 20,000 mph re-entry from space. Crews past, present and future have a debt of gratitude to this "human computer with a calculator".

Artist's rendering of an Apollo Command Module's fiery re-entry and the eroding away its ablative heat shield. Credit: NASA via Retro Spae Images

Houbolt, Kelly, Foraker, Shea, Silver and Lee. These tireless, dedicated men and women worked silently and diligently in the background towards a national goal and a wider vision that defined a generation. They were just six out of a national work force supporting three men that climbed aboard a rocket, flung themselves into the void and walked on another world. This cast of hundreds of thousands committed themselves to a historic achievement that was larger than anything they had been part of before and since. These are the true unsung heroes of Apollo. We all can learn from their example. The high ground of space is still there for us, if we only commit ourselves to that wider vision defined long before…

"William Bradford, speaking in 1630 of the founding of the Plymouth Bay Colony, said that all great and honorable actions are accompanied with great difficulties, and both must be enterprised and overcome with answerable courage. If this capsule history of our progress teaches us anything, it is that man, in his quest for knowledge and progress, is determined and cannot be deterred. The exploration of space will go ahead, whether we join in it or not, and it is one of the great adventures of all time, and no nation which expects to be the leader of other nations can expect to stay behind in the race for space…. We choose to go to the Moon! We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard, because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one which we intend to win!"

- President John F. Kennedy speaking at Rice Stadium, September 12 1962

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

Wally Schirra and Scott Carpenter (sitting) get some help while studying star charts at Morehead Planetarium.
Credit: NASA via Retro Space Images.

Learning celestial navigation at Morehead Planetarium

By Tony Rice

You might not think a visit to a planetarium could save your life but that's how at least seven astronauts see the Morehead Planetarium and Science Center in Chapel Hill, North Carolina.

Nearly every astronaut in the Mercury, Gemini, Apollo, and Skylab programs made multiple visits to Morehead to learn celestial navigation. Each spent at least two days learning the basics of celestial mechanics and practicing star recognition.

Astronaut training began at the NASA's Langley Research Center in nearby Hampton, Va. Morehead's location allowed astronauts to keep their six-day a week schedule by landing their T-33 and T-38 trainer jets at the university's airport before moving on to Cape Canaveral, Houston, or Langley for additional training or briefings.

It all began in 1960 planetarium director Anthony Jenzano saw the facility's potential in teaching America's newly minted heroes how to find their way in space. Planetarium technicians put their experience building special effects to enhance public shows to work creating a training environment which replicated challenges astronauts might face in their capsules should something go wrong. And something did go wrong, more than once.

"If all else fails, we will use the stars as our only reference," said Gemini astronaut Walter Cunningham.

The facility's Zeiss Model II star projector was among the finest in the country. It had recently been upgraded to more accurately represent the 42 brightest stars. It was also capable of displaying stars visible from both the Northern and Southern hemispheres giving astronauts a much needed and unfamiliar view.

The first day of training began at 8:30 a.m. with an introduction to the facility and the Zeiss projector. Astronauts quickly rolled up their sleeves as Doctoral candidate James Batten provided an introduction to the celestial coordinate system that would be used throughout the training to identify stars as they passed through view ports of their simulated spacecraft. The remainder of the day was spent learning to identify constellations of the zodiac and their stars in sequence. The second day of training focused on star identification and practicing course corrections along the planned orbital path of each astronaut's mission. A "spin-the-world" game was developed where star positions were shifted with the projector lamp off to simulate a spacecraft off course.

"I thought I knew a lot about the stars but I found there was more to know that I had anticipated" commented Mercury astronaut Gordon Cooper.

Planetarium technicians created increasingly complex trainers to match the view and controls astronauts would have from their capsules. A small mechanical flight simulator originally used to train pilots during World War II was modified to simulate the yaw controls of a Mercury capsule's thrusters. Simulators were also created for Gemini and Apollo capsules seating multiple astronauts. Materials used to ranged from plywood and paint to simple cardboard and tape to an old barber chair.

Some astronauts continued star identification as they flew from training site to training site.

"You've got a wonderful view of the sky and it was a great opportunity to practice. We would be flying at a high altitude of 40,000 feet and would turn the lights completely down in the cockpit." Neil Armstrong recalled. Armstrong spent the most time training at Morehead, 130 hours over 20 days.

That knowledge gained under the planetarium dome was put to mission and life saving use at least three times.

The Morehead Planetarium and Science Center in Chapel Hill, North Carolina was an instrumental place for teaching Mercury, Gemini, Apollo and Skylab astronauts about the basics of celestial navigation. *Credit: Morehead Planetarium*

During the final orbits of the final Mercury mission, navigational controls failed. Gordon Cooper recalled his Morehead training, using the stars to aligned his "Faith 7" spacecraft to the 34° angle required to prevent burning up during re-entry. Cooper's splashdown was the most accurate in mission history.

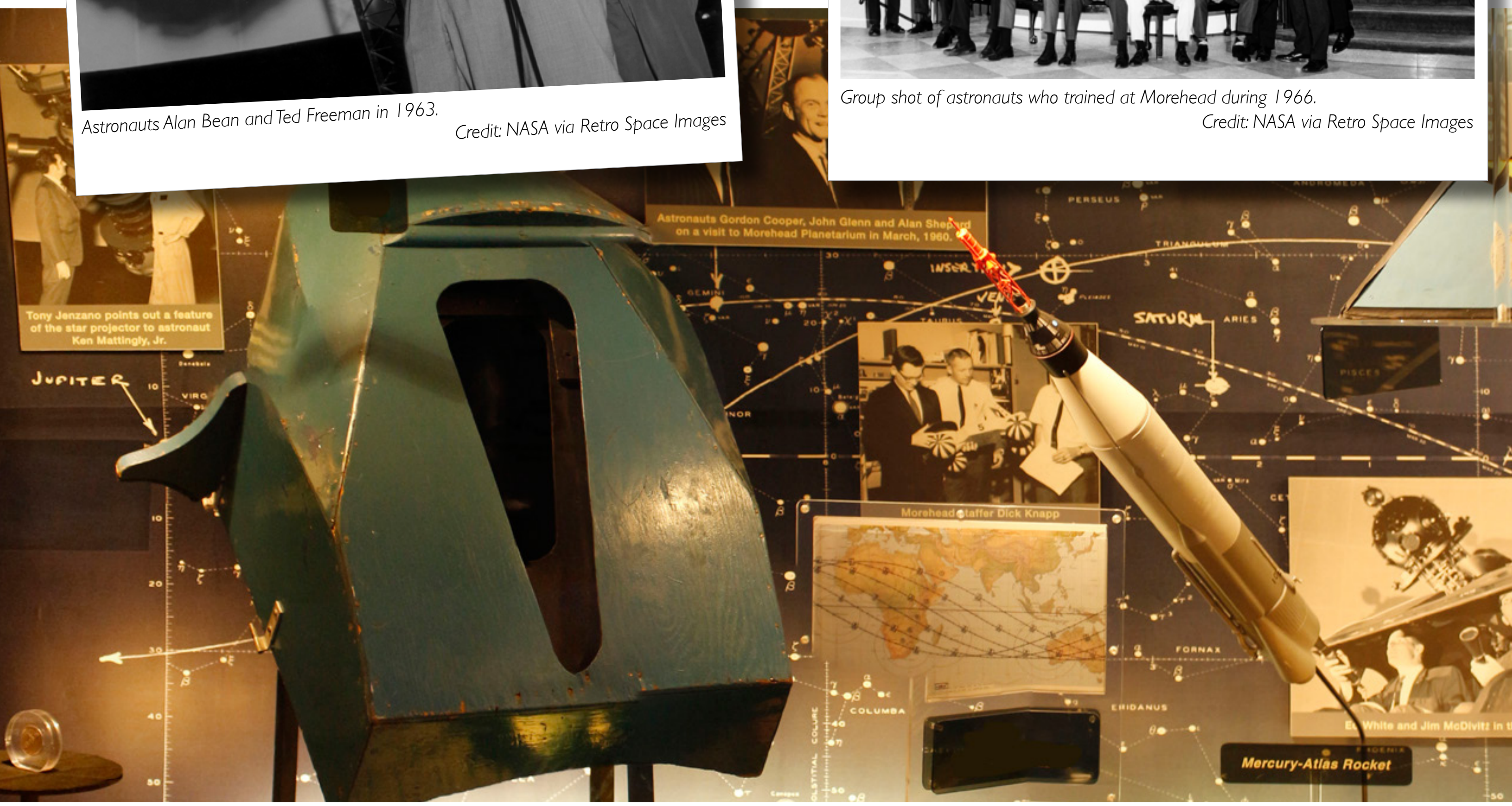
Thirty-six seconds after lift-off of Apollo 12, two bolts of lightning struck the rocket and traveled down the ionized exhaust plume to the ground. The Saturn V rocket itself triggered a lighting discharge as it passed through electrically charged grey rain clouds. Power in the command module failed, all systems were down and the astronauts were on emergency batteries three miles

Astronauts Alan Bean and Ted Freeman in 1963.

Credit: NASA via Retro Space Images

Group shot of astronauts who trained at Morehead during 1966.

Credit: NASA via Retro Space Images



over Florida. John Aaron, a quick thinking 24-year-old engineer recalled a little used switch in the capsule. His recommendation to "switch SCE to AUX" restored power to the mission but astronauts Charles "Pete" Conrad, Jr., Richard Gordon, Jr. and Alan Bean were still in low earth orbit without a functional navigation system. They were able to reset the guidance system by sighting key stars allowing the mission to continue.

An explosion in an oxygen tank crippled power generation aboard Apollo 13 en-route to for a Moon landing. The capsule, service module and lunar lander were left with limited power forcing navigation systems to be switched off.

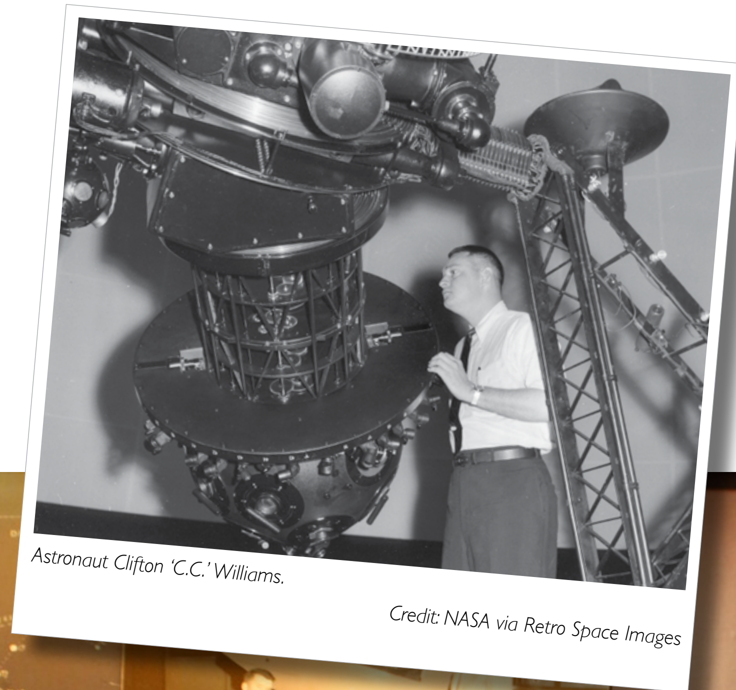
The crew verified their position via the stars as they continued for a fly-by while engineers (including John Aaron) figured out how to get the crew home. Debris from the explosion further complicated things making spotting those stars difficult. The view cleared in time for command module pilot John Swigert to locate stars Altair and Vega hours before a safe reentry.

Apollo 13 astronaut Jim Lovell even passed on some of what he learned at Morehead 25 years later to actor Tom Hanks. Hanks visited Lovell at his Horseshoe Bay, Texas home to prepare for the Apollo 13 movie. Lovell took him flying at night, pointing out the stars he'd learned about at Morehead. "Antares and Nunki, the two stars we saw on Apollo 13 as we flew into the shadow of the Moon."

Donald K. Slayton was the last astronaut to train at Morehead in 1975 for the Apollo-Soyuz mission. The program ended as NASA moved on to the Space Shuttle and its more reliable guidance computers.

You can visit The Morehead Planetarium and Science Center on the campus of the University of North Carolina at Chapel Hill and learn about the same stars under the same dome as 62 astronauts. Or visit the center's website at www.moreheadplanetarium.org.

Astronauts Jim Lovell and Frank Borman. Credit: NASA via Retro Space Images



Astronaut Clifton 'C.C.' Williams. Credit: NASA via Retro Space Images

Equipment created by planetarium staff in training astronauts on exhibit at Morehead Planetarium and Science Center. Credit: Tony Rice

Learning about the night sky from where you live

Not everyone will be able to travel to North Carolina and learn about the stars just like the early astronauts did, however, that doesn't mean you can't learn from where ever you are.

There are hundreds of planetariums located across the United States. To find the closest planetarium to you, check out the state-by-state list at:

- http://www.go-astronomy.com/planetariums.htm

Wikipedia has a worldwide list of planetariums at:

- http://en.wikipedia.org/wiki/List_of_planetariums

There are also a large number of astronomy clubs located throughout the country. These clubs if asked will often bring telescopes to your school for a star-viewing party. Check out the Night Sky Network to find the nearest astronomy club at:

- http://nightsky.jpl.nasa.gov/club-map.cfm

To learn more about the Universe itself, we suggest visiting these two websites:

- http://www.cosmos4kids.com/
- http://solarsystem.nasa.gov/planets/

Apollo 11
a giant leap for mankind

"It was a wondrous opportunity to be part of something historical. We just had a hard time comprehending what it would mean to other people, what it would mean to ourselves." – Buzz Aldrin

By David Clow

It was too much for us to grasp at the time. America was in hot battles at home and in cold wars abroad. Our campuses were in turmoil, our cities on fire. Our sons and brothers were in a war that divided our families and generations. Space travel was new, visionary, and dangerous, and we understood that for all its romance, the race to the Moon was yet another front like Berlin or Cuba in a struggle that made us do duck-and-cover drills under our schooldesks. Whatever winning was, we had to do it. And in the midst of all of that fear and fatalism, we saw the Earth whole for the first time, little and alone in the black of space, and two Americans stood on another world and said, "We came in peace for all mankind." We were seeing our world as it might be, not as we had let it become.

None of us could have been ready for it, not the ones who did it or those who witnessed it. Buzz Aldrin had a knack for capturing the feeling in succinct phrases like "magnificent desolation." Perhaps his best characterization of it came after splashdown, when he realized the immensity of the world's attention on Apollo 11, and saw that while he and his colleagues had been focused on deploying experiments, taking photos, collecting samples and making observations about the immediate, ("109:46:08 Aldrin: There's absolutely no crater there at all from the engine") hundreds of millions of people felt their lives changed in way they could not explain. "Neil," he told Armstrong, "We missed the whole thing."

We might still be missing it.

Armstrong and Aldrin had precious little time to spend on the grandeur of the place and the significance of the moment. Their heirs have had decades to weigh it all, and even with all this time, it remains irresistibly tempting for us to lose ourselves in the details. We can still be enthralled by the minutiae of acronyms and schematics. As years pass, the primary sources fade into archives; the facts get dramatized and mythologized; the people who did all this become heroes having sought only to be good at their jobs; and those of us most devoted to the real history of Apollo 11 can become merely the curators of specifics. We can spot a forged Armstrong autograph. We can explain a 1201 alarm, and navigate the meaning of "Mode Control, both Auto. Descent Engine Command Override, off. Engine Arm, off. 413 is IN" as though we are there now, much like the re-enactors with perfect reproductions of Civil War arms and uniforms can stand at the Bloody Angle at Gettysburg and tell visitors about Alonzo Cushing and Lewis Armistead. Retelling the old stories is irresistible, but the risk is the same one the crew of Eagle faced: missing the big picture, missing the reasons for it and the meaning of it while we focus on the tasks at hand; missing the whole thing.

Those of us who were lucky enough to have seen Apollo 11, and who remain privileged to shepherd its memory, might, as Americans, think of ourselves as part of the "we" who were first the Moon and of the "we" who came in peace. But we were observers, not participants. We watched it, we supported it, but we didn't make it happen. A tiny sliver of Americans were involved hands-on. It was theirs.

Ours is what remains unfinished in the mission.

The generation before us went to the Moon. We have not been back since they did it. If "we" want to lay claim to the achievements and the legacy of Apollo 11 and to be part of something historical, let us deliver more than our memory for details. We are the spinoffs. We are the inheritors of the potential of Apollo. It fell to us to create the future of manned lunar exploration, and not just to witness it executed by someone else. The momentum flagged on our watch, but the questions raise fifty years ago still give us a galvanizing agenda, if we can take it. What ongoing steps of manned lunar exploration will best advance the first one? What can we do with what our predecessors learned? What does it mean to be multiplanetary humans? Can there really be such a thing on this divided world as "all mankind," and can we rediscover that inspiration?

In viewing these iconic photos again, keep a quote from Buzz Aldrin in mind. It is not something he said on the Moon. He said it later, reflecting on what happened and on what happens next:

"Something is useless only if we do not know how it use it. If we use our Moon experience wisely in the years to come, there is no doubt that it will be a vital basis for greatly expanding our knowledge of the universe."

