

RocketSTEM

Vol. 2 • No. 3 • May 2014 • Issue 7

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of citizen scientists
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10 years of discovery
for Cassini at Saturn

Jim Adams aligns
NASA technology
for future missions

All the equipment
you need for doing
astrophotography

Discussing string theory,
ice cream, and more
with physicist Brian Greene





NASA selfie during Earth Day 2014

NASA Astronaut John Mace Grunsfeld takes a quick selfie with astronauts at the International Space Station at the NASA sponsored Earth Day event April 22, 2014 at Union Station in Washington, DC. NASA announced the "Global Selfie" event as part of its "Earth Right Now" campaign, celebrating the launch of five Earth-observing missions in 2014. On May 22, NASA released the 3.2-billion-pixel sized NASA Earth Day Global Selfie 2014 photo mosaic. The image is comprised of more than 36,000 individual photos submitted by people around the world. To view the entire mosaic and related images and videos, please visit: <http://go.nasa.gov/1n4y8qp>.

Credit: NASA/Aubrey Gemignani

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On the Cover: Astrophysicist Brian Greene gives a presentation at the Smithsonian in Washington, D.C.

Credit: Kurt Raschke

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Brian Greene

Famed theoretical physicist and string theorist educates us on a variety of topics.



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Cassini

A decade of discovery and images while orbiting Saturn, its rings and 62 moons.



Jim Adams

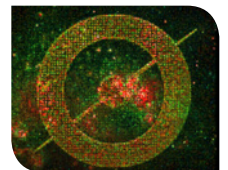
During his career at NASA, Adams has been involved with dozens of missions.

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'Smoke and fire' rise over Utah Salt Flats as student rockets soar in NASA challenge

The 2013-14 NASA Student Launch rocketry challenge has come to an end -- and brought something new to the Bonneville Salt Flats in Tooele County, Utah, where car and motorcycle enthusiasts regularly watch cutting-edge vehicles put to the test, speeding across the vast, flat expanse.

On May 17, all eyes there turned upward as 16 student-built rockets, ranging in size from 7-1/2 feet to 15 feet, soared high into the cloudless blue. Each sophisticated machine carried three working science or engineering payloads. Some roared to altitudes of nearly 20,000 feet. Each successful parachute deployment and vehicle touchdown on the white hardpan was met with cheers and applause from the crowd -- which included approximately 250 students from 15 states and some 500 spectators.

The social media audience, watching live coverage on NASA Television and UStream and following real-time updates on Twitter, was equally jovial. One proud

father, whose son was part of the team from Mississippi State University in Starkville, summed up the day's launches on the NASA Student Launch Facebook page: "This is awesome!"

This was the first year the challenge was held at the Utah site. It is organized annually by NASA's Marshall Space Flight Center in Huntsville, Alabama, and sponsored by ATK Aerospace Group of Magna, Utah.

Teams designed and built their rockets and experiments beginning in the fall of 2013. They maintained websites to document their experience and visited elementary and middle schools in their communities to inspire younger students to pursue the study of technical subjects critical to the work of NASA and the nation.

For more information, including a complete list of participating schools, visit: www.nasa.gov/audience/forstudents/studentlaunch

Archived launch-day coverage is available at: www.ustream.tv/nasahdvtv



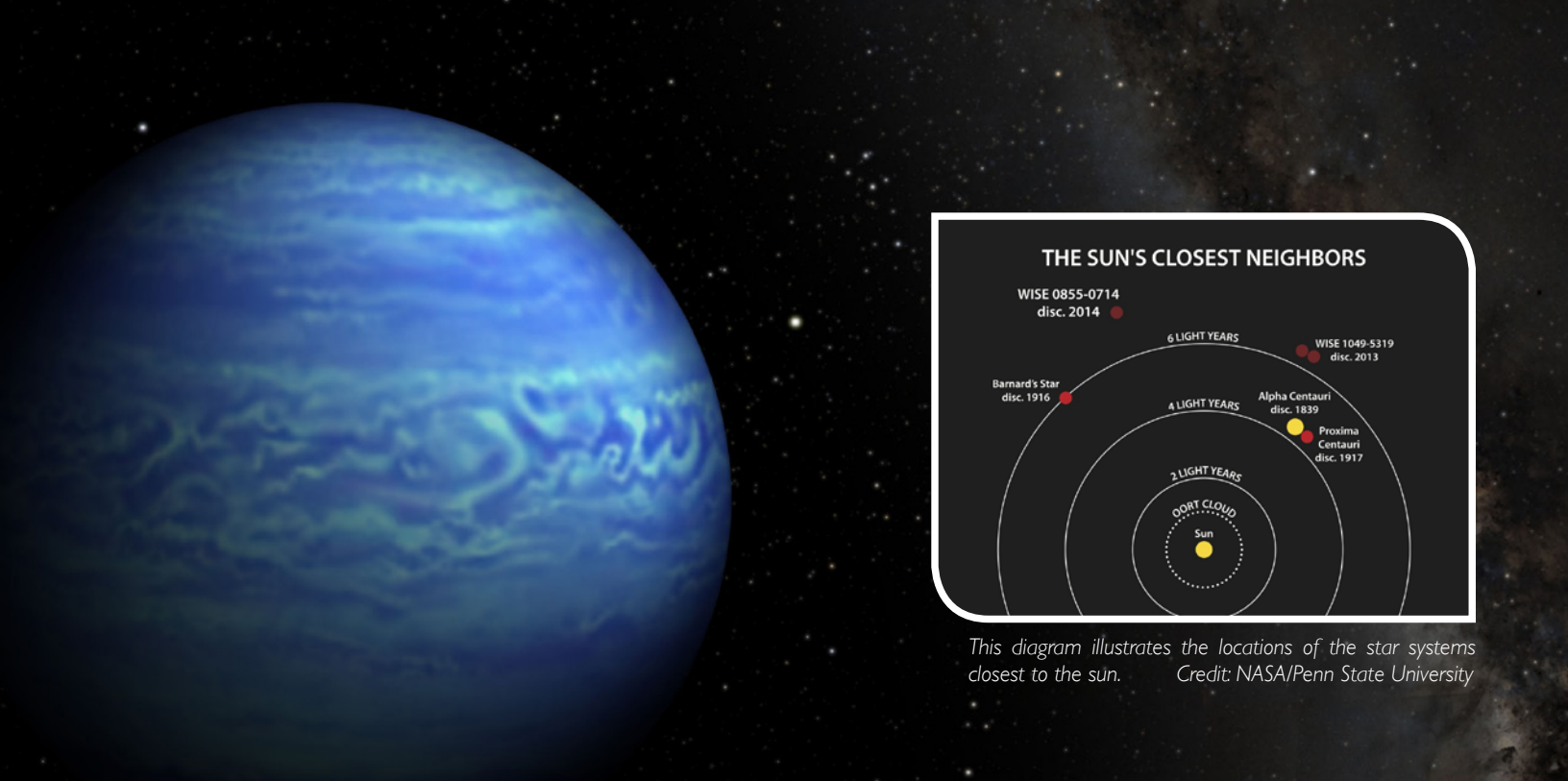
Credit: ATK/Justin Loeloff



Credit: NASA



Credit: MSFC/Dusty Hood



This diagram illustrates the locations of the star systems closest to the sun. Credit: NASA/Penn State University

This artist's conception shows the object named WISE J085510.83-071442.5, the coldest known brown dwarf. It is as cold as the North Pole. This celestial orb is also the fourth closest to our sun, at 7.2 light-years from Earth. Credit: NASA/JPL-Caltech/Penn State University

Coldest brown dwarf found nearby

NASA's Wide-field Infrared Survey Explorer (WISE) and Spitzer Space Telescope have discovered what appears to be the coldest brown dwarf known— a dim, star-like body that surprisingly is as frosty as Earth's North Pole.

Images from the space telescopes also pinpointed the object's distance to 7.2 light-years away, earning it the title for fourth closest system to our sun. The closest system, a trio of stars, is Alpha Centauri, at about 4 light-years away.

"It's very exciting to discover a new neighbor of our solar system that is so close," said Kevin Luhman, an astronomer at Pennsylvania State University's Center for Exoplanets and Habitable Worlds, University Park. "And given its extreme temperature, it should tell us a lot about the atmospheres of planets, which often have similarly cold temperatures."

Brown dwarfs start their lives like stars, as collapsing balls of gas, but they lack the mass to burn nuclear fuel and radiate starlight. The newfound coldest brown dwarf is

named WISE J085510.83-071442.5. It has a chilly temperature between minus 54 and 9 degrees Fahrenheit (minus 48 to minus 13 degrees Celsius). Previous record holders for coldest brown dwarfs, also found by WISE and Spitzer, were about room temperature.

WISE was able to spot the rare object because it surveyed the entire sky twice in infrared light, observing some areas up to three times. Cool objects like brown dwarfs can be invisible when viewed by visible-light telescopes, but their thermal glow – even if feeble – stands out in infrared light. In addition, the closer a body, the more it appears to move in images taken months apart. Airplanes are a good example of this effect: a closer, low-flying plane will appear to fly overhead more rapidly than a high-flying one.

"This object appeared to move really fast in the WISE data," said Luhman. "That told us it was something special."