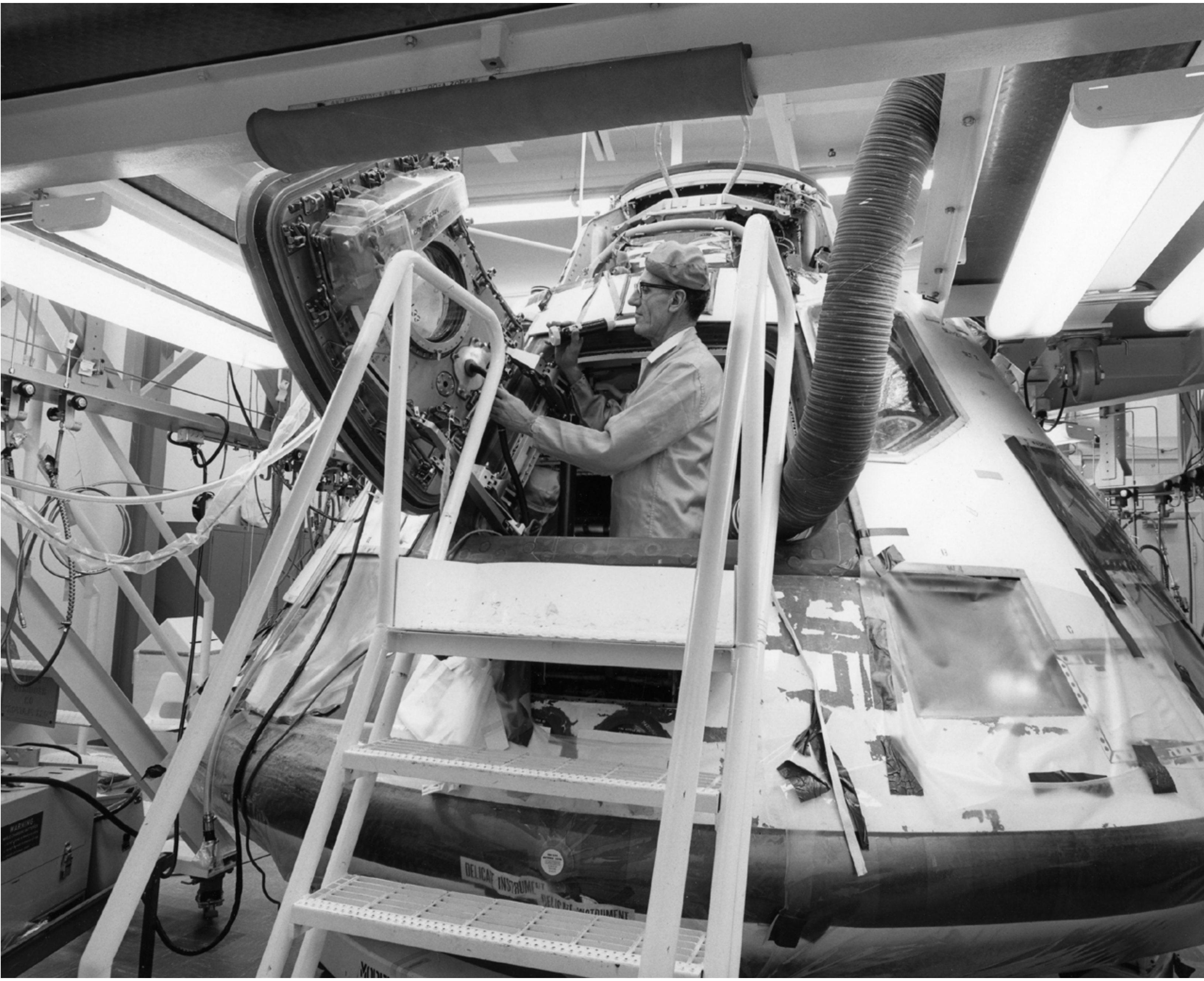
Apollo changed nothing if we decline to live the change. The whole thing is yet to be fulfilled. Neil Armstrong made one small step. The giant leap is for us to make.

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

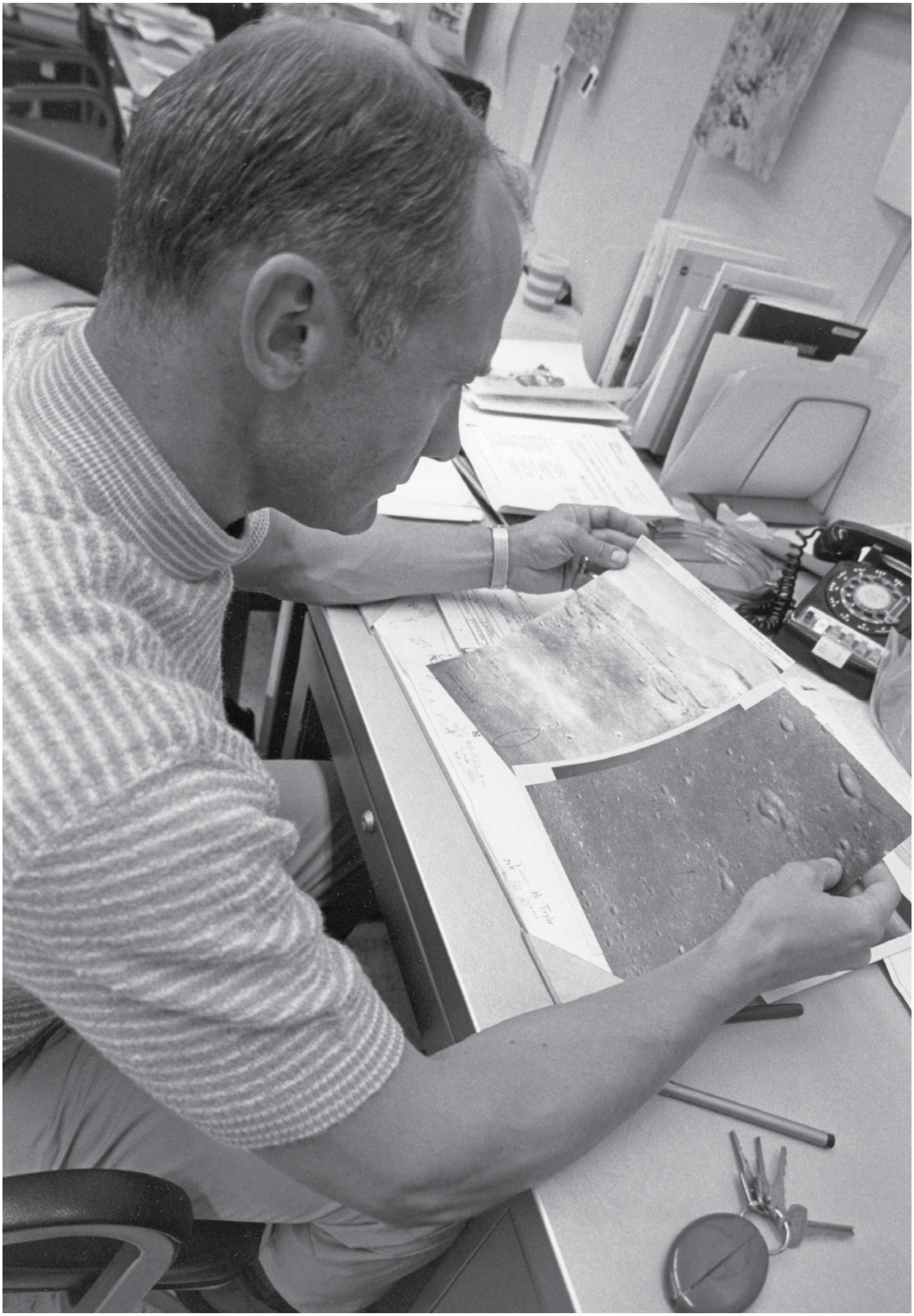
Images provided by Retro Space Images. The company has a vast number of comprehensive image discs of NASA manned space missions containing thousands of high-resolution photos from NASA, contractors and other sources.

The Apollo 11 Lunar Module undergoing checkout at KSC in April of 1969.

Neil Armstrong stands in front of the lunar lander trainer at Langley on February 12, 1969.



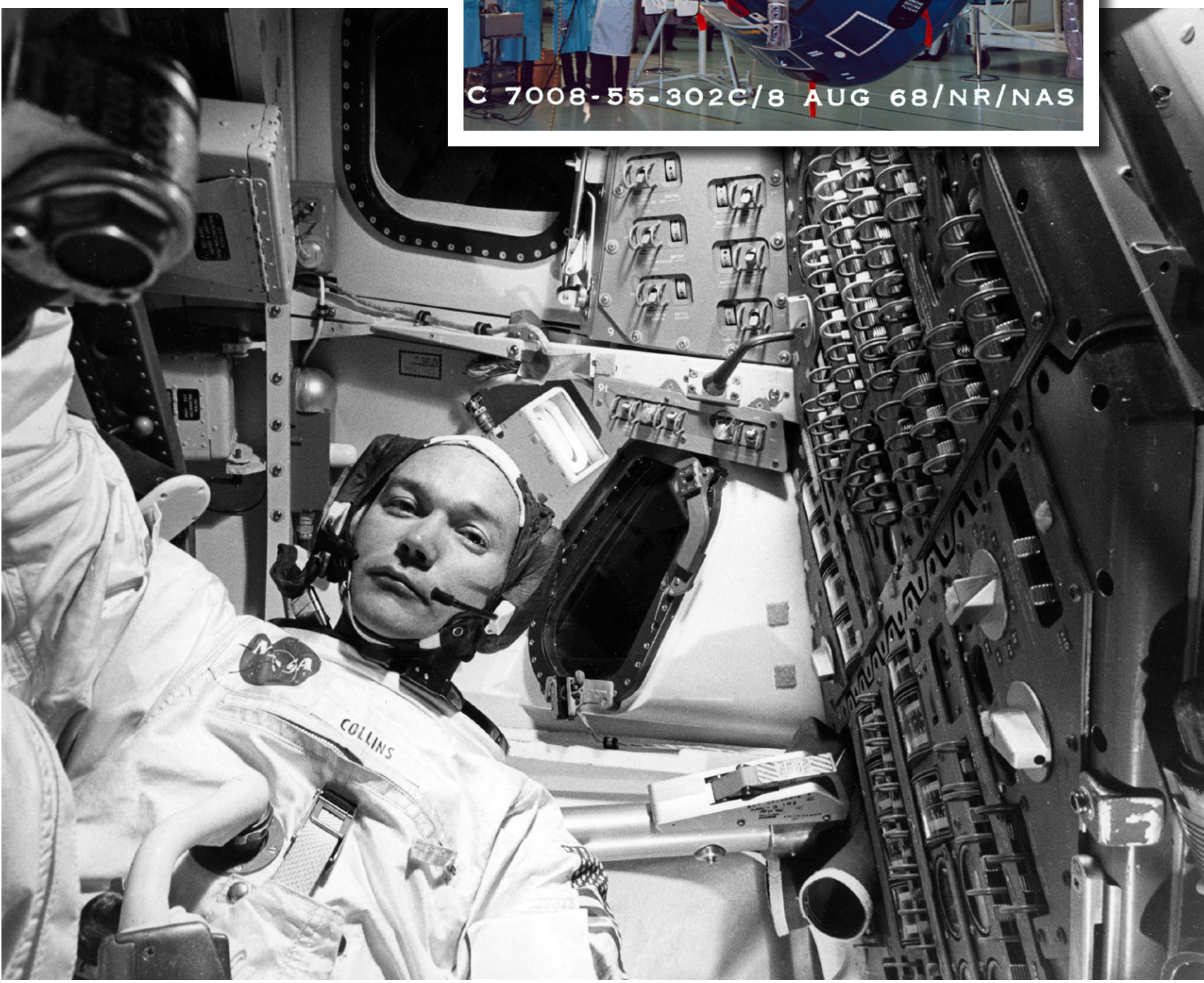
Apollo 11 Command Module (CM-107) during construction and testing at the Rockwell plant in Downey, California.

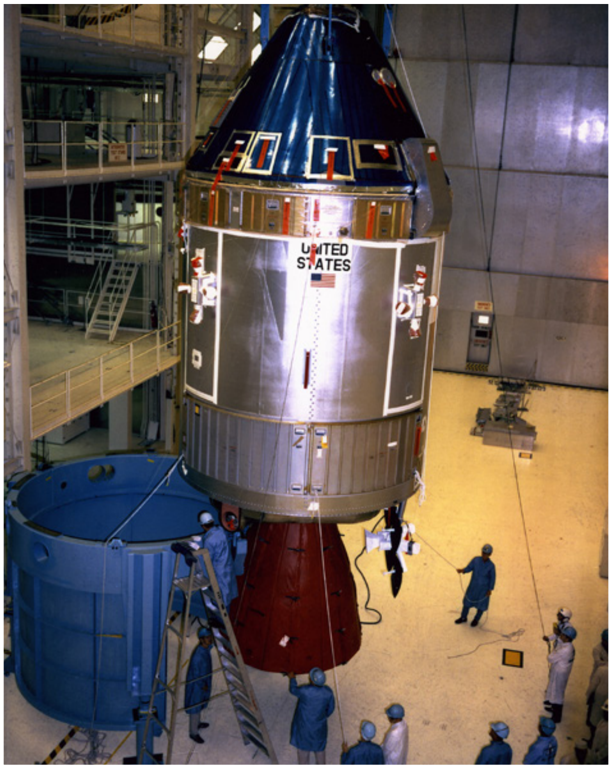


Edwin "Buzz" Aldrin reviews photos of the lunar surface at KSC on July 14, 1969.

The Command Module at the Rockwell plant in Downey, Calif. on August 8, 1968 just prior to shipment to KSC.

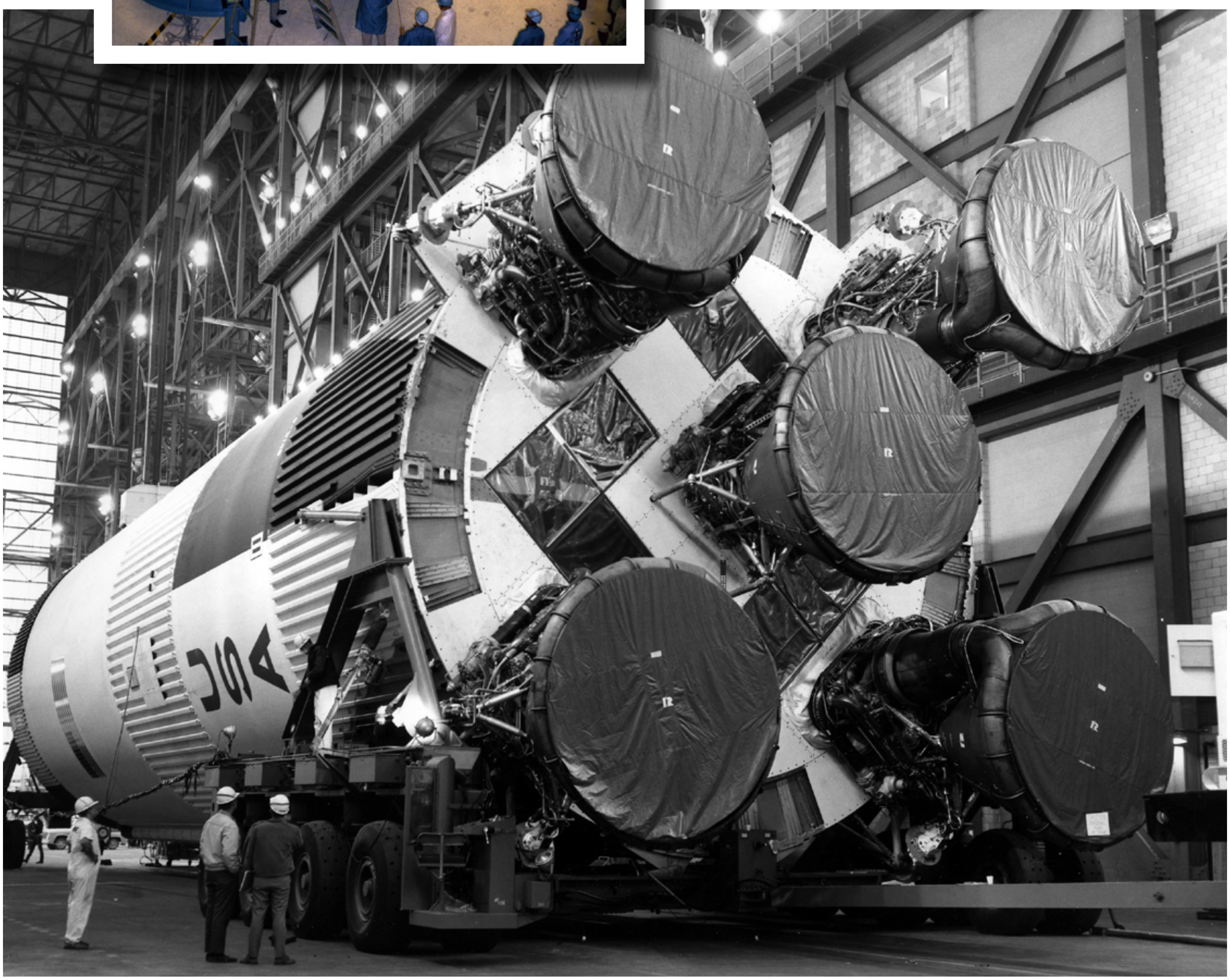
Michael Collins practicing in the CM simulator on June 16, 1969.





The Apollo Spacecraft 107 Command and Service Modules being moved from workstand 134 for mating to the Spacecraft Lunar Module Adapter (SLA) while inside the Manned Spacecraft Operations Building at KSC during April of 1969.

The S-IC first stage in the transfer aisle of the VAB on February 21, 1969.



Edwin 'Buzz' Aldrin and Neil Armstrong participates in an EVA simulation of deploying and using lunar tools on the surface of the Moon during a training exercise in Building 9 of the MSC at Houston, Texas on April 18, 1969.

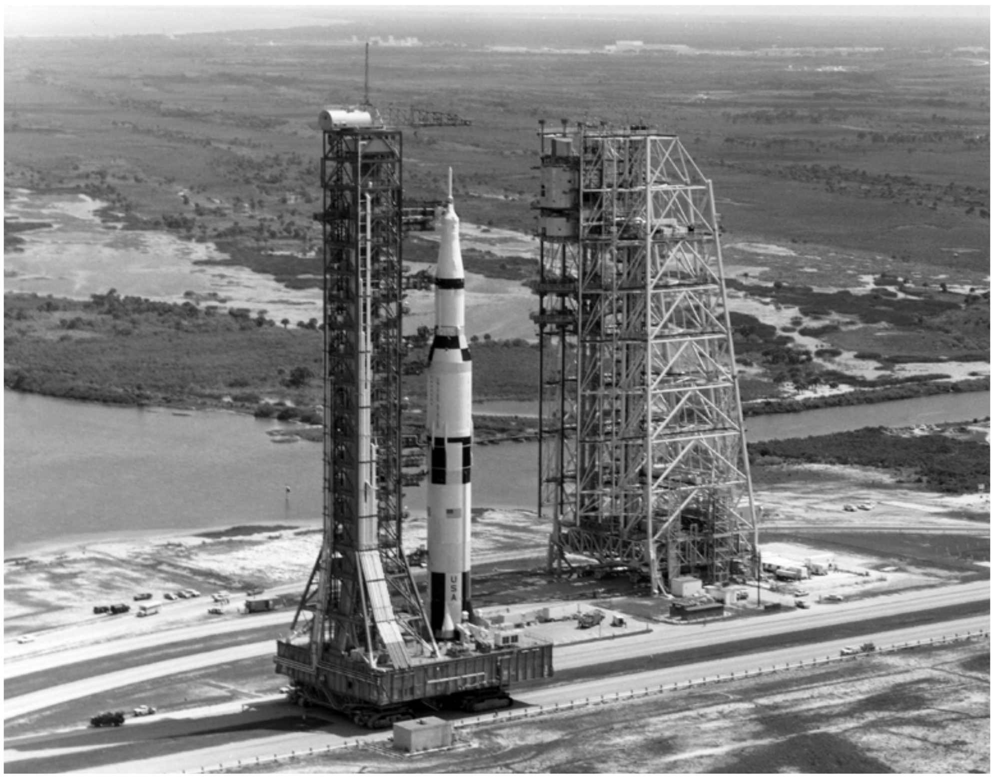
Edwin 'Buzz' Aldrin suited up for a simulation at the MSC in Texas on April 18, 1969.

Neil Armstrong preparing to enter the LM simulator on June 16, 1969.

The SLA with the CSM are mated to the Saturn V inside a high bay of the VAB on May 1, 1969.

The S-IVB third stage is raised inside the VAB at KSC for mating to the second stage on March 21, 1969.

May 20, 1969. Saturn V SA-506, which will launch the Apollo 11 crew toward the Moon, is slowly driven out of the Vehicle Assembly Building on May 20, 1969.



While traversing the 3.5 mile crawlerway to LC 39-A, the Saturn V passes the Mobile Service Structure, which will join it atop the pad as launch preps are continued.

It was estimated that one million people were present on the Space Coast to see the launch of Apollo 11, with some families even sleeping on nearby beaches the night before the launch.

Edwin 'Buzz' Aldrin and Pad Leader Guenter Wendt in the White Room leading into the CM atop the Saturn V rocket at the launch pad on July 16, 1969.

Michael Collins is helped by stuit tech Joe Schmitt while suiting up on July 16, 1969.

Neil Armstrong suiting up on July 16, 1969.

After having departed the transfer van at Pad 39A on launch morning, the crew prepares to board the first (ground level) elevator at the pad. They would soon transfer to a second elevator that would take them to the White Room at the 320 ft. level.

Liftoff of Apollo 11 at 9:32 a.m. on July 16, 1969 as seen from a camera high up on the mobile launch tower.

Vice President Spiro Agnew (gray blazer) and former President Lyndon B. Johnson (blue suit) view the liftoff of Apollo 11.

The 70mm ALOTS tracking camera mounted on an Air Force EC-135N aircraft flying at about 40,000 feet altitude photographed this event in the early moments of the Apollo 11 launch.

In their own words

The rocket that rocked our world

By Dauna Coulter

Forty-five years ago a mammoth rocket and some pioneers of great vision helped humankind achieve a remarkable feat: walking on the Moon. The event had a profound effect on those who witnessed it and created endless possibilities for those who came after.

Those of us old enough to have lived in Huntsville before NASA's Apollo 11 Moon mission can still recall the ground shaking as the mighty Saturn V first-stage rocket boosters, secured in a colossal test stand at nearby Marshall Space Flight Center, rumbled and roared. As the Earth trembled, we clung to our swing sets, paused our bicycles, jumped off our pogo sticks, and just stood still – mesmerized and amazed by what we knew was history in the making.

Soon after, the rest of the nation stood equally still – mesmerized and amazed as Neil Armstrong took his legendary "small step" on a distant world. A feat made possible by the same rocket.

It was one of those "transcendent moments of awe that change forever how we experience life and the world." Although John Milton wasn't speaking of the moment humankind set foot on the Moon, his words aptly describe the profound effect events of such magnitude have upon those who witness them.

July 20 marks the 45th anniversary of the famous footstep – the result of a long and concerted effort by 400,000 NASA and contractor team members from across the country.

This incredible event inspired and uplifted the people who watched it unfold. Black-and-white televisions flashed patterns across darkened living rooms as viewers stared into the light at the almost surreal scene.

"I woke my two youngsters up to watch," said Ed Buckbee, formerly of Marshall Public Affairs and the first director of the U.S. Space and Rocket Center. "They were half asleep on the couch – yawning, their eyelids drooping – but my eyes were open wide! I could hardly believe what I saw. We actually pulled it off – humankind walking on the Moon! It was like something out of a science fiction novel."

Ken Fernandez, who has worked at Marshall for more than 40 years, was 23 when the first moonwalk took place:

"The night of the moonwalk, I was in the Lake Guntersville campgrounds with a group from my church. We were watching the event on a portable TV plugged into my car. It was fairly late in the evening, but over 100 people from surrounding campsites gathered around our TV. Up on the Moon, Armstrong came down a ladder and then stood on the lander's pad. When he stepped off onto the lunar surface, there was a spontaneous cheer that was probably heard across the lake. It was one of those moments that you never forget."

James Daniels, who worked for NASA from 1956 to 1981, attended the Apollo 11 Saturn V launch and then headed up to Fort Walton Beach for a brief respite.

"I rented a room in a beachside apartment with a screened deck overlooking the Gulf. I put a little black-and-white TV out on the deck and watched most of the Moon voyage coverage. I watched all during the late afternoon and early night of landing day. I was so relaxed by the Apollo landing time, which was late night at Fort Walton, that I dozed off in my chair in front the TV with the sounds of the ocean waves lapping the beach in the night. Fortunately, I awakened as Armstrong began his exit from the Lunar Module. I sat entranced by the ghostly glare of Armstrong's space suit while he backed down the ladder in the darkened shadows of the vehicle and dropped off the last rung.

"When he uttered, 'That's one small step for a man, and a giant leap for mankind,' I cried. My thoughts reeled at his words, which so well captured the event's historic importance to us all."

The Saturn V, the rocket that made it all possible, was designed at Marshall under the direction of Dr. Wernher von Braun. Bob Ward, the Huntsville Times' first full-time space and missile reporter from 1962 to1966 and then Sunday editor, later wrote a book about the famous rocket scientist. And in 1969, he couldn't resist stepping back into his reporter shoes to cover the big story.

"For old times' sake, I assigned myself to Cape Canaveral in July 1969 to help cover the Apollo 11 launch. At NASA's press site shortly after liftoff, I was sitting up in the press bleachers tapping out my story on an old typewriter when I suddenly spotted Dr. Ernst Stuhlinger leading an elderly gentleman whom I recognized through the crowd below. I hurried down from the bleachers and intercepted the pair. Amid the swirl of people moving about, I asked Stuhlinger if he would introduce me to his companion, Dr. Hermann Oberth, first space mentor to a teen-aged Wernher von Braun in Germany.

"With Stuhlinger translating, I interviewed the 75-year-old space pioneer – one of the founding fathers of rocketry and modern astronautics. Oberth found the Apollo 11 launch 'even more exciting' than he had dreamt as a boy. He said that NASA must press on and 'undertake a manned Mars mission.' It struck me as so very fitting that Professor Oberth should be present for this epochal mission to the Moon."

Fitting indeed. Twelve years before the launch, Oberth had written these words in his book Man Into Space:

"This is the goal: To make available for life every place where life is possible. To make inhabitable all worlds as yet uninhabitable and all life purposeful."

Forty-five years ago, a big rocket rocked our world by helping a human step forth onto another world.

"Shall we follow…?" (from T.S. Eliot's Four Quartets, Burnt Norton)

Flight Director Gene Kranz (left) is joined in Mission Control by astronaut Eugene Cernan during the Apollo 11 mission.

Earth is captured through the astronauts' camera during the translunar journey toward the Moon.

The full lunar disc photographed from the Apollo 11 spacecraft during its transearth journey homeward.

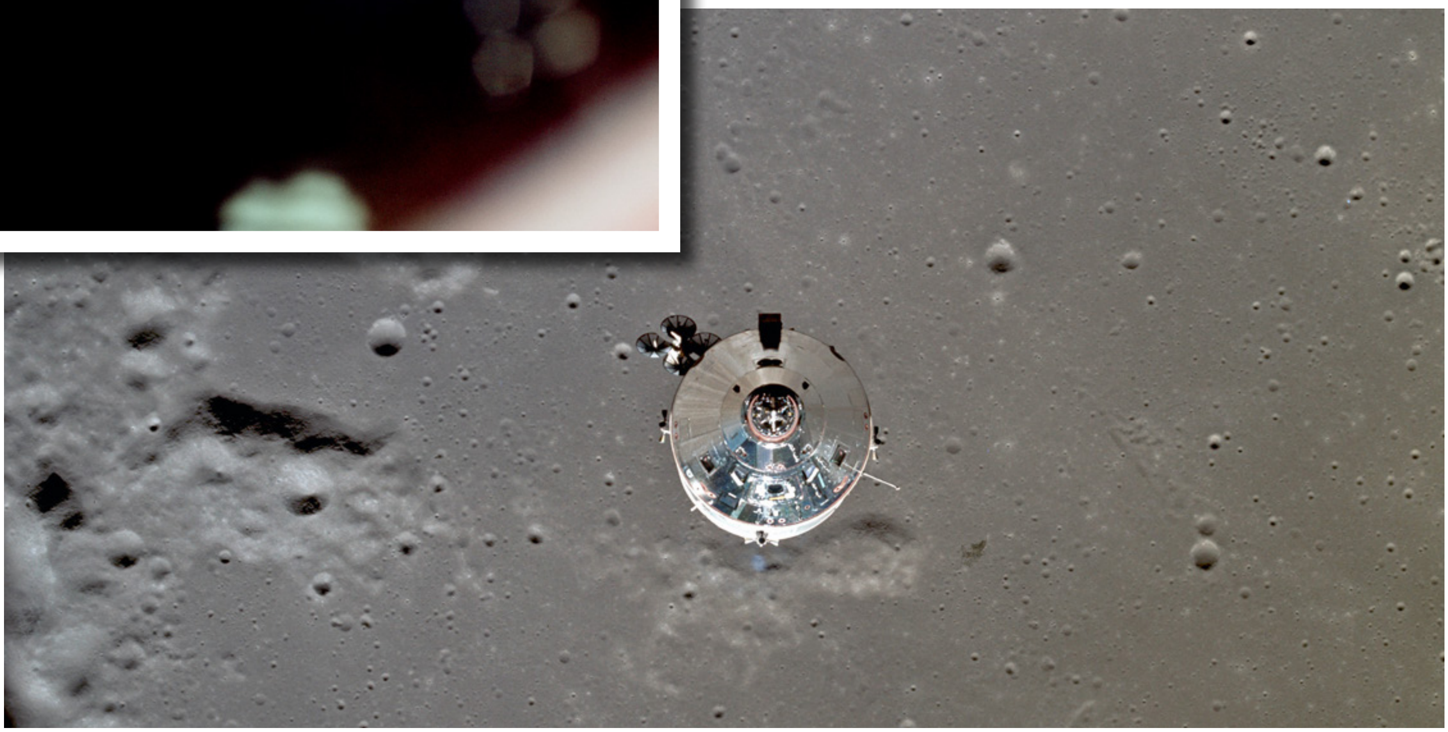
Michael Collins aboard the Apollo 11 spacecraft during the trip to the Moon. As the Command Module Pilot, Collins stayed in orbit around the Moon, while Neil Armstrong and Aldrin descended to the surface and became the first men to walk on the Moon.

"It's human nature to stretch, to go, to see, to understand. Exploration is not a choice, really; it's an imperative."

– Michael Collins

View of the Lunar Module as witnessed from the Command Module shortly before the LM's descent to lunar surface.

The CM seen orbiting the Moon just after separation of the LM. The lunar surface below is in the north central Sea of Fertility approximately 125 km below the spacecraft..



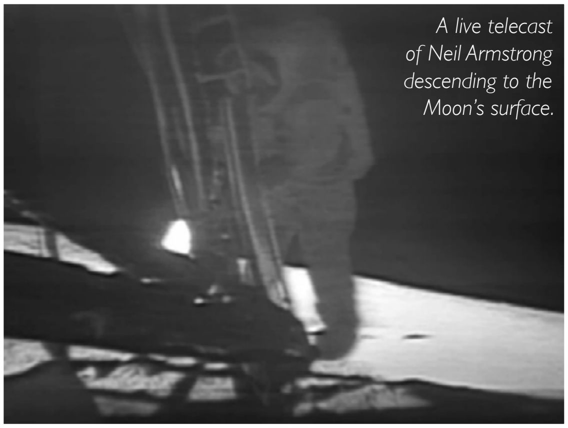
In their own words

Kicking up the dust and everything

As chief of public affairs for the Manned Spacecraft Center, Paul Haney was known as the "Voice of Mission Control" for the Gemini and first four manned Apollo flights. In 1969, he left NASA to report on space missions for ITN (Independent Television News) in London. The astronauts were his friends, and he understood spaceflight procedures. He recalled his thoughts as the Apollo 11 lunar module was trying to land on the Moon.

When the 1201 emergency [computer] alarm was sounded, I was just listening to that as they came down [for lunar landing]. I knew that was an abort parameter and, boy, I took a bunch of breaths. Then I remember it was [Buzz] Aldrin saying, "Just ignore that." He said that very quickly. And he did one hell of a job calling the landings. If you listen to that tape, he was busy. Charlie Duke was capsule communicator. After the landing, he said something like, "We're all about to turn blue down here," which was a pretty honest reaction. They had something like three or four seconds worth of fuel left in the descent tank. You couldn't cut it any closer. But Neil seemed to know what he was about, kicking up the dust and everything. That was really hairy, I thought. What if the lift-off rocket doesn't work in the LM? There was no backup. There was just one way to get out of there. It had to work, and that was the piece that was developed at White Sands, Las Cruces. They fired that thing up how many hundreds of times, and it worked real well. It had one hell of a success record. It worked six times on the Moon, too.

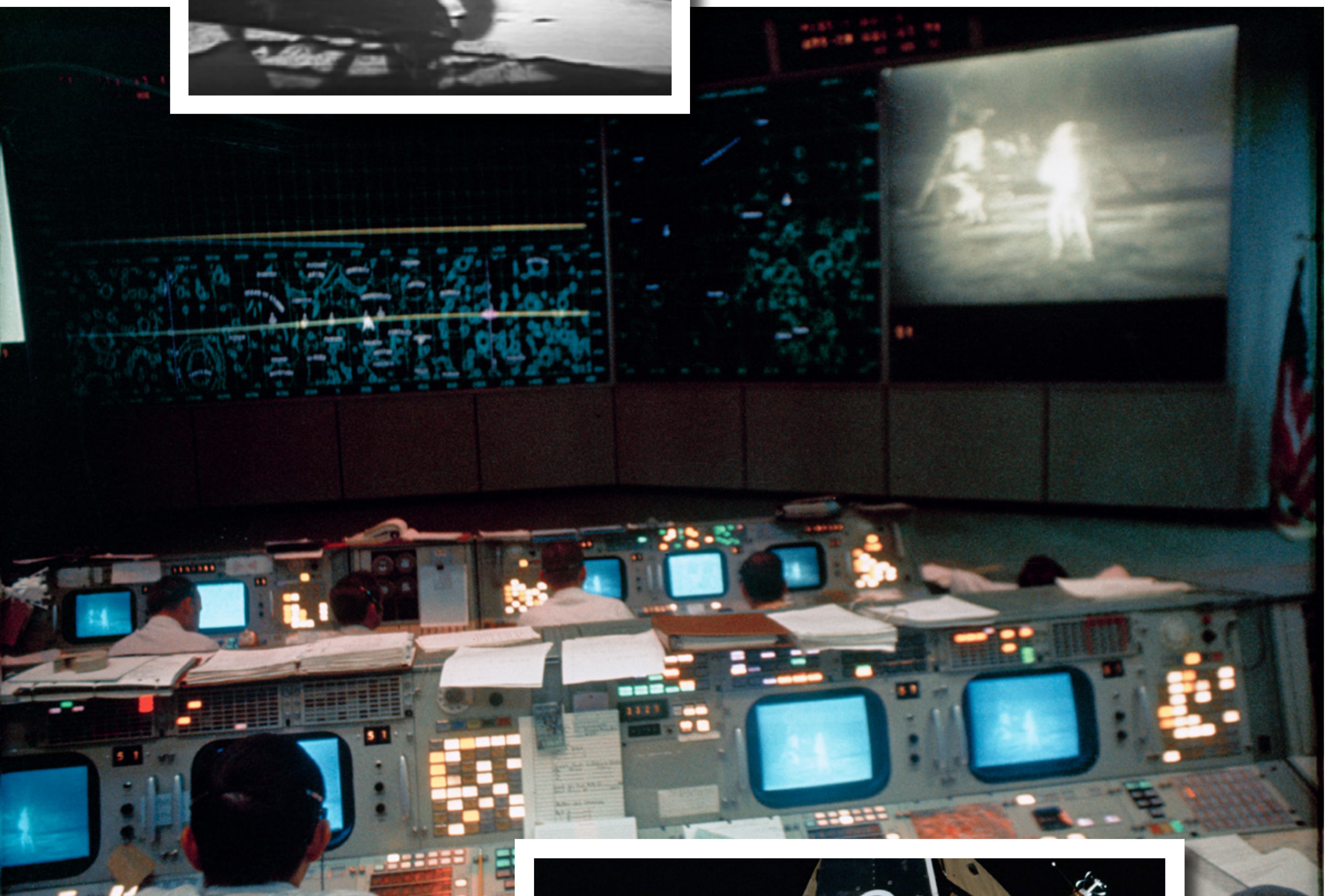
This is an excerpt from the book, "Space Pioneers: In Their Own Words" which was authored by Loretta Hall and released last month. The book is available for purchase at www.amazon.com.



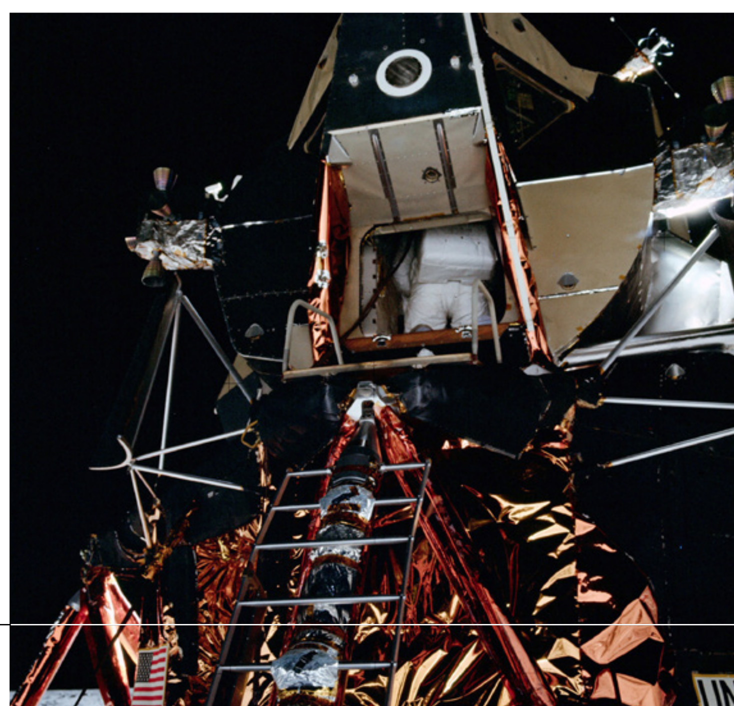
A live telecast of Neil Armstrong descending to the Moon's surface.