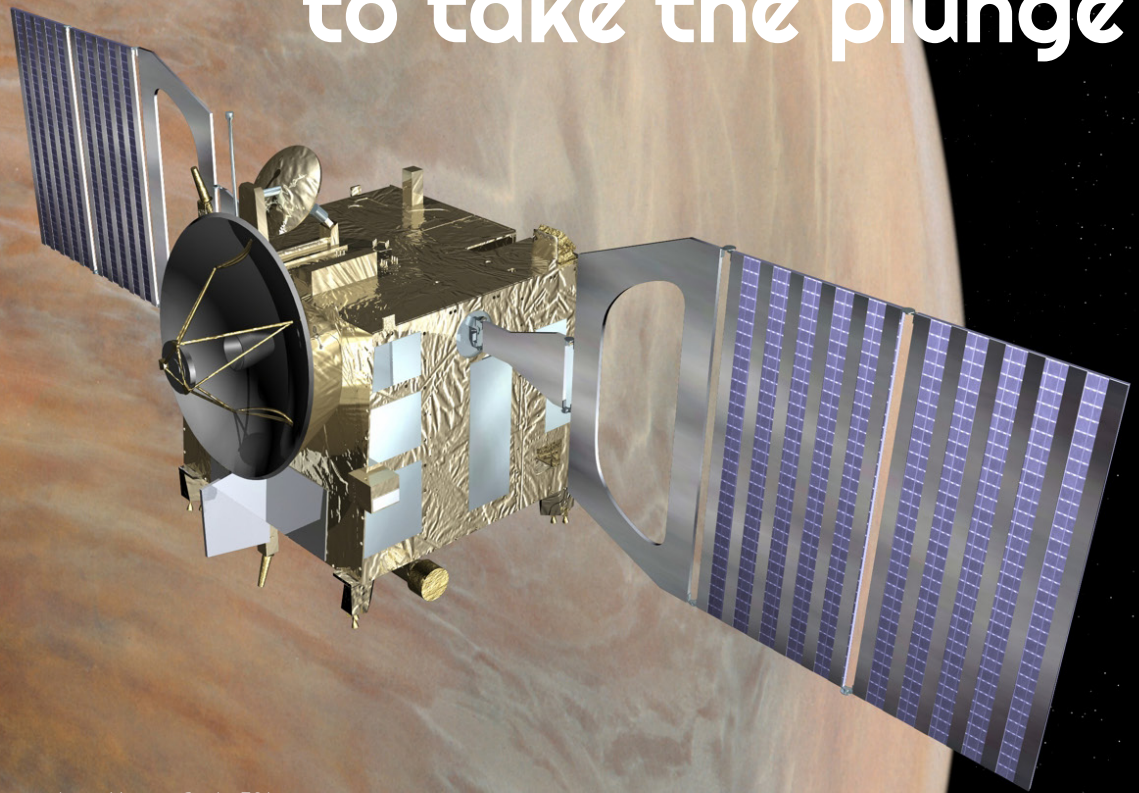
Combined detections from WISE and Spitzer, taken from different positions around the sun, enabled

the measurement of its distance through the parallax effect. This is the same principle that explains why your finger, when held out right in front of you, appears to jump from side to side when you alternate left- and right-eye views.

"It is remarkable that even after many decades of studying the sky, we still do not have a complete inventory of the sun's nearest neighbors," said Michael Werner, the project scientist for Spitzer at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "This exciting new result demonstrates the power of exploring the universe using new tools, such as the infrared eyes of WISE and Spitzer."

WISE J085510.83-071442.5 is estimated to be 3 to 10 times the mass of Jupiter. With such a low mass, it could be a gas giant similar to Jupiter that was ejected from its star system. But scientists estimate it is probably a brown dwarf rather than a planet since brown dwarfs are known to be fairly common. If so, it is one of the least massive brown dwarfs known.

Venus Express gets ready to take the plunge



Artist's impression of Venus Express orbiting Venus. Credit: ESA

After eight years in orbit, ESA's Venus Express has completed routine science observations and is preparing for a daring plunge into the planet's hostile atmosphere.

Venus Express was launched on a Soyuz-Fregat from the Russian Baikonur Cosmodrome in Kazakhstan on 9 November 2005, and arrived at Venus on 11 April 2006.

It has been orbiting Venus in an elliptical 24-hour loop that takes it from a distant 66 000 km over the south pole – affording incredible global views – to an altitude of around 250 km above the surface at the north pole, close to the top of the planet's atmosphere.

With a suite of seven instruments, the spacecraft has provided a comprehensive study of the ionosphere, atmosphere and surface of Venus.

"Venus Express has taught us just how variable the planet is on all timescales and, furthermore, has given us clues as to how it might have changed since its formation 4.6 bil-

lion years ago," says Håkan Svedhem, ESA's project scientist.

"This information is helping us decipher how Earth and Venus came to lead such dramatically different lives, but we've also noticed that there are some fundamental similarities."

Separated at birth?

Venus has a surface temperature of over 450°C, far hotter than a normal kitchen oven, and an extremely dense, choking mixture of noxious gases for an atmosphere. But from the mission's infrared survey of the chemical composition of the rocky surface, we have learned that Venus might have once had a plate tectonics system like Earth, and even an ocean of water.

Just like Earth, Venus is losing parts of its upper atmosphere to space and Venus Express measured twice as many hydrogen atoms escaping out of the atmosphere than oxygen. Because water is made of two hydrogen atoms and one oxygen

atom, the observed escape indicates that water is being broken up in the atmosphere.

Today, the total amount of water on Earth is 100 000 times that on Venus. But because the two planets are about the same size and formed at the same time, both may have had similar amounts of the precious liquid in their early years.

Meanwhile, the spacecraft's cameras have tracked thousands of features in the cloud tops some 70 km above the planet's surface, including an enormous swirling vortex at the planet's south pole that shares similarities with hurricanes on Earth. The spacecraft also recorded bursts of lightning – identified by their electromagnetic signature – generated in clouds of sulphuric acid.

Studies of the planet's 'super-rotating' atmosphere – it whips around the planet in just four Earth-days, much faster than the 243 days the planet takes to complete one rotation about its axis – also turned

up some intriguing surprises. In one study, average wind speeds were found to have increased from roughly 300 km/h to 400 km/h over a period of six Earth years.

Conversely, a separate study found that the rotation of the planet had slowed by 6.5 minutes since NASA's Magellan, which completed its 5-year mission at Venus 20 years ago, measured it.

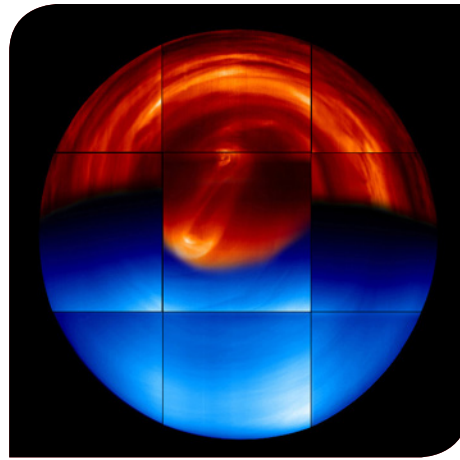
However, it remains unknown if there is a relationship between the increasing wind speeds and the slowing rotation.

Magellan's radar survey of the planet revealed that its surface was heavily altered in the past by a large number of volcanoes. But Venus Express has provided tantalising hints that the planet may well be still geologically active today. One study found numerous lava flows that must have been created no more than 2.5 million years ago, just yesterday on geological timescales, and perhaps much more recently.

Indeed, measurements of sulphur dioxide in the upper atmosphere have shown large variations over the course of the mission. Although peculiarities in the atmospheric circulation may produce a similar result, it is the most convincing argument to date of present-day active volcanism.

Final swansong

Now, after eight years in orbit, the fuel supplies necessary to



This global view of the southern hemisphere of Venus is a mosaic of images obtained by Venus Express. The night-side hemisphere (in red at the top) shows the lower layers of the cloud deck surrounding the planet at about 45-km altitude. The day-side hemisphere (in blue at the bottom) is made of ultraviolet images showing the cloud top layer at about 65-km altitude. The red part of the central panel shows the double vortex at the south pole, at an altitude of about 60 km, surrounded by a collar of 'cold' air.

Credit: ESA/VIRTIS-VenusX IASF-INAF, Observatoire de Paris (R.Hueso, Univ. Bilbao)

maintain the elliptical orbit are running low and will soon be exhausted. Thus, routine science operations concluded this week, and the spacecraft is being prepared for one final mission: to make a controlled plunge deeper into the atmosphere than ever before attempted.

"We have performed previous short 'aerodrag' campaigns where we've skimmed the thin upper layers of the atmosphere at about 165 km, but we want to go deeper, perhaps as deep as 130 km, maybe even lower," says Patrick Martin, Venus Express mission manager.

"It is only by carrying out daring operations like these that we can gain new insights, not only about usually inaccessible regions of the planet's atmosphere, but also how the spacecraft and its components respond to such a hostile environment."

This 'experimental aerobraking' phase is planned for 18 June – 11

July, during which time some limited science measurements with the spacecraft's magnetic field, solar wind and atom analysing instruments will be possible. Also, temperature and pressure sensors will record the conditions that the spacecraft is experiencing.

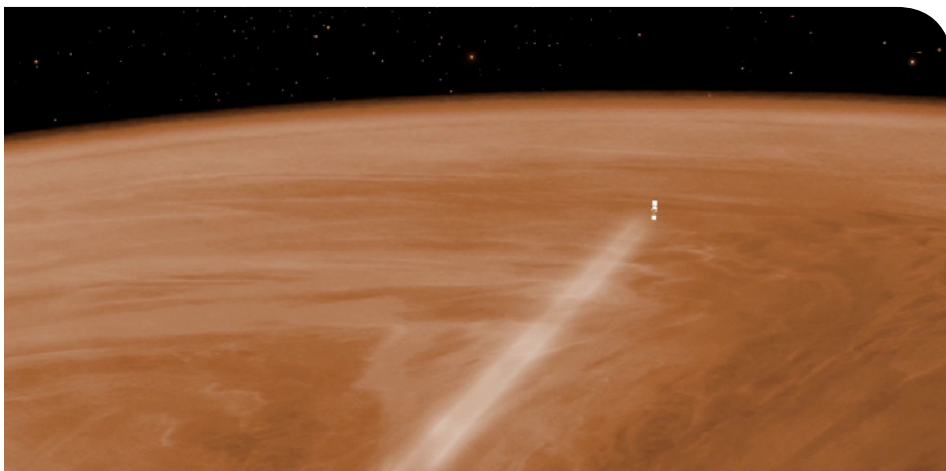
"The campaign also provides the opportunity to develop and practise the critical operations techniques required for aerobraking, an experience that will be precious for the preparation of future planetary missions that may require it operationally," says Paolo Ferri, head of mission operations.

Aerobraking can be used as a way of getting into orbit around planets without having to carry quite so much fuel, thus reducing the launch mass.