"Houston, Tranquility Base here. The Eagle has landed."

– Neil Armstrong



View of NASA Mission Control in Houston, Texas during the lunar surface EVA by Armstrong and Aldrin. The television monitor shows them on the surface of the Moon.



Edwin 'Buzz' Aldrin, lunar module pilot, egressing the lunar module during the extravehicular activity on the lunar surface.

Armstrong and Aldrin deploy the American flag outside near the Lunar Module at Tranquility Base in the Sea of Tranquility on July 20, 1969.

"The biggest benefit of Apollo was the inspiration it gave to a growing generation to get into science and aerospace."
– Buzz Aldrin

'The Eagle Has Landed' proclaims the front page of The Washington Post on July 21, 1969. Photograph taken by Jack Weir of his daughter.

In their own words

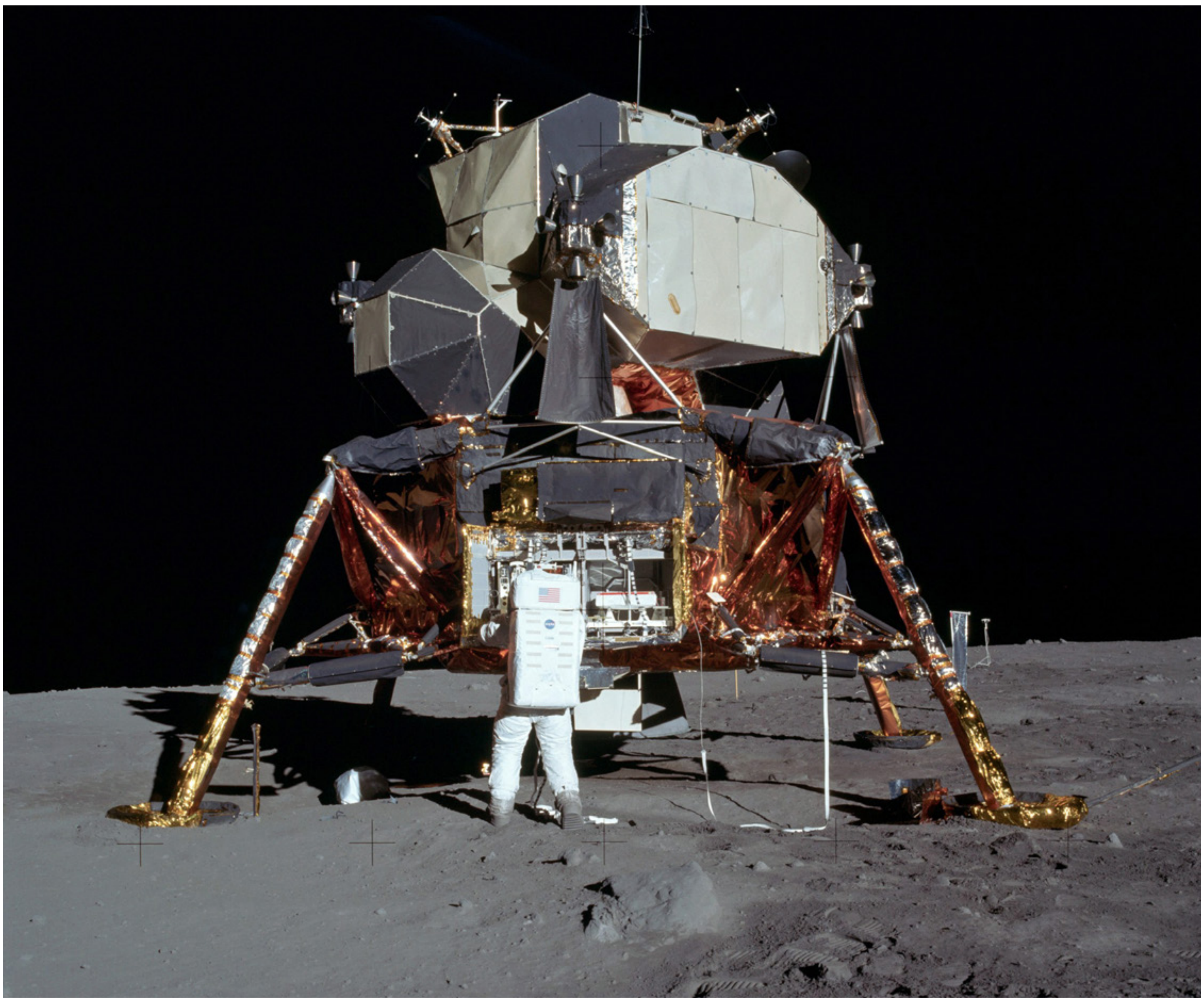
Tears in the middle of the night

Skip Chauvin was a spacecraft test conductor for every one of the Apollo missions, overseeing the closeout crew on the day of launch for Apollo 11.

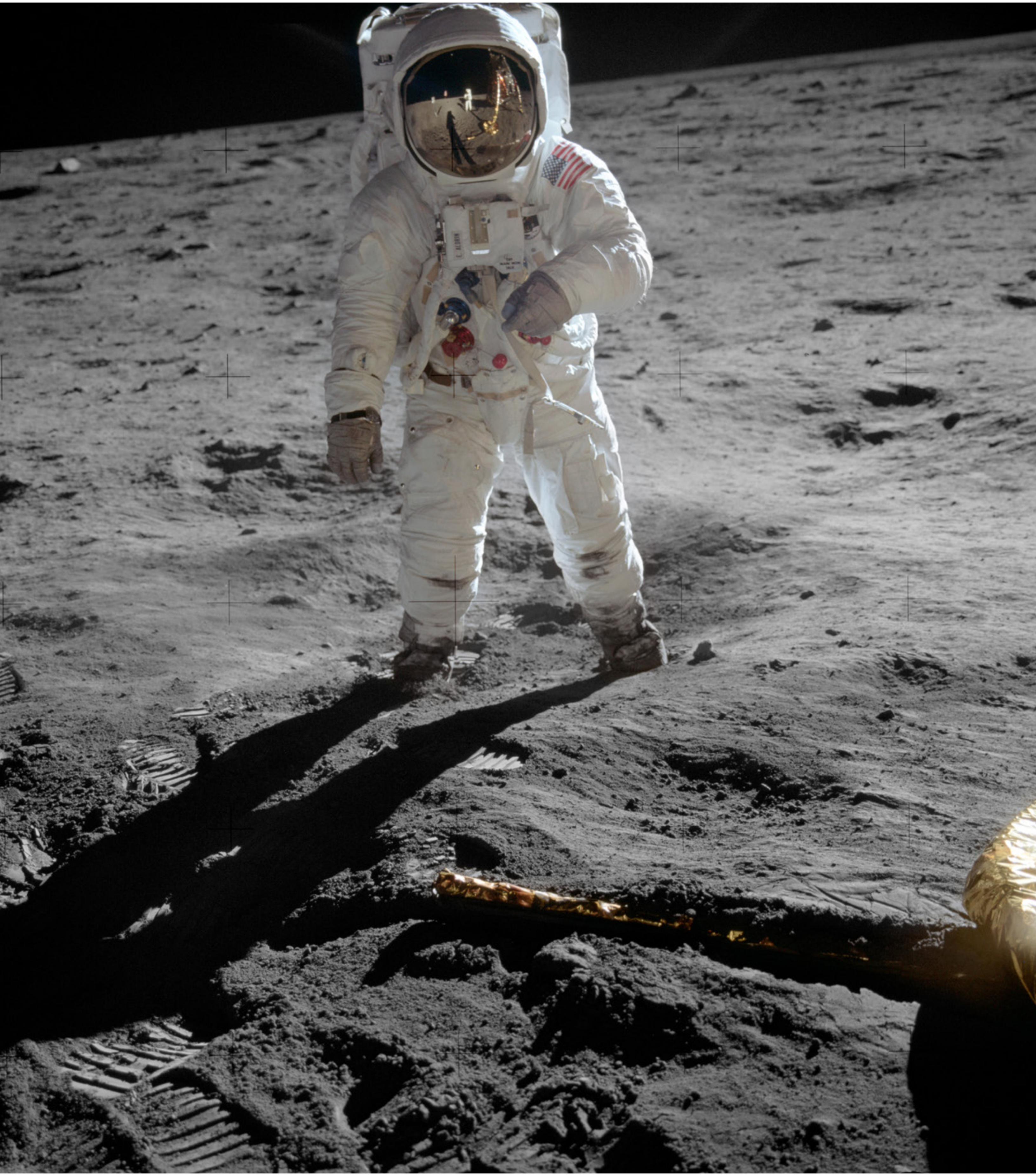
Things were going so fast in those days that, all the way through countdown, I never felt a big rush, like oh my god, oh my god, i'm nervous and can't do this. I suppose in retrospect I should have been surprised that I wasn't all nervous and uptight. But it just rolled on. We had done several before that, and I think we were all so anxious to each do our parts to the best of our abilities, that none of us seemed to be all excited.

The crazy part about it is, after liftoff, once we were sure things were OK, I packed up my family – three kids and my wife – and the boat and we took off south to Lake Worth down in southern Florida. So all during that time it was busy, busy, but when it came time for the landing itself on the Moon, I remember it was the middle of the night and all the family was asleep. I had the TV on and the sound down low and when it finally came time, you know, "The Eagle has landed," I started crying. All by myself there with everyone else asleep. And I started crying.

It just built up inside me I guess and it all came out at that point. Tears were streaming down my face and I guess I said to myself, "Oh my god we did it.' I say 'we' as a great many people that I worked with and others across the country contributed so much in every facet of the game. It all came together, and that is what I remember most about the lunar landing.



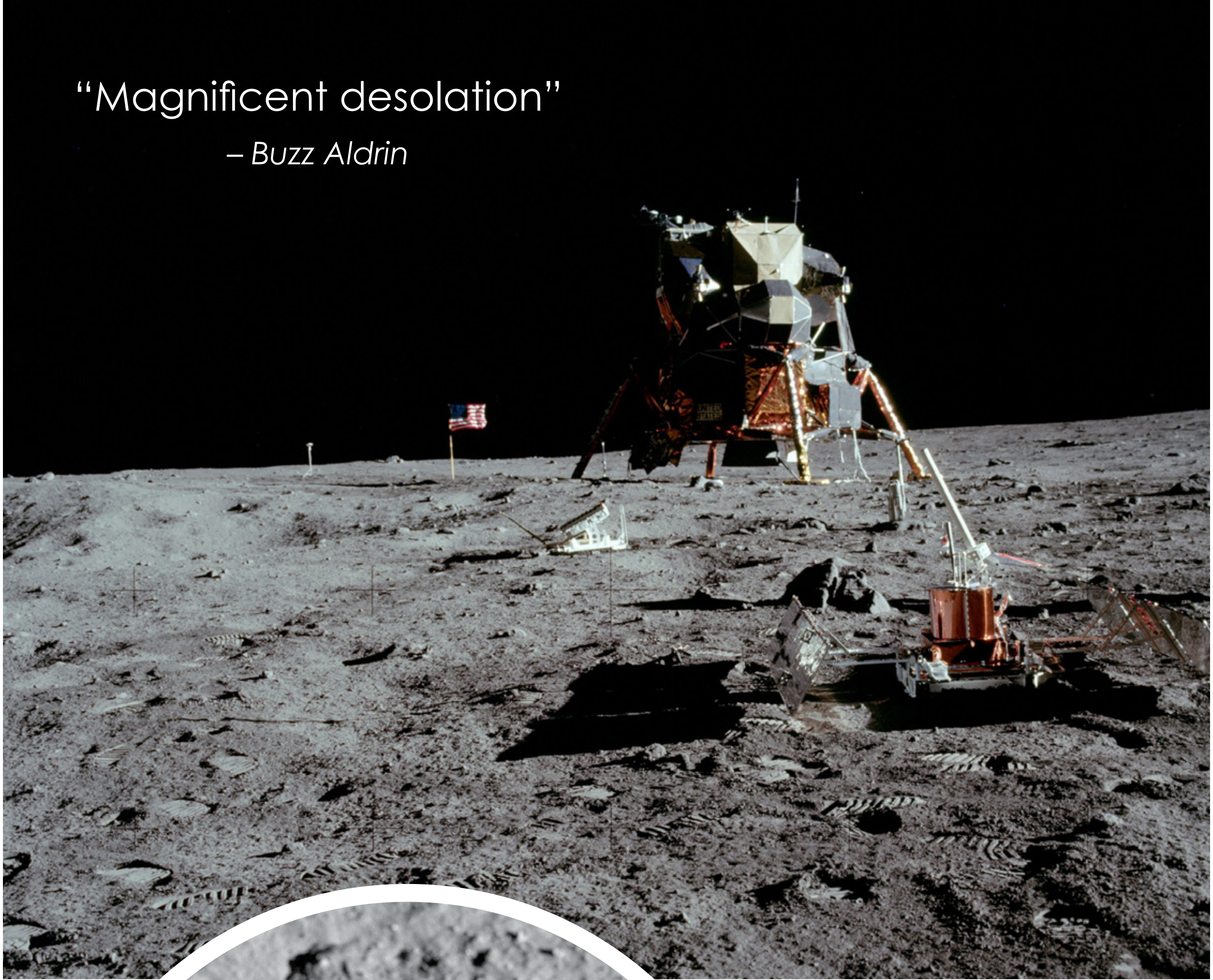
Edwin 'Buzz' Aldrin removes the EASEP experiment from the Lunar Module.



Edwin 'Buzz' Aldrin walks on the lunar surface. The plexiglass of his helmet reflects back the scene in front of him, including Neil Armstrong taking his picture.

“Magnificent desolation”

– Buzz Aldrin

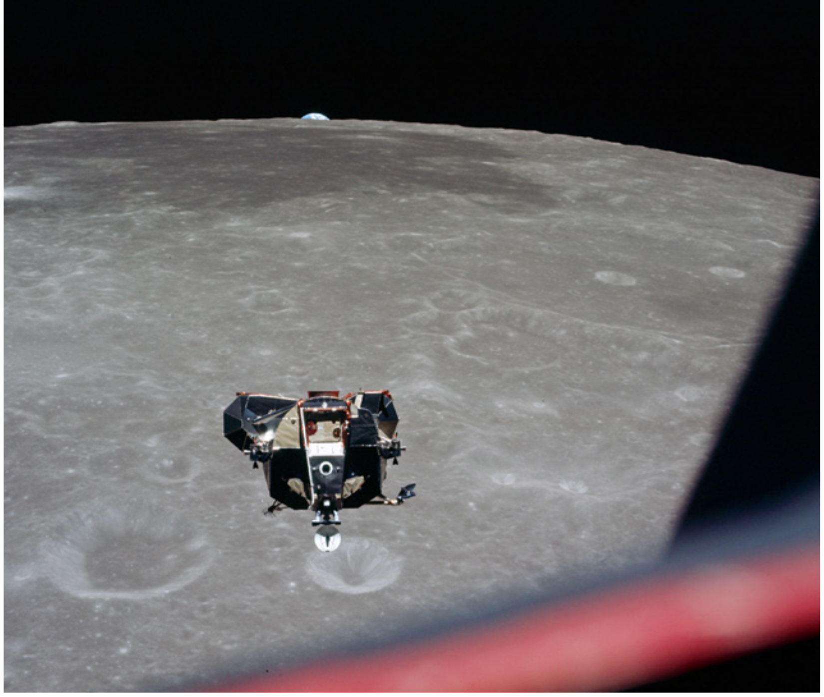


Resting on the lunar soil is a seismometer, part of the Early Apollo Scientific Experiments Package (EASEP). The Lunar Module and American flag can be seen in the distance.

Edwin ‘Buzz’ Aldrin’s bootprint in the lunar soil.

“That’s one small step for a man, one giant leap for mankind.”

– Neil Armstrong



Michael Collins photographs the returning Lunar Module with Neil Armstrong and Edwin 'Buzz' Aldrin inside. Soon after, the journey back to Earth began.

The American flag left on the Moon is viewed from the Eagle LM .The flag was blown over by the exhaust from the ascent engine during the return to orbit.

In their own words

A change of plans

As retrofire officer for Apollo 11, Charles Deiterich was in charge of planning and monitoring the maneuvers to remove the command module from lunar orbit and head it back toward Earth. He recalled an unplanned schedule change after the lunar module (LM) lifted off from the Moon and rejoined the command module in lunar orbit.

On Apollo 11, once you get all the rocks and stuff out and close out the LM, you really don't want to hang around it. They had another rev to go before they were going to close the hatch. Well, they come around the corner [from the back side of the Moon] and the hatch was already closed. We go, hey, we don't really want to stay on this thing, because it's got the engine with things armed, and it's ready to do stuff. So we had to separate one rev early. We would deorbit that thing out of lunar orbit, and then we'd check the seismometers from the ground on the Moon's surface.

This is an excerpt from the book, "Space Pioneers: In Their Own Words" which was authored by Loretta Hall and released last month. The book is available for purchase at www.amazon.com.

A half-eclipsed Earth as seen from the Moon's orbit during the Apollo 11 mission.

It was a scorching reentry for the Columbia CM as seen from a tracking camera in the Pacific.

An unidentified crew member is hoisted aboard the recovery helicoptor for transport back to USS Hornet.

"The important achievement of Apollo was demonstrating that humanity is not forever chained to this planet and our visions go rather further than that and our opportunities are unlimited."

– Neil Armstrong

The Apollo 11 CM is slowly towed over to the USS Hornet before being brought aboard.