It is possible that the remaining fuel in Venus Express will be exhausted during this phase or that the spacecraft does not survive these risky operations. But if the spacecraft is still healthy afterwards, its orbit will be raised again and limited operations will continue for several more months, fuel permitting.

However, by the end of the year, it is likely that Venus Express will have made its final descent into the atmosphere of the planet, bringing a fantastic scientific endeavour to an end.

"Venus Express has penetrated deeper into the mysteries of this veiled planet than anyone ever dreamed, and will no doubt continue to surprise us down to the last minute," adds Håkan.



Visualisation of Venus Express during the aerobraking manoeuvre, which will see the spacecraft orbiting Venus at an reduced altitude of around 130 km from 18 June to 11 July. Credit: ESA–C. Carreau



Credit: Kurt Raschke

Brian Greene

and THE CHALLENGES OF PHYSICS

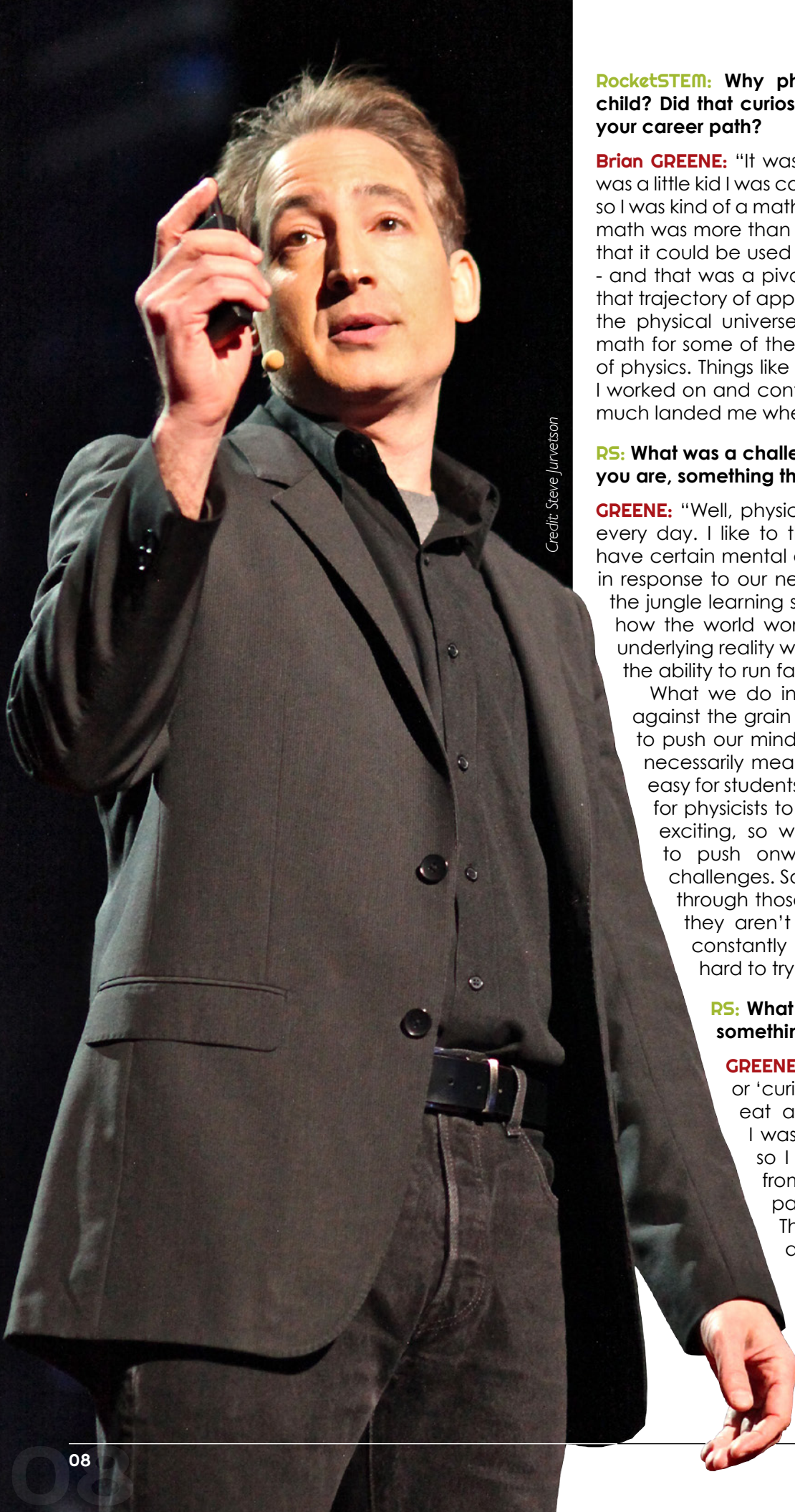
Interview by Sherry Valare

Have you ever stared up at the night sky contemplating how the universe works? Have your thoughts ever drifted off into the realm of the infinite? Theoretical physicist Brian Greene not only ponders these questions, but his research into String Theory could one day prove successful in answering them.

Greene is an author, professor, creator of his own Massive Open Online Courses (MOOC), and a vegan ice cream lover. He has even made guest appearances on high profile television shows, such as "The Big Bang Theory". First and foremost, through his research, Greene is searching for answers to some of the deepest questions surrounding the structure and creation of the universe.

The simplicity behind the thoughtful explanations to questions that boggle the greatest minds in science, stood out to me most when interviewing Greene. Because he is extremely talented at generating descriptive and vibrant explanations, it felt like he was splashing color on a canvas in my mind. He carefully approached every question without judgment – from the far-out and theoretical, to the concrete and factual.

At the beginning of our interview, I furiously took notes, but as we progressed, I let the recorders do the work and just listened to the stream of thought he shared with me on some of the most beautiful and elusive mysteries surrounding the cosmos.



Credit: Steve Jurvetson

RocketSTEM: Why physics? Were you curious as a child? Did that curiosity guide you gracefully towards your career path?

Brian GREENE: "It was a pretty seamless path. When I was a little kid I was completely fascinated by numbers, so I was kind of a math kid. A little later on I learned that math was more than just something you played with – that it could be used to describe how the world works – and that was a pivotal moment for me. I carried on that trajectory of applying mathematics to understand the physical universe, then as a grad student using math for some of the more esoteric and far-out ideas of physics. Things like unified theories and string theory I worked on and continue to work on, and that pretty much landed me where I am now."

RS: What was a challenge you overcame to get where you are, something that people can relate to?

GREENE: "Well, physics is challenging every minute of every day. I like to think of it the following way: we have certain mental abilities that were largely formed in response to our need to survive. When we were in the jungle learning survival skills, really understanding how the world works and the mathematics of the underlying reality wasn't useful. What was useful was the ability to run fast enough to catch your dinner.

What we do in physics is, in some way, going against the grain of evolution. We are really trying to push our minds into a place that they weren't necessarily meant to go. That's not easy. It's not easy for students to learn physics and it's not easy for physicists to do physics, but the ideas are so exciting, so wondrous, that we're compelled to push onward, and push through those challenges. So I encourage all students to push through those challenges and recognize that they aren't alone – even professionals are constantly scratching their heads, working hard to try to make progress."

RS: What is a really cool fact about you – something that no one would expect?

GREENE: "Well, I don't know if it's a 'cool' or 'curious' fact, but I am vegan. I don't eat anything of animal origin. When I was nine years old, I was a city kid, so I didn't know where meat came from; it was just this stuff that came packaged from the supermarket. Then my mother made spare ribs, and that made the connection for me. The fact that it was an animal was obvious all the sudden and that sickened me. So, I stopped eating meat at that age, but I still ate dairy.

Then much later, about 20 years ago, I went to an animal



Credit: NASA/Goddard/Wade Sisler

Physics is challenging every minute of every day. But the ideas are so exciting, so wondrous, that we're compelled to push onward, and push through those challenges.

sanctuary in upstate New York, a little town called Watkins Glen, and I learned about the dairy industry and how the animals are so mistreated. I could feel it coming, and a few days later, I just could not eat dairy anymore. I've been vegan ever since."

RS: What is your favorite ice cream? Oh, wait! You don't eat ice cream – that strikes that question!

GREENE: "Well, that's not true! So, there are now ice creams that are dairy-free. My favorite one is ... um ... goodness. Well, it's my favorite but I can't remember its name. It's a coconut vegan ice cream...it has bliss in the name...Coconut Bliss! My favorite flavor is ...um...I forgot its name, too. You can ask me about the universe, but my favorite ice cream stumps me.

(He took to Google at this point.)

What is that flavor, that's not it, that's not it, negative, negative...OH! Cherry Amaretto, man, that is my favorite."

RS: Would you want to live forever?

GREENE: "YES! So long as I could have my wife and my kids. And my ice cream, too."

RS: What was your inspiration for creating World Science U and what kind of student did you have in mind?

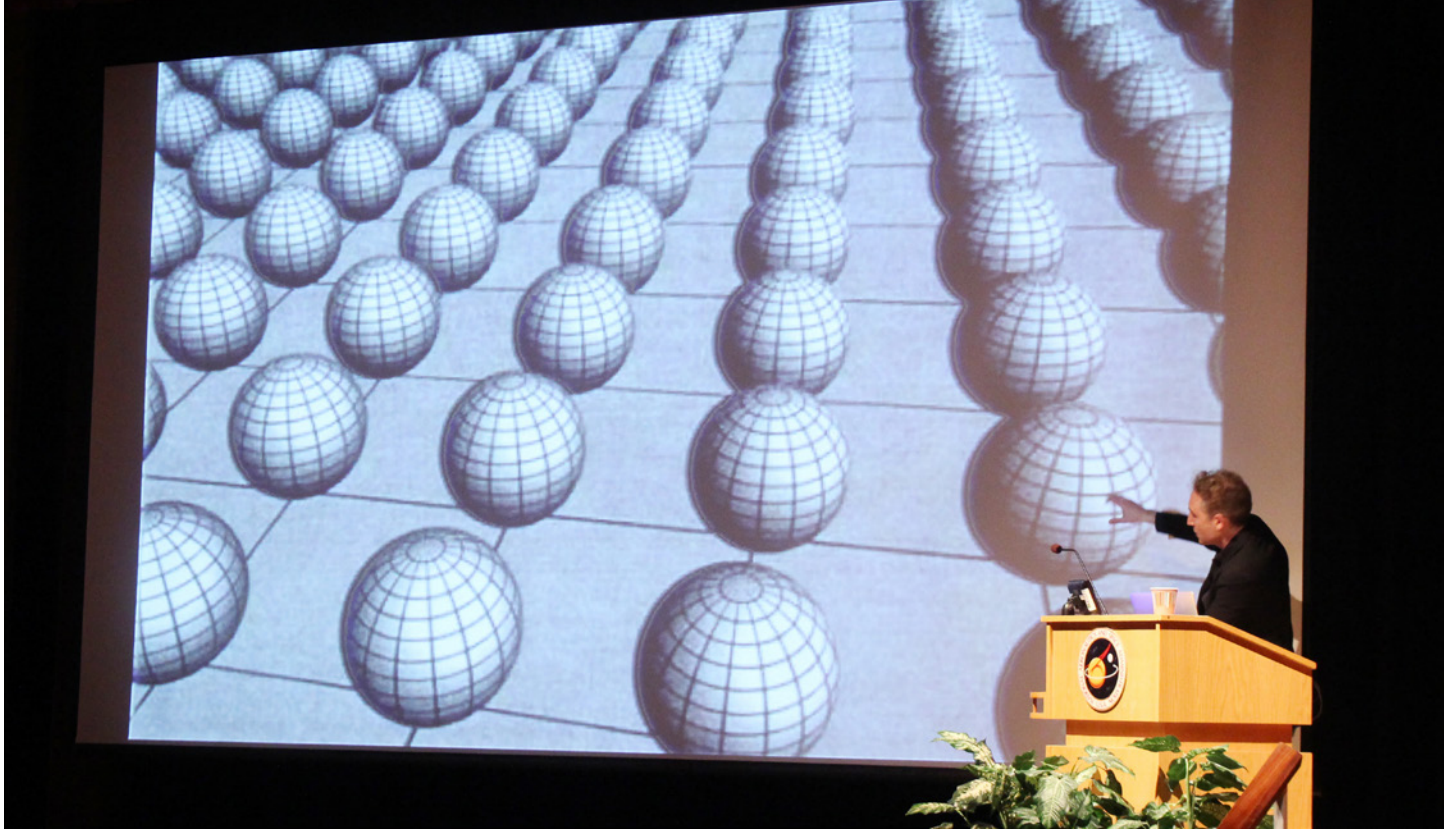
GREENE: "The point of World Science University (WSU) is to bring science education to anybody who wants it. And I mean that literally – it really can be for the high school kid who is very advanced and finds school not challenging enough, for the college student who's having difficulty in the classroom and needs help outside of the traditional instruction at their college.

It's for the lifelong learner who gave up on science many years ago, but has always wanted to reconnect with it, and didn't want to go back to college and enroll in classes – but this is a way in which, in his or her own time, one can immerse themselves in many wonderful ideas. The intended audience is broad."

RS: How do you hope your students will utilize what they have learned in your courses?

GREENE: "Well, the initial courses that WSU is offering are in Einstein's Special Relativity. That's a subject which is not something that a student is going to apply to everyday circumstances – it tells us how the world behaves in unusual circumstances – when things are moving very, very quickly.

Rather than thinking about somebody using this material to specifically do something, what I really want is for people to leave the class with a completely changed perspective on how reality works – a very



Earlier this year, Brian Greene presented "Where Do We Stand with String Theory" in the John Bahcall Lecture at NASA's Goddard Space Flight Center.

Credit: NASA/Goddard/Wade Sisler

different perspective on the meaning of space, on the meaning of time, on the meaning of math, on the meaning of energy.

It is a course that has a capacity to really shake up one's perspective on how the universe works."

RS: Do you plan on eventually morphing this into a degree or certificate program?

GREENE: "We do offer certificates now to people that

complete the initial courses. In terms of degrees – who knows? Way down the line I could very well imagine that there might be a more formal way in which a student can get credit for achieving a level of proficiency in these online courses."

RS: Are you going to teach the courses yourself in the beginning?

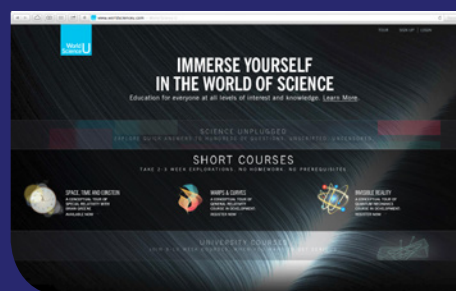
GREENE: "Yes, I am the initial instructor, just to get the

World Science U launches online learning for everyone

By Sherry Valare

World Science U is an up and coming web based school that offers massive open online courses (MOOC). It was created by Dr. Brian Greene, Theoretical Physicist, so that top researchers and educators could guide any student's way through the expansion of their scientific knowledge at whatever level they are most comfortable approaching.

There are no time limits on how long you have to complete the class, and students have the ability to pause then restart where they left off. Select courses even have a live discussion feature where Greene himself will be available to



The website: www.worldscienceu.com

discuss concepts with students at scheduled times, similar to office hours during an in-person course.

There are several levels of courses students can attempt, after a very quick registration requiring no more than basic information. Greene offered the following explanation

about how his course structure has been designed to provide a top notch learning experience for anyone with a desire to learn.

"There are three layers of difficulty that a student can choose from. The first layer is "Science Unplugged", which is a collection of short video answers to a wide range of questions on topics such as: time and space, what matter is made of, and how the universe began. Anyone can engage with these questions – they don't need any background at all and it can be done for a few minutes or however long you find the experience exciting.

The next layer is what we call "Short Courses", which are

ball rolling, but we are now in conversation with a number of leading scientists, in a variety of areas, who are slated to be the next people in."

RS: What are you most looking forward to about the World Science Festival later this month?

GREENE: "It is always full of surprises and great programs. I'm doing a program on quantum mechanics with a number of world renowned folks, whose expertise is in quantum physics. I also know there is a really cool event happening on the Intrepid ship in the Hudson river, and we are doing a screening of a science related film, together with astronauts to interact with families and audiences after the film. We like to think of it as a coming together of science and music and art and theater and film to create a celebration of one of the most important things our species does, which is explore.:

RS: What is your opinion of a "Horton Hears a Who" scenario for the universe? Stepping out of the science, what kind of ideas do you have about 'what we are'?

GREENE: "The notion that there are worlds within worlds and that the reality we experience in everyday life is one level of reality – whether a very tiny realm or a very big realm, there are vastly different phenomena that take place – that really is true. That is what modern physics has taught us.

It hasn't taught us that little tiny people live down there, but it has taught us that the laws at work in the

microscopic realm are so different from the ones that we experience up here, that it is its own wondrous, distinct, separate universe. And the metaphor, the Dr. Seuss story, I think is aligned well with modern thinking.

Now, consider this. We think of ourselves as intelligent life. We share 99 percent of our DNA with chimps so a little tiny shift in our DNA takes you from chimp to us. Now, that suggests that if there are other creatures in the universe whose DNA differs from ours, for example, by a few percent in the right direction, their intelligence could be so enormous compared to ours, that they would look at us as if we were a bacteria. They would look at us as if we were worms crawling around on the surface of the earth.

So we always ask ourselves if there is other life in the universe. The answer might turn out to be that there is, and that life is so intelligent that when compared to ours, they're really not interested in us, just like we really aren't that interested in worms or bacteria, in that sense."

RS: What do you think is outside of space? How did something come from nothing?

GREENE: "First of all, as for what is outside of space, well there simply may not be an outside of space. It makes sense to talk about what's outside of your building, or what's outside of your country, what's outside of the earth, the galaxy – all that makes sense. But when it comes to the universe, it may be that it truly encompasses everything. And the notion of an

*The laws at work
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separate universe.*

conceptual in the sense that the ideas are the real ideas of science, but you don't need math background, and you don't need to do homework – you just take in the material.

The third and deepest level of engagement is the university level courses. The pilot course is Einstein's Theory of Special Relativity. For this level, you need high school Algebra and a bit of high school Physics to be comfortable with the place where the courses begin."

As an afterthought, Greene added, "The whole point, though, is that the courses take abstract ideas and make them



Brian Greene speaking at the Smithsonian National Air and Space Museum in Washington, D.C. Credit: Kurt Raschke

understandable, by making them visual. There are hundreds of animations we have built to

illustrate the core ideas. I think they are an essential part of why this online experience, in my mind, does a better job of teaching than I typically do in the classroom. I don't have this type of visual resource in the classroom and that's why this is an exciting way to shake up the whole teaching experience."

The World Science U website is simple to navigate with clear instructions to assist you in following your curiosity into the strange world of physics, in whichever manner you choose. For more information, or to try out the courses, visit www.worldscienceu.com.

"outside of the universe" may simply just be a concept that doesn't make any sense."

RS: Back to the big bang...doesn't something have to exist for something else to come from it, though? How did something just start...from nothing?

GREENE: "Yeah, I mean, that's again one of those natural thoughts based on everyday experiences. Because in everyday life, every object we experience, look at, has a history. That history involves us being created from other stuff that existed before the object ever existed. And maybe it will be true of the universe, too. Maybe it will be that our big bang, is not the beginning of everything, it was simply an event in a pre-existing reality and there may be a prehistory to the big bang – that's quite possible.

On the other hand, it may be the case, that the universe is different from a baseball, a painting, or any other objects in the world that all have a prehistory. The universe may have come into existence in a given moment and there may not have been a prehistory there may not have been anything before that event took place.

Or, maybe the laws of physics existed, but somehow there wasn't a physical reality within which those laws operated until those laws somehow coaxed the big bang into taking place, then all of the sudden there was stuff on which those laws operate. Perhaps before all that stuff was there, it was just the laws itself, some abstract realm."

RS: How can there be any more than three dimensions, why is time described as a dimension, and do you see it as tangible?