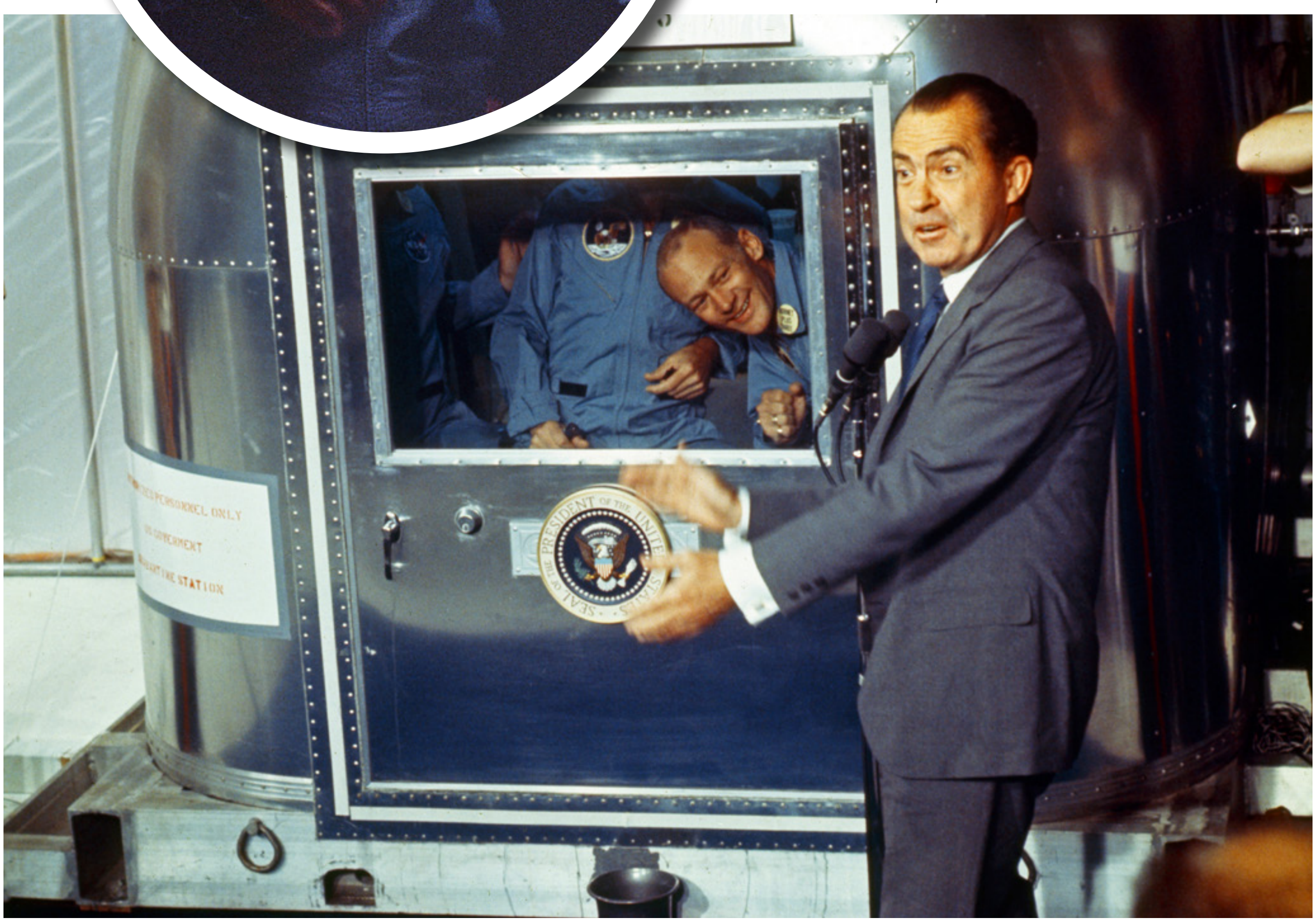
Flags were a common site in Mission Control as they cheered the successful splashdown of Apollo 11 on July 24, 1969.

The Apollo 11 crewmen await pickup by a helicopter from the U.S.S. Hornet after splashing down at 11:40 a.m., July 24, 1969, about 812 nautical miles southwest of Hawaii.

A member of the NASA recovery personnel waves to Apollo 11 crew (Michael Collins in front) as they depart the recovery helicopter aboard the USS Hornet.

Armstrong strums a ukulele inside the quarantine facility aboard the USS Hornet on July 24, 1969.

Already confined to the Mobile Quarantine Facility, President Richard Nixon welcomes the Apollo 11 astronauts aboard the U.S.S. Hornet.



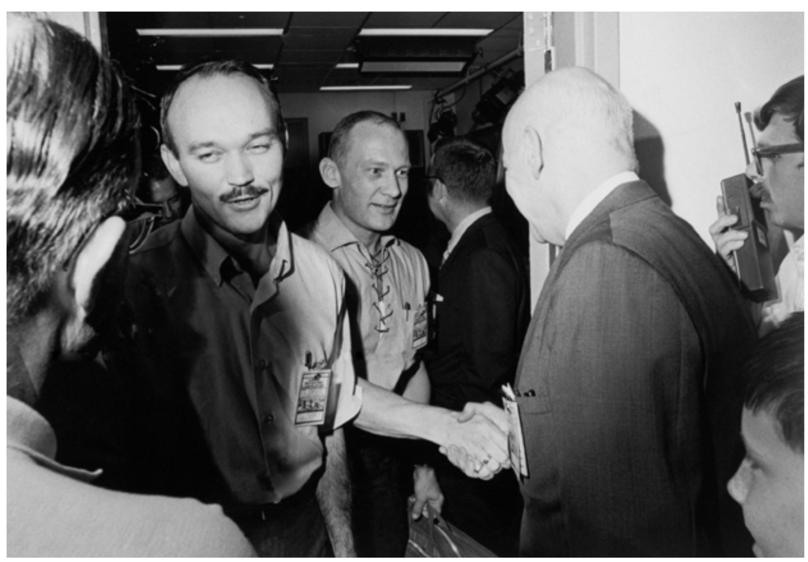
The first Apollo 11 sample return containers are unloaded at the Lunar Receiving Laboratory of the Manned Spacecraft Center in Houston.

Lunar rock samples being unpacked at MSC on July 25, 1969.

The Apollo 11 crewmen, still under a 21-day quarantine, are greeted by their family at Ellington Air Force Base after a flight aboard a C141 transport from Hawaii.

New York City welcomes Apollo 11 crewmen in a showering of ticker tape in a parade termed as the largest in the city's history on Aug. 13, 1969.

British Queen Elizabeth II with the Apollo 11 astronauts at Buckingham Palace in Great Britian during the astronauts' world tour in 1970.



The Apollo 11 crew is greeted by Dr. Robert R. Gilruth, director of the Manned Spacecraft Center upon the astronanuts' release from quarantine on August 19, 1969.

Buzz Aldrin

It's time to colonize the Red Planet

Interview by Chase Clark

Credit: NASA via Retro Space Images

At 84 years of age, Apollo 11's Buzz Aldrin still has a lot to say. And with a lifetime of experiences behind him – and ahead of him yet as well – he's hoping those in power in Washington, D.C. and at NASA will listen to his plans to colonize the planet Mars during the next four decades.

July 20th, 2014 marks 45 years since Aldrin, Neil Armstrong and Michael Collins ventured to the Moon during the Apollo 11 mission. While Collins stayed in orbit aboard the Columbia module, Armstrong and Aldrin made history by taking the Eagle module down to the surface and creating mankind's first footprints on another celestial body.

Forever known as 'the second man to walk on the Moon,' Aldrin has been the more outspoken of the trio in the decades since. While Armstrong advocated for going back to the Moon, believing that there was much left to learn from the Earth's nearby satellite, Aldrin has been a strong proponent of extending mankind's grasp by aiming instead for the Red Planet.

Despite a busy speaking schedule as the 45th anniversary nears, Aldrin was gracious enough to spend nearly an hour and a half speaking with RocketSTEM over the phone from his Los Angeles office. The topics were varied and the shared knowledge was immense, but this reporter did his best to absorb all that Aldrin had to say.

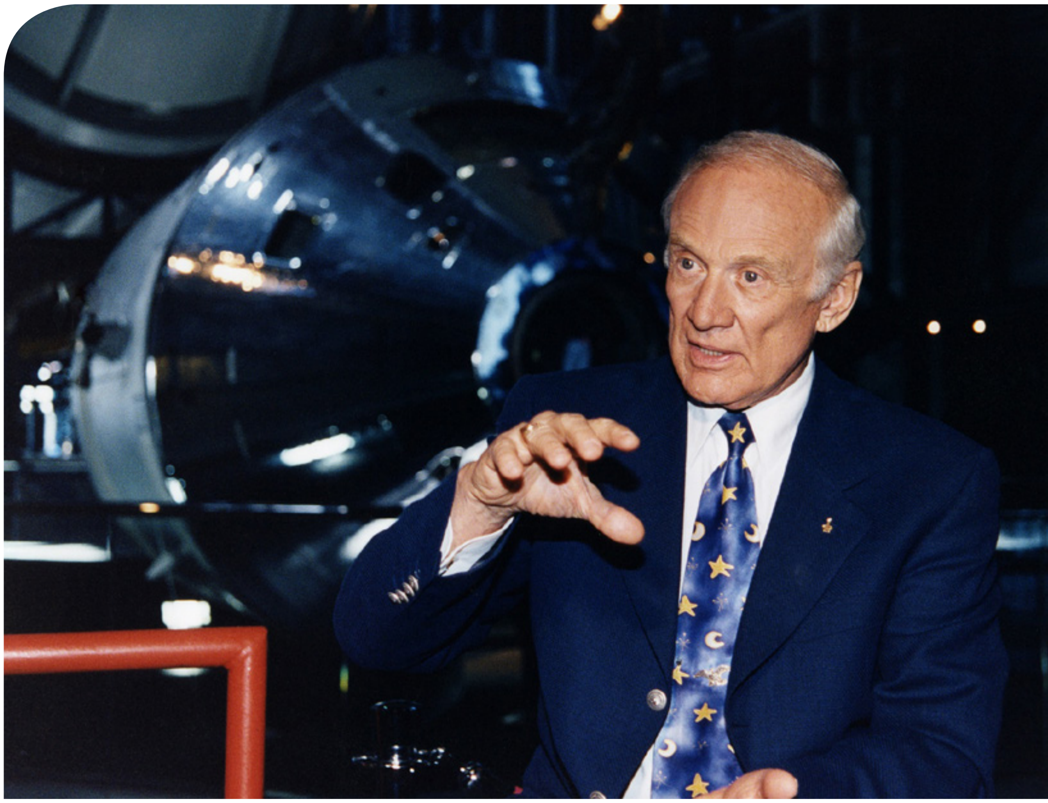
Becoming an astronaut did not always seem to be in the cards for Aldrin, who holds degrees from West Point (B.S. in Mechanical Engineering) and MIT (Doctorate of Science in Astronautics). Aldrin flew F86 Sabre jets for the U.S. Air Force during the Korean War and was decorated after shooting down two Mig-15s. But it was a decision he made after the war that he thought might have closed the door on him becoming an astronaut.

Awareness of the possibility of space exploration "really originated for the ordinary citizen in 1957 with Sputnik. Now we just assume that the Russians did Sputnik because the Russians did Sputnik. But why? Why didn't the United States do that? There probably were reasons, but I was pretty busy when 'beep, beep, beep, beep' went overhead as I was in Germany on five minute alert with nuclear weapons on my aircraft. So that was not foremost in my mind."

"I discovered a couple of years later in Time magazine that the human beings who would be carrying out America's human space program had to have attended test pilot training. I had not chosen to do that and was about to embark on a significant academic program so that it probably would not have made sense to follow back with test pilot training. That essentially wrote off that profession, but that didn't mean that I didn't have an interest and that I didn't see the parallel between being a fighter pilot and getting on an ideal intercept and rendezvous in space.

"My education was paid for by the Air Force Institute of Technology in Dayton, Ohio, which emanated out of an Air Corps engineering school where my father was the commandant between 1920 and 1925. The school of aviation technology that my father was the beginnings of as a result of his MIT doctoral work, became the institution that sponsored and paid for my doctor of science at the same place, MIT, which launched me on a space career as Dr. Rendezvous."

Aldrin was selected by NASA in 1963 to become part of the third group of astronauts. He was the first astronaut to hold a doctorate, an education which would become important to future of manned spaceflight. The docking and rendezvous techniques he devised for orbiting spacecraft were among the keys to the success of the Gemini and Apollo programs. Those same techniques are still used by spacecraft to this date.



Buzz Aldrin speaking about his experiences at the Saturn V Center at Kennedy Space Center in during a celebration marking the 30th anniversary of the Apollo 11 mission. Credit: Tom Usciak

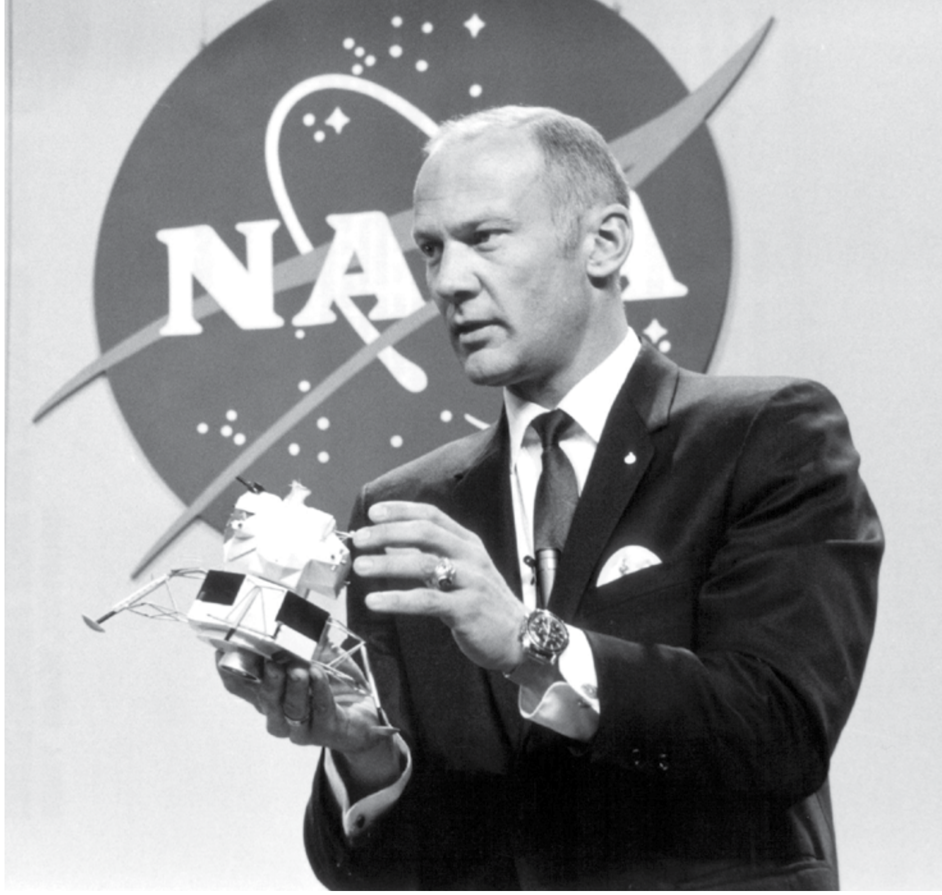
"As crew assignments came out for the progressive Gemini program, it looked as though I would not fly. I was scheduled to be on the backup crew of Gemini X and the crews were already assigned and in training for XI and XII. The backup crew on X would be the prime crew on XIII, but there wasn't a XIII. But things happened, and obviously continued to happen, from the time I crawled out of my crib and got in trouble for getting into the refrigerator."

During the tenth and final manned Gemini flight, Aldrin would fly as the pilot alongside Commnand Pilot Jim Lovell who was on his second spaceflight. The main objective was to demonstrate that an astronaut could successfully conduct a spacewalk. A task which had proven to be problematic to both the American astronauts and Russian cosmonauts in prior missions.

Aldrin had trained for the mission using what was then a novel technique of practicing his spacewalk underwater first on Earth. The training proved to be so successful that it has been a staple of astronaut training ever since. During the mission itself, Aldrin performed a two-hour 20-minute spacewalk while tethered and was able to perform a number of extravehicular activities.

"My education plus my Air Force fighter pilot experience contributed directly to my MIT thesis on manned orbital rendezvous. Now what's a spacecraft got to do with a fighter? Well, it's actually quite similar when you look at the final intercept of a space rendezvous that has been set up by selected maneuvers to reach the correct point, at the correct time, with the correct velocity. So an intercept can then be made that is quite standard and familiar and useful in an optimum backup fashion.

"Following the Moon landing, I eventually applied that orbital mechanics to flybys of the frontside and the backside of the Moon. Since NASA did not have a full appreciation of that then, I switched to Mars. It's kind of hard to discover something that's there, you just haven't found it yet, but in a pioneering discovery I found that there is a cycling orbit between Earth and Mars that continually rotates back and forth with the only interval of Mars access, or departing Mars, which is every 26 months. That has now been improved by my inspiration and work with Purdue University to a dual synodic period cycling spacecraft, which for simplicity is every other 26 months. Therefore it requires two of these cycling spacecraft to transport humans from the vicinity of the Earth to a Mars landing in about five months. Hopefully that will be the standard international way of transporting crews from the Earth to Mars.



Buzz Aldrin holds up a model of the lunar lander during a press conference to announce the crew members for Apollo 11. The briefing was hel d in Houston, Texas on Jan. 10, 1969. Credit: NASA via Retro Space Images

"It makes possible the dream of regular flights to the Red Planet and a permanent human presence there.

"I'm keeping very current on all the changes that might have an affect on phasing this system in so that potentially the next president in July of 2019 — on the 50th anniversary – could make some statement that I believe that within two decades the United States can lead an international human permanence on the planet Mars. Which the more i think about it will be a giant leap of mankind to be remembered for hundreds and thousands of years."

Aldrin admires the work toward launching humans to Mars being done by Elon Musk and SpaceX, as well as the recent successful test of NASA's Low Density Supersonic Decelerator technology in this skies above Hawaii.

"Not only his organization, but I could say Elon himself, has been financially successful as a car designer of excellence and as a rocket developer with spacecraft follow-ons that appear to be potentially very pioneering at this time. But after Curiosity from JPL endured seven minutes of terror – or suspense or whatever you might call it – it dawned on people that to land on Mars in a way similar to how we land on Earth from space would require considerable attention be paid to the thinner atmosphere at Mars. To land like on Earth would require a much larger heat shield called an adjustable or an expandable ablator, a quite large parachute, plus a final descent rocket to land.

"If the entry for landing at Mars can be perhaps a bit more like our descent to land on the Moon, rather than an entry into the thick atmosphere of Earth, if that proves to be true, then it will result in what some might call a game changer. We may

Hanging from a parachute harness, Buzz Aldrin undergoes aircraft ejection training at Perrin Air Force Base near Sherman, Texas during May of 1968. Credit: NASA via Retro Space Images

or may not have to go down both paths before making a choice for both cargo and crew.

"I'm encouraging NASA to look at an exploration sequence, and I find it convenient to limit that to 2020 to 2040 because I think we somewhat understand the limited things that are being scheduled between now and 2020. Of course one has to include what will be available in 2020 but I just don't have enough graph paper to go all the way back another six years."

Aldrin plan includes spending the ensuing decade developing a complete way of launching things from the U.S. and staging out toward the Red Planet in stages. Human and robotic exploration missions could begin in low Earth orbit, then move to Moon, or to asteroid distances beyond the Moon, and eventually settle on the Martian moons, Phobos and Deimos, where real-time exploration of the Martian surface could be controlled by humans in orbit or on the surface of the moons.