GREENE: "When we talk about dimensions of space, indeed we imagine that there are three of them, (length, width, height) but it could be that there are dimensions in addition to those, that for some reason our eyes don't directly see or directly detect.

In fact, I spent much of my adult career developing mathematical theories that'll allow the universe to have a fourth, fifth, sixth dimension and so on in a way that wouldn't contradict the fact we haven't seen those dimensions.

Don't allow your eyes to fool you into thinking that what you see is everything

Now, for time, we think of it as a piece of information necessary to delineate when and where an event takes place. For instance, if you are having a dinner party, you give your guests the street, cross street and floor numbers, to get to your apartment, but you also need to give them a time, so that they know when to show up. In that sense, that's four pieces of information we consider to delineate where the party is taking place – in four dimensions – three of space and one of time."

RS: In the absence of empirical data, how do you decide between different hypotheses? Do you have some kind of intuition for what might be true, do you go for the most beautiful theory, or do you go with the one that is most amenable to mathematical analysis?

*Nature doesn't care so much
about our feelings – nature
has her own set of rules
and it is up to us to try
to discern them.*



Credit: Kurt Raschke

GREENE: "Well I do think that the ultimate arbiter of truth is experimental data. So that is the thing that clearly trumps everything else. In the absence of that, you do use your intuition, your gut feeling – your aesthetic sense of which ideas seem most promising.

That doesn't mean those ideas are right, it does, however, mean that you, based on your personal judgment, feel that they are the ones most worthy of your time and attention in order to be further developed. However, it could well be that things which did not feel intuitively correct, or the right way to go, may ultimately be picked out by nature.

Nature doesn't care so much about our feelings – nature has her own set of rules and it is up to us to try to discern them."

RS: What is the shape of space and what do you think of dark matter?

GREENE: "For the shape of space, the data seems to suggest that space is very close to being flat – in a sense that it doesn't have any intrinsic curviness to it. Rather than being like the surface of a ball, the shape of space is more like that of a tabletop. And that tabletop might go on forever in all directions – that is our best guess at the moment.

As for dark matter, the evidence seems to be accumulating over many decades that there is matter in the universe that doesn't give off light, but it does exist. It is exerting the force of gravity, and that is how we know the matter is there – even though we don't see it – and that sets up a challenge to identify what constitutes dark matter.

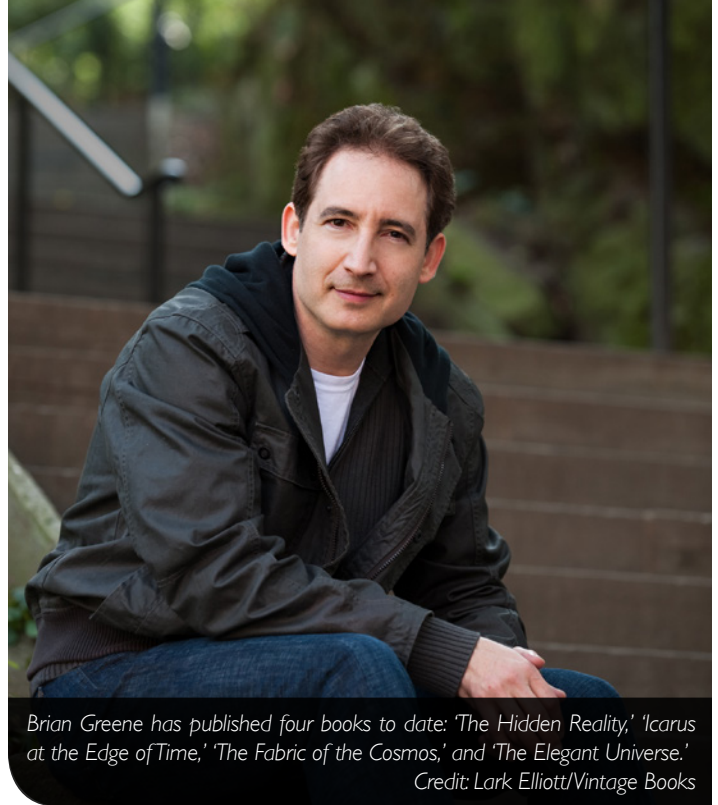
People have been looking for the constituents of dark matter for a number of years – surprisingly yet – nothing has been confirmed. We are hoping in the next few years, that issue will be settled."

RS: In simple terms, can you explain what string theory is?

GREENE: "String Theory is a proposal that tries to reach Einstein's dream of a unified theory of physics. And by that, Einstein meant the theory that from one principle – maybe to be articulated by one mathematical equation – we might describe everything. This includes stars and galaxies (the big stuff), the small stuff, molecules and atoms, and everything in between.

The way String Theory works, is to imagine that matter is not what we thought it was. Rather than matter being little dot like particles with no internal machinery, String Theory envisions that the constituents are little stringy filaments, and their different vibration patterns are meant to describe everything that happens in the world.

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Brian Greene has published four books to date: 'The Hidden Reality,' 'Icarus at the Edge of Time,' 'The Fabric of the Cosmos,' and 'The Elegant Universe.'
Credit: Lark Elliott/Vintage Books

It is a hypothetical theory, and we are still trying to develop it in order to test it – it hasn't yet been tested."

RS: What do you think of the discovery of the gravitational waves that prove the big bang happened?

GREENE: "It is extremely exciting! If the results stand, they will be among the most important findings in cosmology and the search for the origin of the universe.

It will be one of the most important findings in a hundred years. They will give us a new observational window into the earliest moments of creation, which will be a very powerful, new tool for us to use to understand the universe. However, I also want to emphasize that we won't really believe these results until they are independently confirmed by other groups of researchers. But the team did a great job!"

RS: How are we trying to measure some of the alternate energies (i.e. dark energy)?

GREENE: "Well, measuring dark energy is a challenge, but there are very good teams of astronomers that have worked out techniques that often have to do with measuring the properties of supernova explosions. They tell us how galaxies are moving away from us. In the next few years, we are going to gain a lot more insight into the nature of dark energy, whether it changes over time, and if it was constant over the whole course of history.

These are the pretty vital questions to address and I think that we are going to start getting answers."

Kepler finds nearest twin to Earth yet

Using NASA's Kepler Space Telescope, astronomers have discovered the first Earth-size planet orbiting a star in the "habitable zone" — the range of distance from a star where liquid water might pool on the surface of an orbiting planet. The discovery of Kepler-186f confirms that planets the size of Earth exist in the habitable zone of stars other than our sun.

While planets have previously been found in the habitable zone, they are all at least 40 percent larger in size than Earth, and understanding their makeup is challenging. Kepler-186f is more reminiscent of Earth.

"The discovery of Kepler-186f is a significant step toward finding worlds like our planet Earth," said Paul Hertz, NASA's Astrophysics Division director at the agency's headquarters in Washington. "Future NASA missions, like the Transiting Exoplanet Survey Satellite and the James Webb Space Telescope, will discover the nearest rocky exoplanets and determine their composition and atmospheric conditions, continuing humankind's quest to find truly Earth-like worlds."

Although the size of Kepler-186f is known, its mass and composition are not. Previous research, however, suggests that a planet the size of Kepler-186f is likely to be rocky.

"We know of just one planet where life exists — Earth. When we search for life outside our solar system, we focus on finding planets with characteristics that mimic that of Earth," said Elisa Quintana, research scientist at the SETI Institute at NASA's Ames Research Center in Moffett Field, Calif., and lead author of the paper published today in the journal *Science*.

"Finding a habitable zone planet comparable to Earth in size is a major step forward."

Kepler-186f resides in the Kepler-186 system, about 500 light-years from Earth in the constellation Cygnus. The system is also home to four companion planets, which orbit a star half the size and mass of our sun. The star is classified as an M dwarf, or red dwarf, a class of stars that makes up 70 percent of the stars in the Milky Way galaxy.

"M dwarfs are the most numerous stars," said Quintana. "The first signs of other life in the galaxy may well come from planets orbiting an M dwarf."

Kepler-186f orbits its star once every 130 days and receives one-third the energy from its star that Earth gets from the sun, placing it nearer the outer edge of the habitable zone. On the surface of Kepler-186f, the brightness of its star at high noon is only as bright as our sun appears to us about an hour before sunset.

"Being in the habitable zone does not mean we know this planet is habitable. The temperature on the planet is strongly dependent on what kind of atmosphere the planet has," said Thomas Barclay, research scientist at the Bay Area Environmental Research Institute at Ames, and co-author of the paper. "Kepler-186f can be thought of as an Earth-cousin rather than an Earth-twin. It has many properties that resemble Earth."

The four companion planets, Kepler-186b, Kepler-186c, Ke-

pler-186d and Kepler-186e, whiz around their sun every four, seven, 13 and 22 days, respectively, making them too hot for life as we know it. These four inner planets all measure less than 1.5 times the size of Earth.

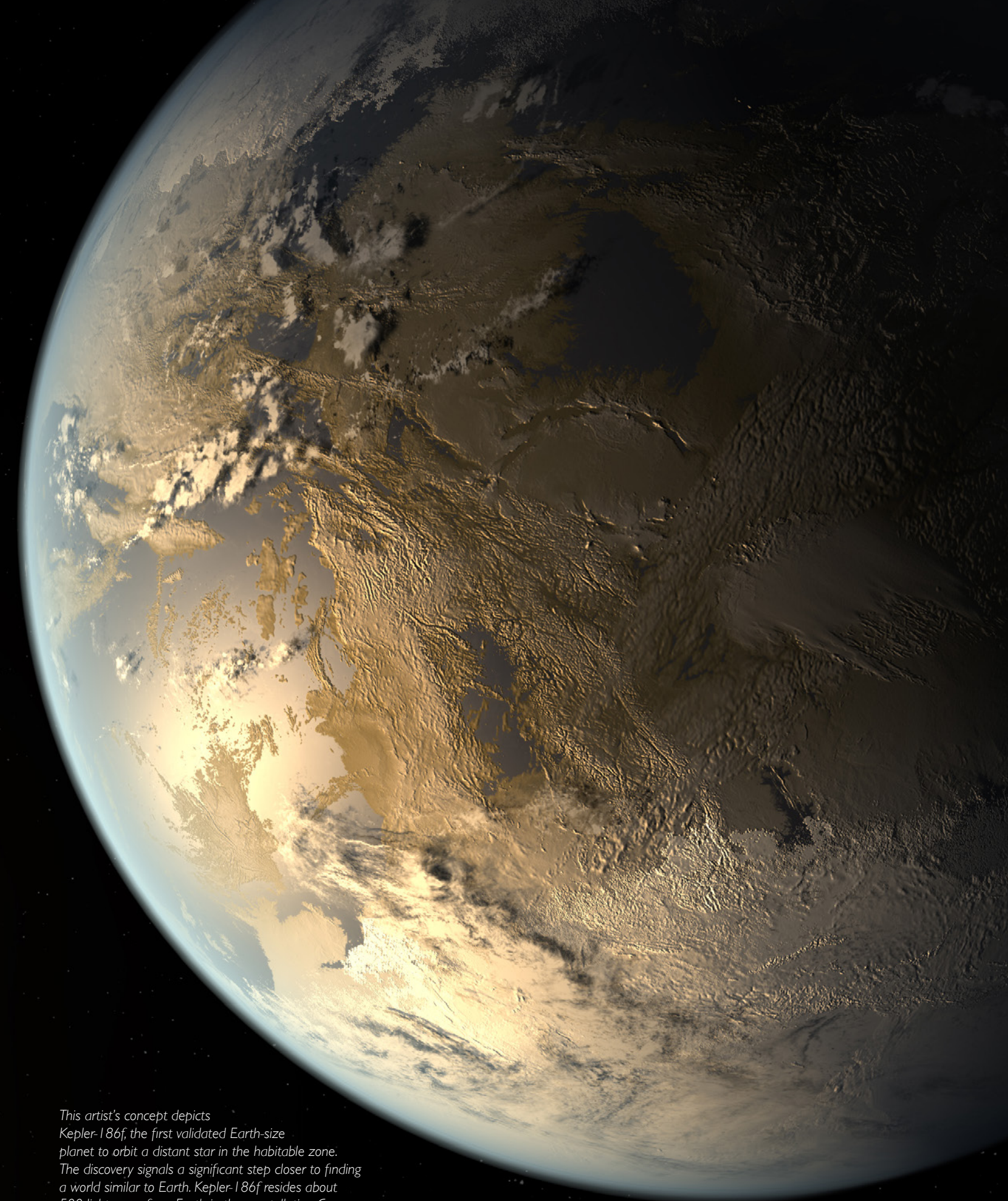
The next steps in the search for distant life include looking for true Earth-twins — Earth-size planets orbiting within the habitable zone of a sun-like star — and measuring their chemical compositions. The Kepler Space Telescope, which simultaneously and continuously measured the brightness of more than 150,000 stars, is NASA's first mission capable of detecting Earth-size planets around stars like our sun.

Ames is responsible for Kepler's ground system development, mission operations, and science data analysis. NASA's Jet Propulsion Laboratory in Pasadena, Calif., managed Kepler mission development. Ball Aerospace & Technologies Corp. in Boulder, Colo., developed the Kepler flight system and supports mission operations with the Laboratory for Atmospheric and Space Physics at the University of Colorado in Boulder. The Space Telescope Science Institute in Baltimore archives, hosts and distributes Kepler science data. Kepler is NASA's 10th Discovery Mission and was funded by the agency's Science Mission Directorate.

The SETI Institute is a private, nonprofit organization dedicated to scientific research, education and public outreach. The mission of the SETI Institute is to explore, understand and explain the origin, nature and prevalence of life in the universe.

For more information about the Kepler mission, visit: www.nasa.gov/kepler.





This artist's concept depicts Kepler-186f, the first validated Earth-size planet to orbit a distant star in the habitable zone. The discovery signals a significant step closer to finding a world similar to Earth. Kepler-186f resides about 500 light-years from Earth in the constellation Cygnus.
Credit: NASA/Ames/SETI Institute/JPL-Caltech

Starting in astrophotography

If you thought buying a telescope was confusing and complicated, then moving on to astrophotography can be even worse. This arises because of the myriad of different types of photography that can be done, the budget available, and the celestial objects that you want to image. Astrophotography can range from taking starscapes with your existing camera at one end of the scale all the way up to using dedicated CCD cameras with filters on tracking mounts, and a whole wealth of options in between.

However getting started in astrophotography does not have to be expensive, a lot can be achieved using imaging equipment that you may already own, or could borrow. This article will just focus (pun intended) on the equipment side for your introduction into astrophotography. Taking the picture is only part of the sequence to obtaining some stunning images.

Getting started in astrophotography does not have to be expensive, a lot can be achieved using imaging equipment that you may already own.

A later article will look at the software processes on your computer that will turn the output from your camera into a jaw dropping picture. I will also cover more advanced astrophotography in another article discussing guiding and combining images to reduce noise and bring out more detail.

One way to get going in astrophotography is to try and use the imaging equipment that you have already without spending a penny. People may laugh at this, but it is perfectly feasible. You will not get the best results, but at least you will get some passable imagery, and with a bit of patience and perseverance these can be very acceptable. This of course means that you start with your existing camera. These days almost everyone has a camera in the form of a smartphone, and believe it, or not, the smartphone can take some good astro pictures.



Smartphones can take images through a telescope with an adapter, such as the Orion SteadyPix, that holds it over the eyepiece. Credit: Orion

Using a Smartphone

To use the phone's camera all you need to do is line it up with the eyepiece of a telescope and take the picture. A lot of these will not be very good, but with some practice you will improve.

This method of astrophotography is called afocal imaging. The manufacturers have realised there is a market out there for this type of photography and have developed a number of attachments for telescopes that hold the camera firmly in the correct position. This makes the process a lot more reliable and repeatable.

Using this method of imaging can also be applied to compact cameras. all that is required is that the camera can focus on the image in the eyepiece.

Of course there are limitations to this, in particular the fact that this is a snapshot of the image and is not suitable for long exposures, but it is a start.

Using a Compact Camera

Staying with the concept of not spending any money you can use your existing camera to take starscapes. All you need is a camera that can take exposures up to 30 seconds or one that has a night scene setting. The camera should be set at the highest ISO setting of 3200 or 6400. You will then need a tripod, beanbag or some other form of stabilisation to prevent the camera moving during the exposure. If you find a nice dark spot with no lights around this will give you some lovely images of the stars, showing you far more than you could ever see with your eyes. If your camera has a bulb setting and a means of triggering it without touching the camera then you can start to take longer exposures of 2 to 3 minutes. With exposures of this length you will start to see the stars trailing.

These star trails occur because the heavens rotate around the celestial poles. In the northern hemisphere they rotate around Polaris. Star trailing is something that astrophotographers try to eliminate, but they can be used in a very artistic manner by taking lots of images and then merging them together to form streaking lines as the heavens rotate. In general you will find that any exposure longer than 30 seconds will start to show trailing, if you use telephoto lenses then that time can be reduced to just a few seconds.

Using a DSLR

A single lens reflex camera with interchangeable lenses or more specifically the DSLR that has replaced wet film cameras is the dream imaging device for budding astrophotographers. I used my trusty old Nikon D300 as my main camera in astrophotography for quite a while before I moved on. The DSLR is such a flexible camera that it can be used in a number of ways to create some stunning images. The beauty of the DSLR is not only the interchangeable lenses but also the control that can be gained over the exposure of the image.

A standard DSLR has a slight drawback in that the infrared filter over the sensor also blocks light in the hydrogen alpha (HA) spectrum. The HA spectrum is where the light from the stunning red emission nebulae originates. However, don't be put off, there are still thousands of objects that can be imaged.

Again starting with just a DSLR and a tripod you have a lot of artistic capacity to utilise. I like to use a wide angle or standard lens and take exposures of up to 30 seconds. The wider the angle the longer the exposure that you can take. My 10.5mm fisheye lens is perfect for taking the majority of the night sky and is wonderful for meteor showers where the meteors can streak across the sky from just about any location. Moving up to the 50mm standard lens the narrower field of view is ideal for imaging constellations. My longest lens is a 200mm telephoto lens, which is a



*The iOptron SkyTracker is ideal for long exposure imaging with a DSLR camera.
Credit: Mike Barrett/www.wired4space.com*

great lens for terrestrial photography, but not so good for astrophotography as trailing occurs at even short exposures. There is a way around this which I will explain later.

The important thing about taking images with your DSLR is to keep it very still whilst taking the exposure. This will generally require a tripod, but you can improvise with beanbags, or even a wall. A cable release of some form or other will allow the camera shutter to be controlled without having to touch the camera. This means that there will be no shaking or movement when taking the picture. As a guide to exposure you should put the camera into manual. I generally shoot with the aperture wide open for 30 seconds at the



Performing astrophotography doesn't require a telescope. A DSLR camera can be coupled with the iOptron SkyTracker to produce pretty good long exposure images.
Credit: Mike Barrett/www.wired4space.com

highest ISO setting on the camera. You can use a lower ISO setting to reduce the noise in the image, but you will also lower the sensitivity and the number of stars that can be recorded.

Focusing can be a little problematic as the lens actually focusses beyond infinity, so you cannot just set it at the end of the focus movement. You need to set the focusing mode into manual focus and turn off any image stabilisation, if the lens has it. I find that focusing during the day on something as far away as possible helps me get set up. A piece of electrical tape is your friend here as it can be placed over the focus ring and prevent movement. When night falls and you set up to take your pictures there should only be a small amount of fine adjustment required to bring the image into full focus.

Computerised Camera Control

If you want to get a bit more serious about astrophotography and have a laptop and compatible camera you can shoot in tethered mode. This is where the computer controls the features of the camera. Canon cameras are particularly useful for this as there is a lot of software available, both Commercial and Freeware, that can control the entire imaging process. I still have my D300, but I decided to get a dedicated astrophotography camera, and after a lot of comparisons decided to go for the Canon T3i a versatile workhorse that could be fully controlled by my computer. I also use APT - Astro Photography Tool a Freeware imaging application. APT does far more than just control the camera, but this is the area that I am covering here. For more details about APT check their website at www.ideiki.com.