"I've always had the concept in the back of my mind that we would occupy maybe both of the moons of Mars. If you're in orbit around Mars at a moon or otherwise, what that means is you can control two rovers on opposite sides of Mars. Steve Squyres (former principal investigator of the Mars Exploration Rover' program) who's now the head of NASA Advisory Council, he said what they did in five years on Mars (with the Spirit and Opportunity rovers) could've been done in one week if we had a human being in orbit around Mars giving instructions directly with less than a second time delay to the rovers on the surface.

"What I would add to that understanding is that if we are in orbit around Mars, and there are very good reasons to do that, but if we are not ready to commit to permanence on the surface, then do not land until you are committed to permanence. The purpose of sending humans to the Mars – along with the judgment, the perspective, the stories, the impact – is to increase the settlement colony, growing the presence of humans to help each other survive. The most difficult and most expensive ones to bring back are the first ones that land. I think that realization needs to be made clear to the American people that the way some of us see it is that is the way to depart orbit around Mars.

"My estimation is pretty clear that the Chinese if they land the first humans on Mars that they would stay and establish the first Chinese outpost on another planet. And the Russians the same way. We are talking about leadership in history for hundreds and thousands of years. That is what your RocketSTEM should be communicating.

"There was a father that came up to me with his eight-year-old son at a book signing, and he said 'You know my son wants to go to Mars.' Rather than asking the boy the difficult question of how long do you think its going to take to get there, I said 'Now when you get to Mars how long do you want to stay?' It puzzled him a little bit, and he looked up at the ceiling, and then he said 'Oh, a couple of days.' I thought that was an interesting answer, and an understandable answer considering what eight year olds are generally aware of. It's very instructive to look up at the Moon and ask the question, 'Now where's the Sun? And which way is north?' and watch how kids deal with that.

"I am quite excited about the Mars exploration sequence that I have put forth and I feel that this is a very opportune time that should be encouraged by all STEM students."

Understanding and learning from the past is necessary toward moving forward and avoiding making the same mistakes over and over again. With that in mind Aldrin is has formed two organizations he hopes can influence the direction of the nation's space exploration programs. The first is a foundation called USS Enterprise which stands for United Strategic Space Enterprise. The foundation will examine space policies from the very beginning of the space program all the way through the present.

"Once we get it up and running, my son will carry through because it is going to be a significant undertaking. The things that are hampering our space program right now, maybe we can change that by knowing what we did right and what we did wrong, and look to the root cause. If it is our system of government then we better think carefully about where it's taking us in high technology, high reliability, human protection ventures."

The second organization is the Unified Space Vision Institute (USVI). It will be focusing on the future of space exploration.

"It's a very small number of worker bees right now. I wish I had started it a little sooner, but we get smarter and smarter (as people) as the clock goes round."

Coming back from the Moon was not something anyone could have adequately prepared for. After quarantine, debriefing and a worldwide tour celebrating the mission, each of the three astronauts dealt with the weight of their accomplishment in different manners.

"It's not necessarily a universal significance change. In my case there were, not mitigating, but outside influences. That is why I titled my first autobiography 'Return to Earth' instead of 'Journey to the Moon' or 'The Moon and Back.' That is because the return proved to be the most difficult part of the mission. There are a couple of autobiographies that cover my inherited depression and alcoholism. You don't arrest either one, but I have 35 years of sobriety and my mental state most of the time is positive."

While Aldrin admits he can't carry a tune, and isn't likely to ever be seen climbing a mountain, he is still a man who has travelled the Earth and beyond in the name of adventure. He has been an avid scuba diver for more than 55 years and has made recreational dives at locations all around the world. At present he's been in a 'holding pattern' for five years waiting to reach the South Pole via a hovercraft. Definitely not your typical summer vacation destination.

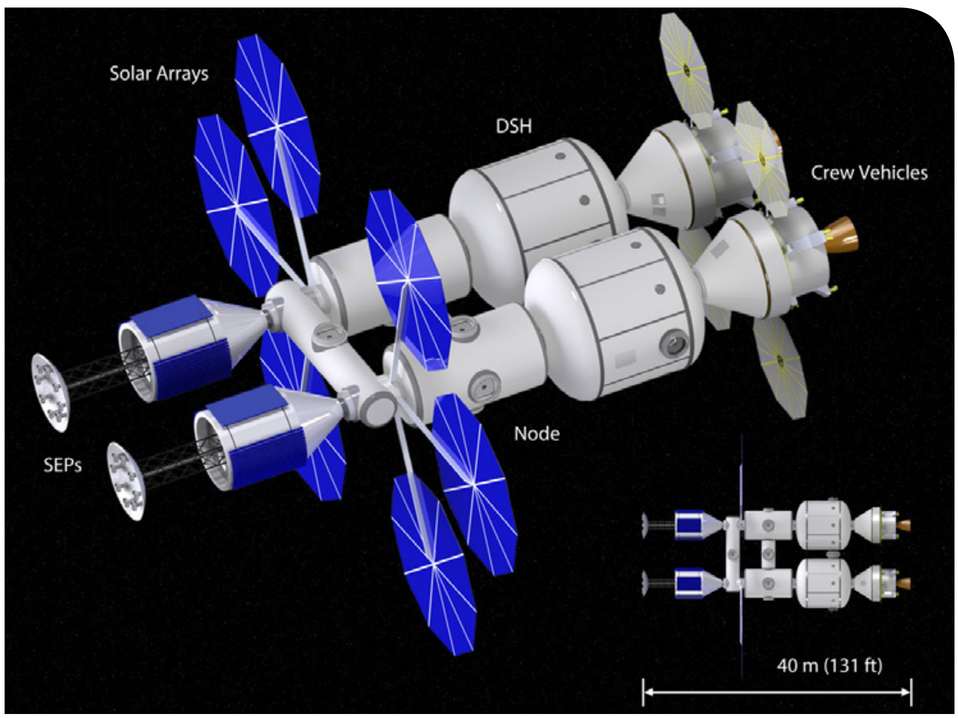
"I've been to the North Pole on a Russian nuclear icebreaker. That was quite enlightening. Even more so years before that in a French yellow submarine for three people – two spoke French and one did not, that's me – we went down for a total of 11 hours visiting the Titanic. I was given a baseball cap that says 'Bottom Gun.' Not 'Top Gun.' It was given to me because Bob Ballard felt that anyone that had been down to see the Titanic – even an Air Force guy – should have a cap that says 'Bottom Gun.'

"That's some of the versatility of my inquisitiveness about exploration to the fringes."

With more than 40 years having passed since humanity last stepped on the Moon, it is not a stretch to say that a majority of the world's population has zero recollection of that era. While historians have dissected the details in numerous books over the years, the simple fact remains that only two dozen people truly know what the experience of leaving low earth orbit is like. Getting to that point was not just a shot in the dark. Even though it took less than a decade to accomplish, NASA took a very calculated approach to reach the Moon.

"The Moon landings were prepared for in a gradual way by the three programs of American human spaceflight – Mercury, Gemini and Apollo. I've not really seen this written down, but I've heard that the modules were too heavy to land. The crew rotations would have kept going pretty close to what they actually did. The first landing would have been achieved by Apollo 12 in October of '69 and not Apollo 11 in July '69. Obviously something happened to LEM 5 that made it a qualified lander. It was reduced in weight, but we still sort of jokingly blamed the program manager, who I've gotten to know very well, that he's the guy that caused us to run low on fuel. No, we didn't have less fuel. We were heavier than most later spacecraft. Sometimes things don't work the way you expect them too."

Of course before the Apollo spacecraft could be hurled toward the Moon by the mighty Saturn V rocket, there were a number of

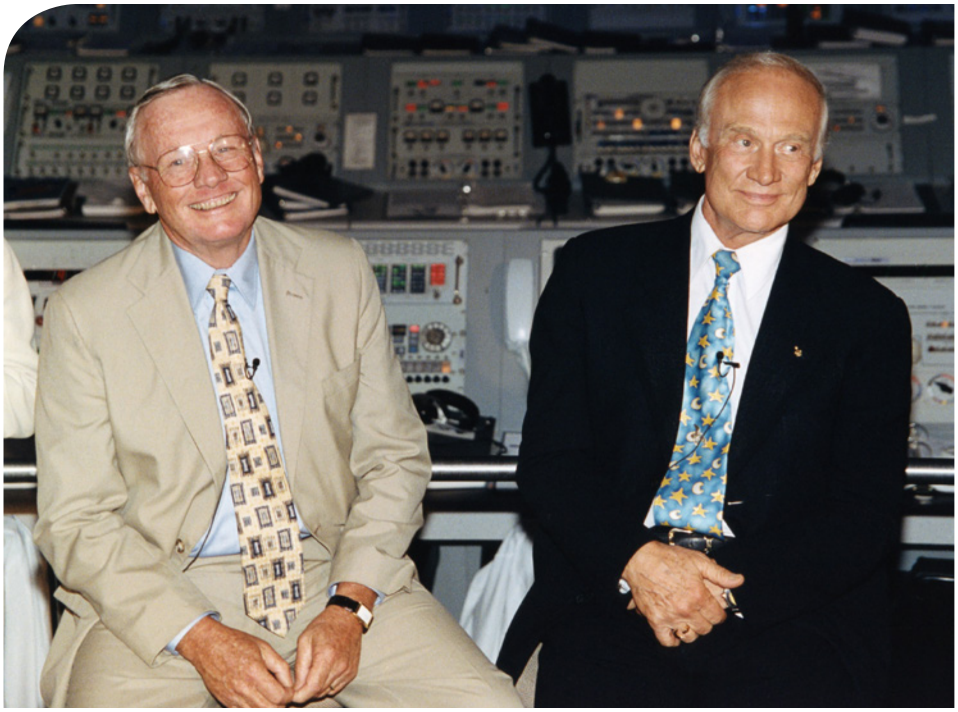


The Aldrin Cycler makes travel to Mars possible via a perpetually cycling route, allowing spacecraft to use far less propellant than conventional means. In each cycle, when the Aldrin Cycler's trajectory swings it by the Earth, a smaller interceptor spacecraft will dock with it. *Credit: Jonathan M. Mihaly and Victor Q. Dang*

reason that 20 Apollo missions were prepared and built to be carried out, was that people felt assured that we would at least land successfully on ONE of those 20 missions. There was a strong belief that President Kennedy's commitment would be carried out.

"In late 1967 and early '68 the first landing on the Moon was going to be in mid October '69 to be accomplished by LEM 6. This was because all the preceding lunar problems that had to be solved, and procedures to test. The Mercury and Gemini programs were the test beds that directly led into the Apollo program.

"The Mercury spacecraft could not maneuver fore and aft, left and right, and up and down. The only thing that allowed it to reenter were that retrorockets slowed it up so it reentered the atmosphere. Now the Gemini system with two people in



While Neil Armstrong advocated for going back to the Moon, believing that there was much left to learn there, Aldrin has been a strong proponent of extending mankind's grasp by aiming for Mars. *Credit: Tom Usciak*

it, could translate significantly in all those directions and rotate also. It was much more versatile, and it allowed a growth period between Mercury and the complex Apollo missions.

"The four essential objectives of the Gemini program were computer controlled reentry to an accurate landing, long duration spaceflight of 14 days, spacewalking outside the spacecraft, and rendezvous and docking. It was those four objectives which equipped us to move to Apollo but there were two ways of getting to the Moon.

"One was by Earth orbit rendezvous, requiring two Saturn Vs, where a propulsion stage to depart the Earth would first be placed in orbit, followed by a quite large spacecraft containing the crew that would do everything else. Instead of lunar orbit rendezvous and segmenting the mission into different spacecraft which required only one Saturn V and was the one that was chosen. That was unquestionably the most successful, the most decisive, the most telling decision made I think throughout the entire U.S. human spaceflight program up to that point.

"We certainly did need to fly the spacecraft in Apollo for a reasonably long time – 11 days with a veteran, Wally Schirra (Apollo 7). Then there were indications that the Russians might fly one cosmonaut around the Moon and back in the Zond spacecraft. Our lander, LEM 3, was delayed so we shifted things around and sent the second crew (Apollo 8) on a Saturn V rocket after only two previous unmanned tests. We sent them not just around the Moon, but to enter orbit around the Moon. Then the testing of the lander in Earth orbit, a dress rehearsal in lunar orbit, and the landing from lunar orbit, all naturally followed.

"I think the crews could see that progression coming and it would keep coming until we landed, or ran out of rockets. The people who were in the astronaut program were either resigned to flying the command module and maybe later landing, or being one of the two guys who might land on the Moon. So we adjusted to that future in an attempt to adjust to the training leading up to the moment of liftoff. We had a lot of time to think about that and watch other people go through that, but to explain to someone who hasn't experienced any of that, what we 'felt like,' is like an alien explaining what his flying saucer is like."

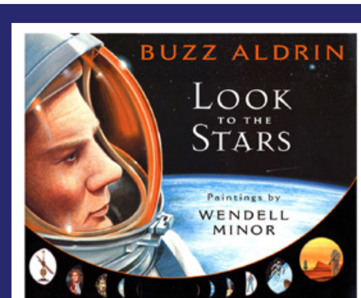
Mentioning UFOs is something that has gotten Aldrin in a bit of hot water in the past. While flying to the Moon, the crew of Apollo 11 noticed sunlight reflecting off something in the distance. While it has never been 100% confirmed, the trio has always believed what they saw was a separation panel from the third stage of the Saturn V rocket.

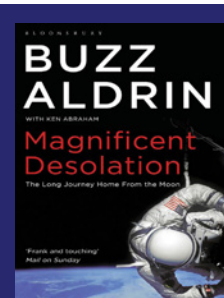
"I felt the debriefing that we did from the quarantine facility to the NASA executives was not privileged information, but the significant parts of it was disseminated in some ways. We certainly explained a light out the window traveling slowly with respect to the inertial background, which we used to say its somewhere not quite as far away as the stars. I'd seen graphs of the panels that are enclosing the lunar module that are set in four different directions when we separate the command module, turn around and dock with the lunar module, then disconnect the lunar module from the rocket. We knew all that, and that is why instead of blurting out 'Hey

Dr. Aldrin: The author

Buzz Aldrin has authored eight books, including last year's "Mission to Mars," "Magnificient Desolation," and the children's book, "Look to the Stars."

All three books may be purchased at Amazon.com and in bookstores.





While flying parabolic arcs to simulate weightlessness aboard a KC-135 at Wright-Patterson AFB in August of 1964, Buzz Aldrin attempts to consume a container of space food. Fellow NASA astronauts Charlie Bassett (left) and Ted Freeman (right) are also trying to eat the specially prepared food. Credit: NASA via Retro Space Images

Houston, there's a light that's towing along with us toward the Moon,' that would not have been too smart a transmission. So instead we ask a reassuring coverup question. We said 'Hey can you tell us how far away the S-IVB is now?' We had watched it lit the engine and move away at an accelerating speed, but the people at Houston were probably puzzled by the question. When they came back 10 minutes later and said it's about six thousand miles away, we figured that either it was going mighty fast still, or that wasn't what we were looking at. We didn't really get great further satisfaction by looking through the telescope or looking through the 28 power sextant.

"It certainly wasn't rotating like a saucer. They was no reason to suspect, other than an unusual sun reflected angle, that it was one of those panels. Now I discovered gradually in talking to people that they had never heard that debriefing.

"I had a long interview with the BBC and I decided to explain it to the best of my knowledge, which always confuses somebody, especially when they want to be confused. So the UFO people back in the States were very angry with me for not giving them the scoop.

"Charles Berlitz wrote his book and established his credibility in the first couple of pages by listing the different spaceflights that had reported observing unusual observations, including Neil and I on the Moon talking about some green creatures on the other side of a crater. That was heard by Charles Berlitz I guess over Anglia TV, so he can blame it on Anglia TV instead of himself. I sued him and that scared him. It cost me a little bit of money but it was worth it. And so was using Bart Sibrel's chin as the target for my right fist (after harassing Aldrin at a hotel and demanding he prove he had walked on the Moon). That cost me a little bit too, but it gave me a lot of prestige."

Aldrin has found himself asked all sorts of questions while out and about during the years. And the questions aren't always about the Apollo 11 mission.

"I was coming back from a trip that landed at LAX two years ago and as I was walking out there were three guys – one with the camera held low and aimed directly at me – and he said 'Hey Buzz Aldrin, what do you think about that guy who set a record and jumped out of a balloon and he came back to Earth? What do you think about Felix Baumgartner?' I had just enough time to get my mind working as I was walking, and I said 'Well, that sure was a giant leap for Red Bull!' I don't think there is going to be second jump. Who's going to do that?"

Only 12 people have walked on the Moon. Another dozen have travelled to the Moon but stayed in lunar orbit (or in the case of Apollo 13 taken a slingshot around the Moon). It is a very small contingent and encountering similar groups of people is not a common thing, but it does happen occasionally.

"I had the opportunity at the Memorial Day parade this year, to meet four survivors of the Doolittle Raid. My father was a contemporary of Jimmy Doolittle, born in the same year. But instead of racing around the pylons, he would be a judge at the Cleveland air races.

"I went up to the copilot who seemed to be the senior officer – I don't know if there was another B-25 commander in the crew that survived. but Colonel Dick Cole was the 98-year-old copilot. I said 'I've got two things i want to talk to you about.' One is the same thing that I told Jimmy is that I used to visit his office frequently after my father died. I said 'Jimmy do you know that our rocket was taller than your takeoff roll on the carrier?' I decided that I would tell Dick Cole the same thing, and I think it finally sunk in what I was talking about. And then I said 'Now there's another thing that whenever I am introduced as a speaker or in the audience, or at an occasion, it is almost unanimous – very very rare is there ever an exception – that I'm introduced as the second man on the Moon.' And I said to Dick, 'Now we share that in common because you're going to be known as the second man on the first plane.' I don't think he was too worried about that.

"It is one of those undone things that i'm going to get together with one or more of the four of them and have them consider what their reunions have meant to them for 72 years.

"I'm always interested in people recognizing that it was not just 12 Americans who landed and walked on the Moon, but it's 24 who reached the Moon. That was enabled by four learning missions and one emergency. I think that 24 is a much better number for students to be aware of, but I have given up on the State Department recognizing all 24 living or deceased as lunar ambassadors. All American and foreign space people should be aware and reminded of what's gone before them."

Buzz Aldrin performs an EVA during the Gemini XII mission. The Agena Target Vehicle is visible in the background.
Credit: NASA

Living on a simulated Mars

Story by Casey Stedman
Photos by Ross Lockwood

How will future astronauts live on Mars? This is the question asked by NASA and many of the organizations working toward the advancement of human spaceflight.

The challenges of landing and living on another planet are difficult to recreate on Earth. In order to do this, NASA and other space organizations use analog studies to prepare for the future challenges space explores might face. Many of these studies take place in remote or hostile places on earth that are similar to those found on the Moon or Mars.