Just above I mentioned the problems with focusing at night. APT is able to control the camera lens and provide you with far finer control over focusing than you can ever do manually. It also has a number of features that assist in achieving focus including live view, lens control, autofocus, and focus aid. Using these tools help you frame and focus your image. APT also has a feature that allows you to program a sequence of shots enabling you to automate the process of your night work. I have just touched on the surface of what the program can do and there are many other alternatives out there that do the same thing. As each camera offers different facilities check with the compatibility charts before you make a final decision about a new purchase or acquisition.

Connecting to a Telescope

So far I have just mentioned using a DSLR as a stand-alone camera, but a main concept of astrophotography

is to take images through a telescope. This is where the benefits of the interchangeable lenses come to the fore. Why not replace the lens with a telescope? The mechanics of this is surprisingly easy. The camera lens bayonet fitting has long been used by manufacturers of third party aftermarket lenses to provide a specific camera mounting to a generic lens. This is known as a T2 mount and has the bayonet connection on one side with a thread inside.

The thread is used to screw in an eyepiece adapter resulting in a sturdy



The bayonet and nosepiece of a T2 camera mount adapter.
Credit: Mike Barrett

camera connection between the and the telescope. The telescope then becomes a long focal length lens.

There are a couple of drawbacks to using this method for connecting a camera to a telescope. The main problems are backfocus and star trailing.

Backfocus in astrophotography is the ability of the focuser to move sufficiently to achieve focus in the camera. If you look at a DSLR there is normally a mark on the body indicating where the sensor is. This is also the focus point of the camera. An eyepiece has its focal point some way below the eye, but a camera has it above the plane where your eye would be. This means that the telescope focuser has to be able to move in far enough for the camera to achieve focus. This is normally not a problem with a refractor telescope or a cassegrain reflector, but can be on a Newtonian reflector. On the Newtonian this can often be overcome by using a Barlow lens which shifts the focus point and can allow the camera to achieve focus.



Shown is a 2-inch T-2 Mount attached to Canon EOS Rebel T3i.

Credit: Mike Barrett/www.wired4space.com

Star trailing was mentioned above and it can be used to generate some lovely artistic effects, but generally astrophotographers want pin-sharp stars and long exposures. Back in the second issue of RocketSTEM we looked at the various types of telescopes and mounts. For astrophotography the German equatorial (GEM or EQ) mount is a must. This tracks the motion of the stars through the night sky allowing longer exposures without the stars trailing. However even with a telescope there is always the bright moon that can be imaged.

Tracking Camera Mounts

So far everything can be achieved with equipment you may already have, but to track the celestial motion you need to have an equatorial mount. This does not mean that you have to buy an expensive telescope mount though a tracking mount is a purchase you may want to make when you get a little more serious and want to start taking longer exposures. There are a number of systems on the market: Astrotrac, Vixen Polaris, and the iOptron SkyTracker are three popular ones. They all work on the same basic principal: the mount is aligned with the celestial pole (close to Polaris

in the northern hemisphere) then the camera mount is rotated at the same rate as the stars revolve around the pole.

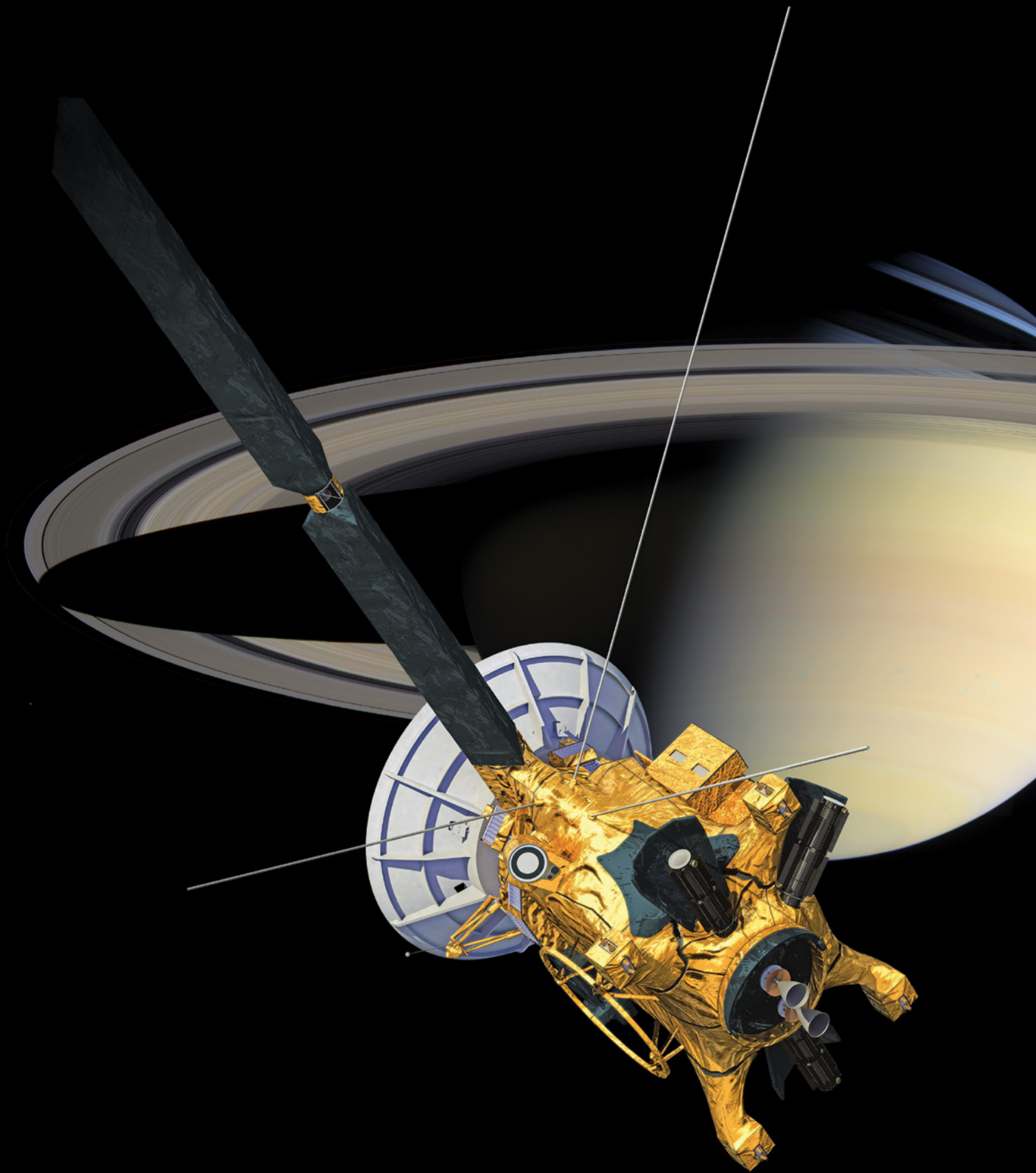
All of these mounts are light, small and very transportable, but require the addition of a tripod, and some kind of tripod head. With the addition of a simple programmable timer this makes for an excellent portable astrophotography system. The exposure can easily be increased from 30 seconds to 3 minutes even with a 200mm telephoto lens. With this type of setup you will be able to do some deep space photography and if you are anything like me you will get the bug and want to improve your skills and take your photography to another level.

Conclusion

As can be seen astrophotography does not have to involve huge expenditures and a lot can be done with equipment that you may already own or have access to. Obviously this is just an introduction to help you get started, and there are so many more levels to the subject. I will be covering some these in future articles, including planetary imaging which can done very easily using webcam.

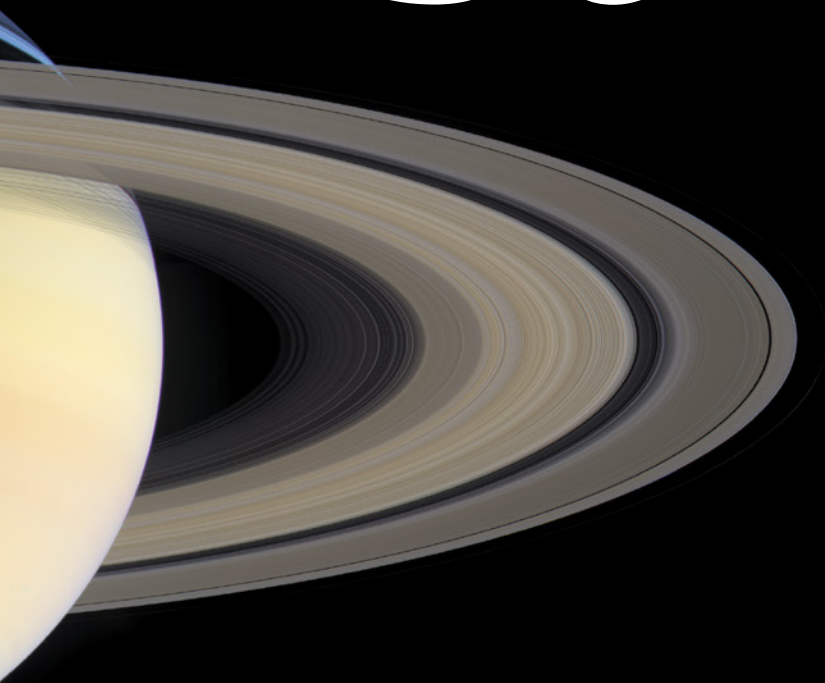
Camera to telescope adapters use a T2 mount and can be used to capture images from a wide variety of sizes of telescopes.

Credit: Mike Barrett/www.wired4space.com



Credit: NASA/JPL-Caltech

Cassini plus Saturn



a decade exploring
the ringed system

CASSINI: AMAZING IMAGES AND EVEN MORE AMAZING SCIENCE

By Lloyd Campbell

The Cassini orbiter has been in orbit around Saturn since June 2004. Launched aboard a Titan IVB rocket from Cape Canaveral Air Force Station on October 15, 1997, it was originally dubbed Cassini-Huygens as the Huygens probe was carried along with Cassini to the Saturnian system.