One of those analog studies is the Hawai'i Space Exploration and Analog Simulation, or HI-SEAS. Operated by the University of Hawaii at Manoa, the HI-SEAS program places six researchers in an isolated habitat module for the purpose of studying the methods of living on Mars over a long period of time. The first mission, which ran for four months in 2013, focused on developing recipes and methods of preparing food for future astronauts. That mission ended in August of 2013, and a new crew entered the habitat in March of 2014.

During this current mission, the crew has been participants in a number of studies that will be used to evaluate their group dynamics and psychological health. The University of Hawaii at Manoa, through grants provided by NASA's Human Research Program (HRP), is investigating the crew's performance throughout the mission. These studies measure their effectiveness as a team, how they react to stress, and their behaviors in a closed environment. The history of exploration is littered with examples of expeditions whom succumbed to failure because of human factors.

Several different studies are being conducted simultaneously to monitor the crew throughout the simulation. Several times a day, each crewmember completes surveys from the participating universities that record information about each individual's health, sleep habits, and emotional states. Each of the crew wears two electronic sensors as well. The first, worn on an armband, records biometrics. The second, worn like a necklace, senses the proximity of the crewmembers to each other, the intensity of their interactions, and the volume of their voices. All of the data from these devices is regularly downloaded and transmitted to the anxious university science teams.

The HI-SEAS habitat is located high on the slope of Mauna Loa, an enormous Hawaiian shield volcano with an environment similar to the Martian surface.

One of the elements of long duration space missions is the isolation the crew will experience. Many millions of miles from Earth, the crew will be alone except for themselves. How will they cope with this? In order to replicate this in the HI-SEAS analog, the crew lives in a structure designed to simulate a habitat module not unlike ones future Mars explorers will likely inhabit.

The module is a two-story geodesic dome, inside of which is everything the crew will need to survive for a lengthy mission. To further enhance the sense of isolation, the habitat

Lucie Poulet and Annie Caraccio conduct an EVA.
Credit: Ross Lockwood

HI-SEAS crew members Tiffany Swarmer, Ron Williams, Lucie Poulet, Casey Stedman, and Annie Caraccio unpack crates of food for the current mission. *Credit: Ross Lockwood*

module is located high on the slope of Mauna Loa, an enormous shield volcano on the island of Hawaii. This has the advantage of distancing the crew from civilization, and being an environment much like that of the Martian surface.

Like all simulations, there are elements of reality that cannot be effectively duplicated. For instance, in the case of HI-SEAS and other Mars analogs, there just is no manner in which to replicate Mar's gravity – which is approximately 38% that of Earth's. The crew must also must contend with terrestrial weather patterns, which are a might bit wetter than those found on Mars. The weak Martian atmosphere only has one percent of the pressure that Earth's does, but the only manner in which to simulate that is to maintain a mental block on the desire to venture outside the habitat.

One aspect of living on Mars that can be replicated is the distance between the planets, or at least the time it would take to communicate with the crew. Mars is far enough from Earth that it takes 20 minutes for radio waves to reach the fourth planet even at the speed of light. Two way conversations are not possible, so NASA has instituted an artificial delay into the computer network used by the HI-SEAS crew. All messages sent to mission support take 20 minutes to arrive. And it takes another 20 minutes to receive a response. This can be a nuisance, but adds to the fidelity of the simulation.

In fact, the only way the crew can exit the habitat module during the mission is wearing an analog spacesuit for EVAs, or "Extra Vehicular Activities". Like real astronauts on Mars, the crew wear spacesuits to exit the breathable atmosphere of

Quick comparision between the Earth and Mars

	Earth	Mars
Average distance from Sun	**93 million miles**	**142 million miles**
Average speed in orbiting Sun	**18.5 miles per second**	**14.5 miles per second**
Diameter	**7,926 miles**	**4,220 miles**
Tilt of axis	**23.5 degrees**	**25 degrees**
Length of year	**365.25 days**	**687 Earth days**
Length of day	**23 hours 56 minutes**	**24 hours 37 minutes**
Gravity	**2.66 times that of Mars**	**0.375 that of Earth**
Temperature	**Average 57 degrees F**	**Average -81 degrees F**
Atmosphere	**Nitrogen, oxygen, argon, others**	**Mostly carbon dioxide, some water vapor**
Number of Moons	**1**	**2**

Learn much more about Mars by visting: http://mars.nasa.gov/allaboutmars/facts/#infographic

Lucie Poulet gets help suiting up for a EVA from her fellow crew members Annie Caraccio and Tiffany Swarmer. *Credit: Ross Lockwood*

the habitat and venture out into the inhospitable Martian landscape. Temperatures on Mars can reach as low as -183 F below zero, and there simply isn't enough oxygen available for complex life-forms. Although it is perfectly safe to be outside in Hawaii, the crew must adhere to the premise to maintain the simulation.

Astronauts on Mars will want to go outside on EVAs for a number of reasons. Some will be for chores like maintaining their habitat systems or rovers, others may be as adventurous as exploring lava tubes and searching for signs of life.

As part of the HI-SEAs program, the crew must conduct regular EVAs to monitor habitat power systems and explore the vicinity of the "landing site" to catalog the geology and search for features that are similarly found on Mars. These simulated EVAs provide the psychologists studying the crew's team performance with opportunities to evaluate their effectiveness during difficult tasks.

Another element of the HI-SEAS simulation is the dynamics of the crew. NASA and the other space agencies are investigating the types of people whom will one day be selected to go to Mars.

The HI-SEAS crew were selected from a pool of more than 700 qualified candidates, all of whom had to meet the minimum criteria required of NASA's astronaut corps. Efforts were made to select individuals for their educations, skills, and compatibility.

Future Mars explorers will be required to well-rounded individuals, in terms of their educations and experience. The crew selected for the HI-SEAS analog was chosen not only for their scientific backgrounds, but for their personalities and resourcefulness as well.

Astronauts traveling to and living on Mars will be required to spend great lengths of time in small spaces with other people. Compatibility is as important trait for future astronauts. Special care was given to selecting candidates that possessed the ideal combination of talents and character.

The current HI-SEAS crew is a diverse collection of international researchers.

The Mission Commander is Casey Stedman, a U.S. Air Force navigator, veteran of the wars in Iraq and Afghanistan, and a graduate student studying human factors in aeronautics. The Medical and Life Support Officer is Tiffany Swarmer, a graduate student from the University of North Dakota's Space Studies program. Systems are the responsibility of Ross Lockwood, the mission's Chief Technologist. He is a doctoral candidate from the University of Alberta studying experimental physics. The Chief Engineer is Annie Caraccio, a chemical engineer from NASA's Kennedy Space Center. The crew has their own Mission Psychologist, a Dr. Ronald Williams of Bloomington, Indiana. And the Chief Scientist is Lucie Poulet, an aerospace engineer from France working for the German aerospace center DLR.

Each crewmember has been accomplishing individual research projects during the mission. Most of these studies are concentrated on developing ways for future astronauts to survive on long duration planetary missions.

Caraccio is diligently recording all of the waste produced by the crew and as part of her "Trash-to-Gas" experiment. Data from this research will help engineers at NASA better understand methods for recycling food, garbage, and materials waste into fuels for future missions.

Similarly, Poulet has planted a number of seeds that have previously flown in space on the Long-Duration Exposure Facility (LDEF) satellite and is experimenting with growing them under different wavelengths of light.

The HI-SEAS crew were selected from more than 700 qualified candidates, all of whom had to meet the minimum criteria to be a NASA astronaut.

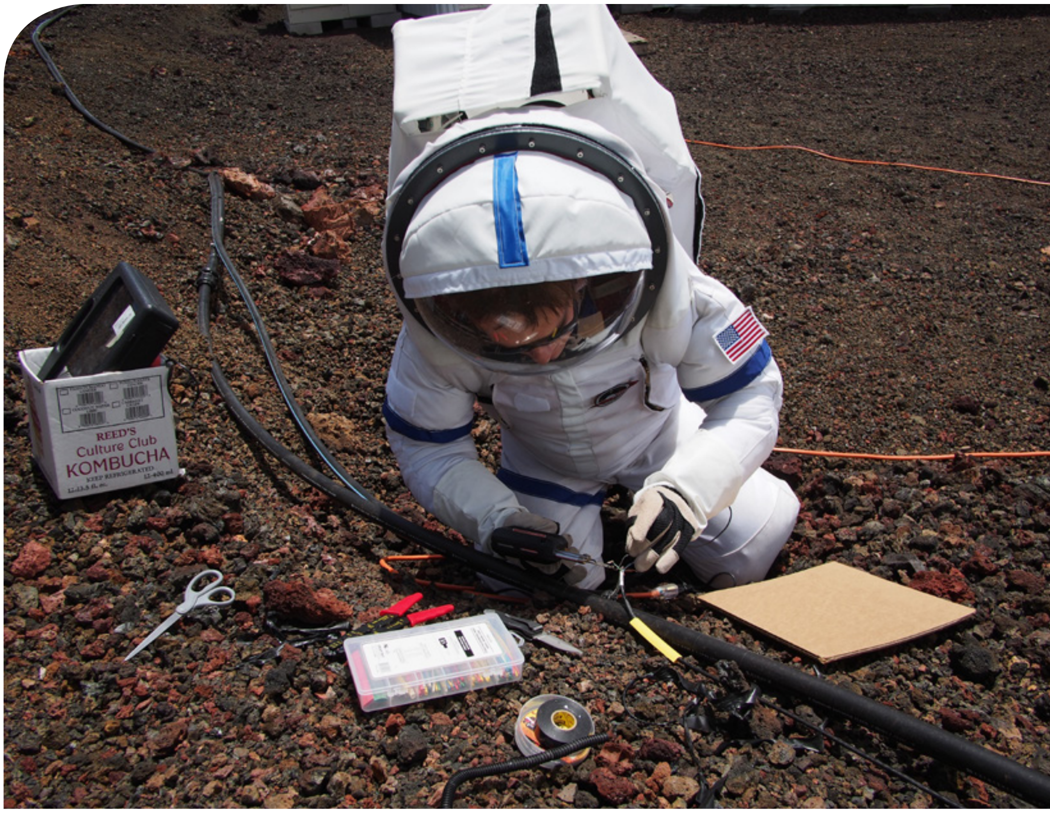
Future Mars explorers will likely have greenhouses for glowing food plants, but scientists must first understand how seeds will react after having been in space for long periods. The greenhouse device being used in the HI-SEAS habitat is a precursor to the VEGIES unit that launched to the ISS earlier this year.

Things people take granted on Earth in our daily lives become precious even in this simulated environment.

Like real astronauts on the International Space Station or those who explore other planets, the HI-SEAS crew must be careful to monitor and ration food, water, electricity, and supplies. Food must be carefully inventoried and divided, every watt of electricity generated by the solar cells must be accounted for, and the use of water is especially monitored. Every effort must be made to use water sparingly. Showers for each crewmember are limited to eight minutes per week. Everything needed to survive this mission had to be brought by the crew to the habitat-just as the first astronauts on Mars will experience.

There have been other analog studies that focused on the development of specific technologies, or situated the crews in a particular environment in order to demonstrate concepts in harsh locales. What makes HI-SEAS unique is that this study is to determine the limitations of the human element. Some pessimistic critics believe that human spaceflight is doomed to failure because humans are inferior to robotics and computers. If HI-SEAS and similar Mars analogs prove anything, this is an absolutely false assumption.

Unlike machines, a human crew can react to unexpected events without having to be reprogrammed to do so. Automation has limitations.



Ross Lockwood splices a cable during an EVA outside the HI-SEAS habitat. While this is a fairly simple operation for an electrician here on Earth, it is made much more difficult when wearing a full spacesuit. *Credit: Casey Stedman*

Like future Mars missions, the crew of HI-SEAS cannot confer with mission control immediately when problems arise. The distance between Mars and Earth means the crew must be able to react to a crisis without waiting for instruction to be passed. Robots and rovers do not yet have the ability to do this. Machines can't yet experience the emotions like fear, anticipation, or compassion-things that humans have developed that keep us alive. The perceived weaknesses of humans are the actually the advantages we need in order to survive a mission on Mars.

Analog studies like HI-SEAS are essential for scientists and engineers to learn what is necessary to survive future mission to Mars. Only from testing the methods and technologies required in a realistic environment can solutions the problems that plague long-duration missions be uncovered. For the second HI-SEAS crew, the four months of rationing resources, isolation, and time spent away from friends and family will one day benefit future astronauts living and working on the surface of Mars.

Meet the crew of HI-SEAS 2

HI-SEAS 2 crew members are: Lucie Poulet, Ross Lockwood (front row), Annie Caraccio, Tiffany Swarmer (middle row) Casey Stedman and Ron Williams (back row).
Photo by Ross Lockwood.

Mission Psychologist: Dr. Ron Williams

Dr. Williams was born and raised in Bloomington Indiana. He received his BA degrees in Psychology and Chemistry at Indiana University Bloomington in 1976. He received his MA degree in Experimental Psychology with a concentration in gerontological psychology from the University of Notre Dame and his PhD in Neuropsychology from Ball State University in Muncie, Indiana.

After a short time working as an analytical chemist he returned to graduate school in psychology and later worked as a counselor and therapist as well as director of programming for older adults at the Dunn Community Mental Health Center in Richmond Indiana from 1979 to 1991.

He has been a part of the professional staff at Fort Wayne Neurological Center since 1991 and is the director of the Neuropsychology Dept. Fort Wayne Neurological Center is one of the largest Neurology/Neurosurgery/Neuropsychology practices in the Midwest.

Dr. Williams' practice involves diagnosing and treating patients with a wide range of neurological and psychological disorders. He is board certified in Neuropsychology by the American Board of Professional Neuropsychology and Diplomate of the American College of Professional Neuropsychology. He is also adjunct professor of psychiatry for the Indiana University School of Medicine. Dr. Williams' most recent research and publications pertain to the identification and measurement of cognitive dysfunction in dementing illnesses and multiple sclerosis.

Dr. Williams' passion for space

exploration dates back to the 1960s as a young boy who was obsessed with everything related to the early days of the US and Russian space programs. He has visited the Kennedy Space Center 28 times since his first visit at age 15 when he witnessed the launching of Apollo 15. He has had the privilege of meeting all three Apollo 11 astronauts and is an avid collector of space related books, artifacts and astronaut autographs.

As a 13 year old, in the 1960s, Ron and a handful of his "space inspired" buddies built a life-size mock-up of a Gemini spacecraft and stayed inside the capsule for extended periods during the time that actual Gemini missions were going on in space.

He is an avid amateur photographer and astronomer. He vehemently believes that man is driven and destined to explore the universe around him and in the process of that exploration will develop and discover countless medical, social and technological advances that will benefit civilization.

Dr. Williams' individual research interest, while on the HI-SEAS mission is exploring the cognitive, personality and psychological characteristics of the crew and their relationship to adjustment, group dynamics and mission success. The effect of lighting on sleep and other adjustment factors are being studied. He is also testing astronomical equipment and techniques for telescope viewing while in space suits and electronic remote viewing within the simulation habitat.

He is organizing a public outreach involving amateur radio contacts with the HI-SEAS habitat that will be totally unique in the HAM radio community due to the imposed reception delay due to Mars-Earth distance.

Chief Engineer: Anne Caraccio

Caraccio grew up on Long Island, New York and earned her B.S. and M.S. in Chemical Engineering from Manhattan College.

Caraccio came on board full time with NASA in 2011 after completing three semesters in the NASA Co-op Program. She is currently working as a chemical engineer on several projects that support deep space exploration.

One main project involves developing a system for recovering logistical waste from long duration space missions to produce usable gases for propulsion, environmental control, and life support systems.

She also supports fiber composite repair technologies for newly developed autoclave and out-of-autoclave systems, as well as chemical analysis support for projects such as Lockheed Martin's Orion Crew Exploration Vehicle.

Caraccio is a graduate of the 2012 NASA FIRST leadership development program. She is also a Ph.D. student in the Department of Chemical and Biomedical Engineering at the University of South Florida.

She is passionate about human space flight and developing systems for future deep space exploration. She carries her passion of the space program out into the world by volunteering with numerous educational outreach events, professional societies and Girl Scouts.

Her recreational interests include softball, surfing, hiking, reading, learning and spending time with friends and family.

Medical/Life Support Officer: Tiffany Swarmer

Swarmer works with the University of North Dakota's Human Spaceflight Laboratory where she provides support as a study coordinator, research assistant, biologist, and emergency medical technician for analog habitat and spacesuit research. She has a B.S. in biology with a focus on microbiology and will be completing a M.S. in Space Studies focused on the human factors of long duration spaceflight. She has a multidisciplinary background with work in DNA sequencing, medical risk management, emergency medicine, public relations, and microbial research.

Active in the space outreach community, Swarmer enjoys promoting STEM work and education through various programs such as high altitude ballooning, tours of the UND aerospace facilities, and maintaining a connection with local media. Recently she was the Lunar analog suit tester during an internationally broadcast event at World Space Week that incorporated many countries in a friendly competition to test their developing suits.

On a leisurely note she has a great interest in fitness and enjoys a wide variety of sporting activities ranging from hiking and rock climbing to tennis and volleyball. Swarmer continues to be active in space analog research and human factors testing and is looking forward to continuing her education in the aerospace sciences.

Mission Scientist: Lucie Poulet

Poulet is a research associate and PhD candidate at the Institute of Space Systems of the German Aerospace Center in Bremen. She works at designing greenhouse modules for space and at optimizing lighting for plant growth, with a focus on hybrid lighting systems.

Space has always been a passion and a motor in her life. As a teenager Poulet used to spend 10 days every Summer in a small amateur observatory located in the French Alps learning visual and telescope observation of celestial bodies as well as astrophotography.

In 2011 she graduated from the National Polytechnique Institute of Lorraine (France) with a Master's in engineering of energy production and process.

In 2012 she graduated from Purdue University with a Master's in aerospace engineering where she worked in Dr. Mitchell's laboratory focusing on energy consumption reduction for

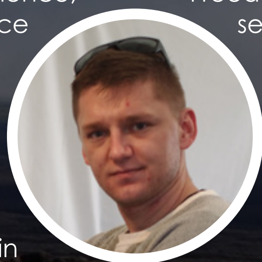
Annie Caraccio checks her gear during an EVA.
Photo by Ross Lockwood.

plant lighting in space. That same year she attended the Space Studies Program of the International Space University with a focus on Space Life Sciences and a team project assessing the possibility of developing a network of spaceports in the solar system.

In February 2014 Poulet spent two weeks at the Mars Desert Research Station in Utah as an executive officer and GreenHab officer within crew 135. In her free-time Lucie enjoys training for marathons, playing rugby, dancing salsa, flying small airplanes and learning Russian.

Chief Technologist:
Ross Lockwood

Lockwood grew up in the small Canadian town of Winfield, British Columbia, where he developed a passion for science, engineering, and space exploration.



He earned a Bachelor of Science in Honors Physics at the University of Alberta in 2008, and is currently in the last year of his PhD in Condensed Matter Physics. In his research he investigates silicon quantum dots and their potential future use in light-based sensors. His training as an experimental physicist focused on experiment design and development, as well as extensive chemical experience in silicon processing.

Lockwood's enjoyment of exploration and photography extends into the underwater world as an active member of the scuba diving community, both as a diver and as an assistant scuba diving instructor.

He shares his commitment to scientific outreach and passion for astronomy through public and educational initiatives at the University of Alberta Observatory, where he worked as a graduate teaching assistant for four years. He communicates his understanding of science as a guest lecturer at the University of Alberta and as a writer for the University of Alberta's Science Contours magazine.

Lockwood is documenting his experience with HI-SEAS on his personal science blog, spincrisis.net, as well as Facebook, and Twitter.

Mission Commander:
Casey Stedman

Stedman is an officer in the United States Air Force Reserve and a passionate advocate of space exploration. Commissioned in the Air Force in 2003, Stedman has logged over 2,500 hours as a navigator in C-130E/H, E-3B/C and T-43 aircraft. He is a combat veteran of both Operations Enduring Freedom and Iraqi Freedom, and has served in numerous contingency operations worldwide.

He is currently serving as a reservist in Youngstown, Ohio, and has been selected for promotion to the rank of Major in June 2014.

Stedman earned a BA in Geography from Central Washington University in 2003, and is now pursuing a Masters in Aeronautical Science from Embry-Riddle Aeronautical University Worldwide. His research focuses on Human Factors in Aviation, where he is investigating the application of Crew Resource Management (CRM) in human spaceflight, studying methods to reduce human error and increase safety in planetary exploration.

When not active with the Armed Forces, Stedman promotes aviation and space exploration by public outreach engagements like the National Space Society, The Planetary Society, and as Ambassador for the Suborbital Applications Research Group. He is active on Twitter as @ casey_stedman He also enjoys hiking, backpacking, mountain biking, and alpine mountaineering.

NASA Administrator Charles Bolden discusses the future of human spaceflight during the exploration forum at NASA Headquarters, in Washington, DC. *Credit: Ken Kremer*

New vehicles pave way for exploration

By Ken Kremer

Why is NASA's Commercial Crew Program to develop private human transport ships to low Earth orbit important?

That's the question I posed to NASA Administrator Charles Bolden when we met for an exclusive interview at NASA Goddard Space Flight Center in Maryland.

The Commercial Crew Program (CCP) is the critical enabler "for establishing a viable orbital infrastructure" in the 2020s, NASA Administrator Charles Bolden explained recently in a one-on-one interview at NASA's Goddard Space Flight Center in Greenbelt, Md.

Bolden, a Space Shuttle commander who flew four time to space, says NASA wants one of the new American-made private crewed spaceships under development by SpaceX, Boeing and Sierra Nevada – with NASA funding – to be ready to ferry U.S. astronauts to the International Space Station (ISS) and back to Earth by late 2017. Flights for other commercial orbital space ventures would follow later and into the next decade.

Since the shutdown of NASA's space shuttle program following the final flight by STS-135 in 2011 (commanded by Chris Ferguson), America has been 100 percent dependent on the Russians to fly our astronauts to the space station and back.

"Commercial crew is critical. We need to have our own capability to get our crews to space," Bolden exclaimed during a visit to the NASA Goddard cleanroom with the agency's groundbreaking Magnetospheric Multiscale (MMS) science probes.

Administrator Bolden foresees a huge shift in how the U.S. will conduct space operations in low earth orbit (LEO) just a decade from now. The future LEO architecture will be dominated not by NASA and the ISS but rather by commercial entrepreneurs and endeavors in the 2020s.

"There are going to be other commercial stations or other laboratories," Bolden excitedly told me.

And the cash strapped Commercial Crew effort to build new astronaut transporters is the absolutely essential enabler to get that exploration task done, he says.

"Commercial Crew is critical to establishing the low Earth orbit infrastructure that is required for exploration. We have got to have a way to get our crews to space."

"You know people try to separate stuff that NASA does into nice little neat packages. But it's not that way anymore."

Bolden and NASA are already looking beyond the ISS in planning how to use the new commercial crew spaceships being developed by SpaceX, Boeing and Sierra Nevada in a public partnership through NASA's Commercial Crew Program.

"Everything we do [at NASA] is integrated. We have to have commercial crew [for] a viable low Earth orbit infrastructure – a place where we can do testing – for example with what's going on at the ISS today."

"And in the out years you are going to be doing the same type of work. But it's not going to be on the ISS."

"After 2024 or maybe 2028, if we extend it again, you are going to see the people on commercial vehicles. There are going to be other stations or other laboratories. But they won't be NASA operated laboratories. They will be commercially viable and operating laboratories."

Private NewSpace ventures represent a revolutionary departure from current space exploration thinking. But none of these revolutionary commercial operations will happen if we don't have reliable and cost effective human access to orbit from American soil with American rockets on American spaceships.

"We need to have our own capability to get our crews to space – first of all. That's why commercial crew is really, really, really important," Bolden emphasized.

The ongoing crises in Ukraine makes development of a new U.S. crew transporter to end our total reliance on Russian spaceships even more urgent.

"Right now we use the Russian Soyuz. It is a very reliable way to get our crews to space. Our partnership with Roscosmos is as strong as it's ever been. So we just keep watching what's going on in other places in the world, but we continue to work with Roscosmos the way we always have," Bolden stated.

The latest example is the recent successful launch of the new three man Russian-U.S.-German Expedition 40 crew to the ISS on a Soyuz.

Of course, the speed at which the U.S. develops the private human spaceships is totally dependent on the funding level for the Commercial Crew program.

Unfortunately, progress in getting the space taxis actually built and flying has been significantly slowed because the Obama Administration CCP funding requests for the past few years of roughly about $800 million have been cut in half by a reluctant U.S. Congress. Thus forcing NASA to delay the first manned orbital test flights by at least 18 months from 2015 to 2017.

And every forced postponement to CCP costs U.S. taxpayers another $70 million payment per crew seat to the Russians. As a result of the congressional CCP cuts more than one billion U.S. dollars have been shipped to Russia

> There are going to be other stations or other laboratories. But they won't be NASA operated laboratories. They will be commercially viable and operating laboratories.

instead of spent on building our own U.S. crew transports – leaving American aerospace workers unemployed and American manufacturing facilities shuttered.

I asked Bolden to assess NASA's new funding request for the coming fiscal year 2015 currently working its way through Congress.

"It's looking better. It's never good. But now it's looking much better," Bolden replied. "If you look at the House markup that's a very positive indication that the budget for commercial crew is going to be pretty good."

The pace of progress in getting our crews back to orbit basically can be summed up in a nutshell.

"No Bucks, No Buck Rogers," Chris Ferguson, who now leads Boeing's crew effort, told me in a separate interview for RocketSTEM.

The Boeing CST-100, Sierra Nevada Dream Chaser and SpaceX Dragon 'space taxis' are all vying for funding in the next round of contracts to be awarded by NASA around late summer 2014 known as Commercial Crew Transportation Capability (CCtCap).

All three company's have been making excellent progress in meeting their NASA mandated milestones in the current contract period known as Commercial Crew Integrated Capability initiative (CCiCAP) under the auspices of NASA's Commercial Crew Program.

Altogether they have received more than $1 billion in NASA funding under the current CCiCAP initiative. Boeing and SpaceX were awarded contracts worth $460 million and $440 million, respectively. Sierra Nevada was given what amounts to half an award worth $212.5 million.

SpaceX CEO Elon Musk just publicly unveiled his manned Dragon V2 spaceship on May 29.

Boeing's Chris Ferguson told me that assembly of the CST-100 test article starts soon at the Kennedy Space Center.

NASA officials have told me that one or more of the three competitors will be chosen later this year in the next phase under CCtCAP to build the next generation spaceship to ferry astronauts to and from the ISS.

In order to certify the fitness and safety of the new crew transporters, the CCtCAP contracts will specify that "each awardee conduct at least one crewed flight test to verify their spacecraft can dock to the space station and all its systems perform as expected."

Concurrently, NASA is developing the manned Orion crew vehicle for deep space exploration. The state-of-the-art capsule will carry astronauts back to the Moon and beyond on journeys to asteroids and one day to Mars. However, commercial crew spacecraft are critical to establishing the low Earth orbit infrastructure that is required for deep space exploration.

SpaceX founder Elon Musk gives a peek inside the next generation Dragon space capsule during a media event to reveal the new design. The Dragon V2 will be the first man-rated spacecraft from the private company. *Credit: Brenden Clark*

Revealing a new Dragon

By Mary Kanian

In my lifetime, I have witnessed what I thought may be the entire life cycle of the era of manned flight in the USA; from the challenge of Russia's Sputnik in 1957, when I was 11 years old, to the ROAR of the last Space Shuttle launch in 2011. Oh, brother. Was I wrong.

Before the dust had settled after the last Space Shuttle launch, private companies eager to take up where the government seemed faltering and uncertain emerged to eagerly fill the void. Among these, the wunderkind of this new generation, Elon Musk, the creator of Paypal (an innovative way of purchasing nearly anything in the world), founder of Tesla Motors (the electric car completely redesigned) and pioneer of the reusable space craft with multiple capabilities. Who would not leap at the opportunity to see and hear this remarkable man?

That very opportunity came my way on May 29, 2014, when invitations were extended to a limited number of media outlets to come witness the unveiling of the next generation of SpaceX's resupply vehicles to the ISS (International Space Station) – the Dragon V-2 – which was to be introduced by Elon Musk himself.

Came the day, we all parked in the lot located across from SpaceX headquarters in Hawthorne, California and walked across the street to the main entrance be checked in by a well-prepared and courteous team of coordinators who checked the required two forms of id and matched our names to their lists. We were provided a separate badge on a lanyard and a 'Group Number' designation to assure each of us of an opportunity to enter the vehicle. Security precautions were in effect and all camera boxes & bags were inspected as would be done at concert halls and sports venues. There were no "pat-downs" and metal detectors were nowhere in sight.

We 50-60 members of the media were ushered into the building at the proper time through a brightly lighted white lobby, skimmed past an open hallway lined with low-walled grey cubicles, through a doorway and into a darkened room already filled with employees and invited guests.

We were placed front and center within 25 feet of the veiled Dragon V-2 capsule. Videographers, reporters and still photographers all quickly positioned themselves and set up

Featuring seating for seven astronauts, the Dragon V2 will be capable of delivering new crews to the International Space Station and eventually Mars. *Credit: SpaceX*

within 15 minutes while we were all being entertained by programming detailing the development of the Dragon and emanating from the two large video screens located left and right of the stage upon which rested the fully-shrouded vehicle.

All was in readiness with people in place in a space adjacent to the company cafeteria and coffee bar. As we faced the stage and the veiled vehicle, the entire space was mood-lighted to the max with undulating blue light complemented by subtle space-age music. To our left was a balcony area filled five or six people deep with employees, fronting the open cafeteria space. Behind us more employees and guests and to the right of us a two-story glass wall enclosing a room filled with 30 or more computers on desks, classroom style, each sporting the white SpaceX logo on its monitor.

Behind the stage area, one could see the soft pearl-gray factory space on two separate floor areas to the left and the right. Photography of the factory areas was not permitted but I must say the personnel were not overly guarding of it; but then again, there wasn't much we could see from our vantage point. Our eyes were filled with the shrouded Dragon V-2 in her sexy blue lighting.

Then, off to the right of the stage, with little fanfare strides the man himself – Elon Musk – to cheers and enthusiastic applause from everyone in the room. He takes the microphone, makes a few words of introduction and gets right to the unveiling… counting down 3, 2, 1. With a burst of light and a puff of mist – the shroud drops and there she is – the Dragon V-2. She is a noticeably larger version of the V-1, a pristine white vehicle resembling a lunar lander, and sleeker and simpler in appearance than her predecessor.

Stairs are rolled up to the vehicle and Elon steps up to open the hatchway and climbs in. SpaceX cameras follow his every move and word as he describes its features and capabilities from one of the reclined seats inside – seating for a crew of up to seven in this configuration, with drop-down controls that open to a multi-screen instrument display.

It was thrilling to watch this one-man show as he described the V-2's range of capabilities from crew taxi to resupply ship with the emphasis on reuseability. Even the usual 'disposable' launch escape system is reusable and uses the same fuel as the landing thrusters. Elon clearly feels that being limited to an ocean splashdown should be a thing of the past. He is fully knowledgeable and conversant with every technical aspect of the vehicle. He believes that the vehicle should have the ability to land with the precision of a helicopter almost anywhere and have a very short turnaround time to the next launch. Other components should also have similar capabilities, such as a booster which can, when spent, land itself wherever it is directed to.

As Elon exits the vehicle, the groups begin to line up to climb into the crew compartment, as promised, to experience the environment for ourselves. It was a thrill.

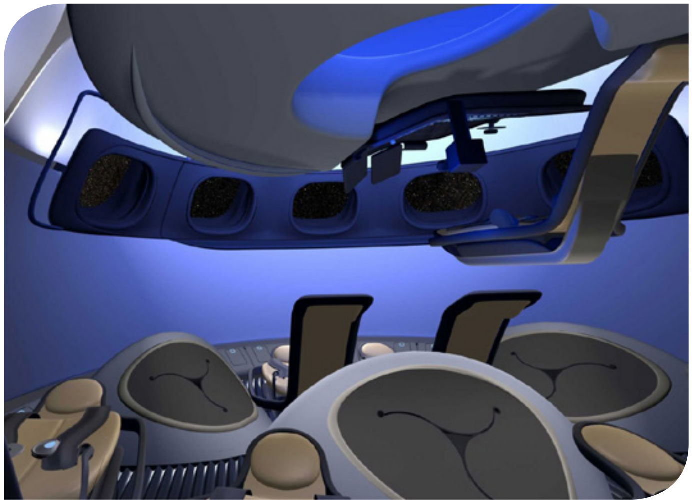
As groups took their turn examining the Dragon crew quarters, Elon moved to the edge of the stage and for 45 minutes it was an "all you can eat" feast of sound-bytes from Elon Musk, the pioneering entrepreneur in the realm of road and space vehicles, among other related pursuits.

To be within 15 feet of his energy field is magnetic and exciting as is listening to this man who thinks "outside the box". The pensive and elusive Elon Musk became the effusive Elon Musk that night, right before our eyes as he shared his many dreams and forward vision. He is made of the same energy and stardust that comprised Steve Jobs and Bill Gates…another visionary with a genius for putting people and technologies together and moving mankind along to other levels of accomplishment.

The Dragon V2 spacecraft. *Credit: Mary Kanian*

Boeing unveils CST-100 spacecraft

By Mike Killian



Boeing brings technology and comfort to its new spacecraft. Credit: Boeing

They say there is no substitute for experience, and when it comes to spaceflight there are few in the world that can match the proven expertise and decades of experience that Boeing brings to the table. Three companies are currently developing spacecraft to fill the void left by the retirement of NASA's Space Shuttle fleet in 2011, and the Crew Space Transportation-100 spacecraft (or CST-100 for short) is Boeing's answer to fill that void, leveraging their five decades of human spaceflight experience to provide the United States with affordable, reliable, and regular access to the ISS.

Boeing has remained rather low-key in the development of their spacecraft, or "space taxi" as they refer to it, which makes sense because that is exactly what it is. However, low-key is not to be confused with no progress. Boeing has been hard at work developing the vehicle they hope NASA will choose as a transport for their ISS crews.

"The CST-100 is a cheap, cost effective vehicle that doesn't 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."

The CST-100, which Boeing is developing in partnership with NASA's Commercial Crew Program will be capable of ferrying a crew of up to seven astronauts to and from the ISS and other low-Earth orbit destinations. 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, but will be able to take manual control of the CST-100 at any time, just in case.

"We [Boeing] 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," said Ferguson. "They will have the ability to get to the ISS and back, as well as the ability to deal with failures and take manual control if necessary."

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; the CST-100 has a control panel that 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 tell you 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.

"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 Boeing CST-100 engineer Tony Castilleja. "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," adds Castilleja. "We're bringing that Boeing element into spaceflight and wanted to create an interior that makes the spacecraft feel a little bit bigger."

If NASA selects Boeing to continue with CST-100 development in the second phase of a two-phased Commercial Crew Program effort this summer, known as Commercial Crew Transportation Capability (CCtCap), then Boeing would move their operations to the Kennedy Space Center to manufacture, assemble, and test the CST-100 flight article.

Boeing, in partnership with Space Florida, is already leasing the former space shuttle Orbiter Processing Facility Bay-3 to do this, modernizing the facility (now known as the Commercial Crew and Cargo Processing Facility, or C3PF) 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 Boeing's CST-100 Program Manager John 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."

Antares rocket launches cargo to space station

A multitude of NASA research investigations, crew provisions, hardware and science experiments from across the country is headed to the International Space Station aboard Orbital Sciences Corp.'s Cygnus spacecraft. The cargo craft launched aboard Orbital's Antares rocket from NASA's Wallops Flight Facility in Virginia on July 13, 2014.

The mission is the company's second cargo delivery flight to the station through a $1.9 billion NASA Commercial Resupply Services contract. Orbital will fly at least eight cargo missions to the space station through 2016.

The Orbital-2 mission is carrying nearly 3,300 pounds of supplies to the ISS, which will expand the research capability of the Expedition 40 crew members. Among the research investigations headed to the orbital laboratory are a flock of nanosatellites designed to take images of Earth; and a satellite-based investigation called TechEdSat-4. Another experiment features a sensor and multiple cameras to enable 3-D mapping and robotic navigation inside the space station. In addition, a host of student experiments are on board as part of the Student Spaceflight Experiment Program.

Expedition 40 Commander Steve Swanson of NASA, with help from Alexander Gerst of the European Space Agency, will use the station's robotic arm to take hold of Cygnus at 6:39 a.m. Wednesday, July 16. In August, the capsule, which will be filled with trash, will depart the station and burn up during reentry in Earth's atmosphere.

Credit: NASA/Bill Ingalls

OCO-2 studying the atmosphere

A United Launch Alliance Delta II rocket carrying the Orbiting Carbon Observatory-2 (OCO-2) payload for NASA lifts off from California. This launch marks the 51st Delta II mission for NASA and Delta II's return to flight.

Orbiting Carbon Observatory-2 (OCO-2) will be NASA's first dedicated Earth remote sensing satellite to study atmospheric carbon dioxide from Space. OCO-2 will be collecting space-based global measurements of atmospheric CO2 with the precision, resolution, and coverage needed to characterize sources and sinks on regional scales.

Credit: ULA