The voyage to Saturn is a long one as Saturn, on average, is 1.43 billion miles from earth. The rocket used to launch Cassini-Huygens was the most powerful in the NASA arsenal at that time, but it was still not powerful enough to send Cassini-Huygens on a direct flight straight to Saturn. Instead NASA utilized

a technique called "gravity assist" a number of times during Cassini's trip to Saturn. A gravity assist uses the gravitational pull of a body in space to increase the vehicle's speed as it flies by. The flyby can also be used to alter the course of the spacecraft.

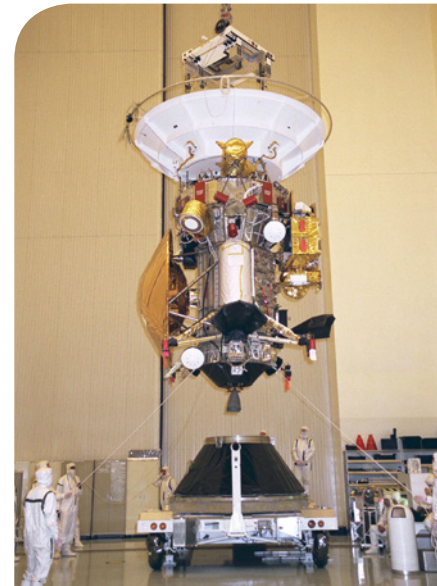
On its trip to Saturn, Cassini-Huygens flew past Venus, twice, Earth once, and Jupiter once. To this day Cassini still uses Gravity Assists to preserve fuel, using the Saturnian moons and Saturn itself to help maintain the

speed of the spacecraft. For example, when flying by Saturn's moon Titan on April 7, 2014, the probe gained speed as it approached Titan, and due to the flight path, while it lost energy pulling away from Titan its speed post encounter was the same as before the encounter started, allowing a scientific flyby using no propellant.

The Cassini orbiter has 12 instruments on board. According to NASA, "the science instruments can be classified in a way that can be compared to the way human senses operate. Your eyes and ears are 'remote sensing' devices because you can receive information from remote objects without being in direct contact with them. Your senses of touch and taste are 'direct sensing' devices. Your nose can be construed as either a remote or direct sensing device. You can certainly smell the apple pie across the room without having your nose in direct contact with it, but the molecules carrying the scent do have to make direct contact with your sinuses."

Cassini's instruments allow it to analyze remotely, it is an orbiter after all, but it is not limited to only visual examinations as it uses radar, radio, and spectrometers

Cassini launches in 1997 to start a seven-year journey to the ringed planet.
Credit: NASA



Cassini is lowered to mate with its launch vehicle adapter in 2004.
Credit: NASA

to analyze from a distance. And for close encounters, the field and particle instruments measure things in the immediate vicinity of the spacecraft such as Magnetic fields, mass, electrical charges, and densities of atomic particles, along with the composition and quantity of dust particles, and the strength of electrically charged gas (Plasma).

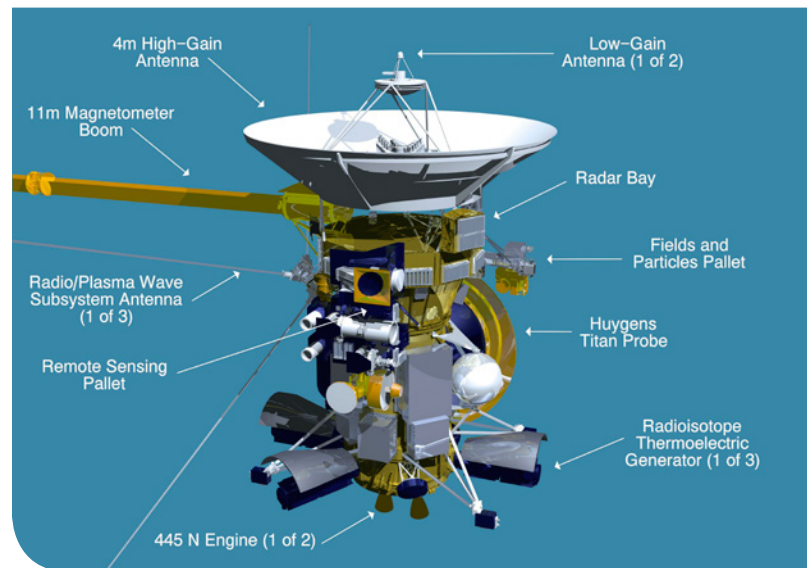
The spacecraft's instruments, propulsion system, maneuvering systems, and communication equipment all require power to operate. Providing the power are three Radioisotope Thermoelectric Generators, also referred to as RTGs. The RTGs generate 885 watts of power. As a comparison, the laptop I am writing this article on has a 126 watt power supply, and a 42" LCD Television uses about 120 watts of electricity.

Solar panels were not an option as due to the amount of power required to operate the spacecraft and its instruments. Using the most advanced solar panels available at that time, that could have met the power requirements, would have required them to be so large it would have made the spacecraft too heavy to launch.

Cassini is still in operation today, having completed its primary mission in June 2008 as a healthy spacecraft, it was decided that a secondary mission, dubbed the Cassini Equinox Mission, was added. That mission lasted until September 2010, and once again with a healthy spacecraft still providing valuable data back to scientists on Earth, a third mission called the Cassini Solstice Mission was added. That mission was recently funded through its scheduled end of mission in September 2017, so there is still a lot of excitement coming from this reliable spacecraft over the next 3 years. The mission's extension is named for Saturn's summer solstice which will be occurring in May 2017. The northern summer solstice marks the beginning of summer in the northern hemisphere and winter in the southern hemisphere. Since Cassini arrived at Saturn just after the planet's northern winter solstice, the extension will allow for the first study of a

complete seasonal period.

So what has Cassini accomplished so far? Well the amazing pictures it has returned to us to see are certainly one of its hallmarks, but the scientific discoveries it has made are also very impressive. We would need to dedicate the entire issue



of this magazine, if not more, to Cassini if we were to list them all with any detail, so I'll just touch on a few.

One of the mission's primary objectives was to deliver the Huygens probe to Saturn's moon Titan. That task was accomplished when the Huygens probe entered the thick atmosphere of Titan and landed via parachute on January 14, 2005. The probe punched a hole some 12cm deep in the surface upon landing. It was then pulled out of the hole by its parachute system and it slid another 30- 40 cm along the surface before coming to a rest. Scientists originally had believed the surface to be soft on top; however now it is believed there is a crust on top of that soft layer. The soft layer is believed to be more like a mud than a dry grainy composition. Huygens transmitted back 350 pictures of its descent and of the surface, along with scientific data, until Cassini was no longer in range to receive data from it. Cassini was the relay to Earth for the Huygens probe. The data sent back included the first ever images of



The first color view of Titan's surface returned by the ESA Huygens probe.

Credit: ESA/NASA/JPL/Univ. of Arizona

Titan's surface, remember that with thick hazy atmosphere, you cannot actually see the surface from above.

Recently Cassini measured the depth of Titan's second largest sea, Ligeia Mare, to be about 560 feet in depth. Since Titan's water bodies are mostly Methane

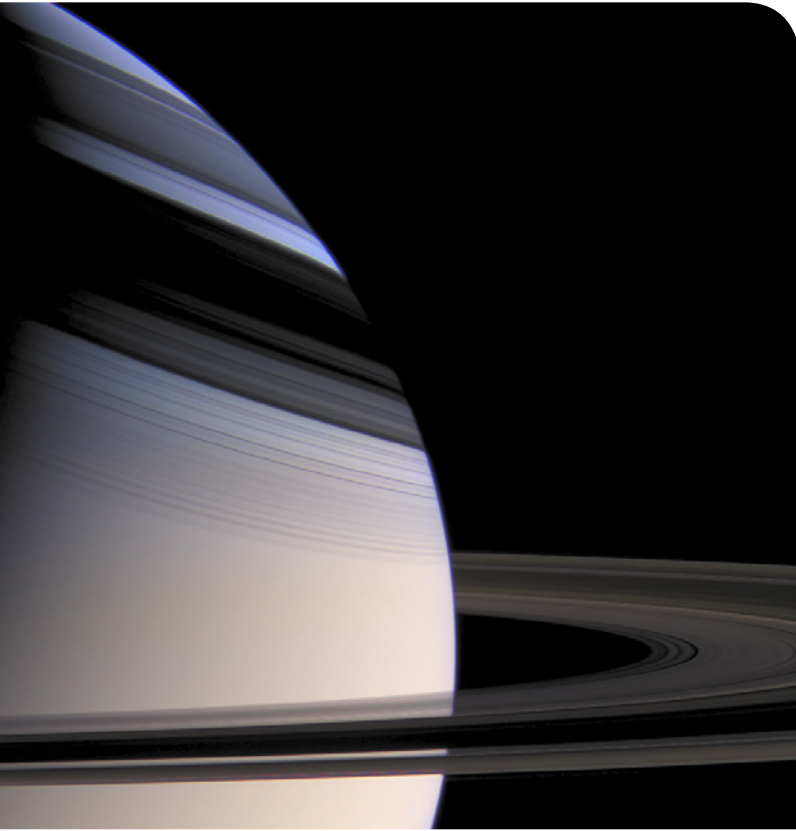
plane," said Scott Edgington, Cassini deputy project scientist at NASA's Jet Propulsion Laboratory in Pasadena, Calif. "You cannot see the polar regions very well from an equatorial orbit. Observing the planet from different vantage points reveals more about the cloud layers that cover the entirety of the planet."

Cassini changes its orbital inclination for such an observing campaign only once every few years. Because the spacecraft uses flybys of Saturn's moon Titan to change the angle of its orbit, the inclined trajectories require attentive oversight from navigators. The path requires careful planning years in advance and sticking very precisely to the planned itinerary to ensure enough propellant is available for the spacecraft to reach future planned orbits and encounters.

In comparison to hurricanes on Earth, the one on Saturn is gigantic with the eye of the storm being roughly 50 times larger than the eye of a hurricane on Earth at approximately 1,250 miles across. Wind speeds at the outer edge of the storm are around 340 MPH. Unlike hurricanes on Earth, this storm does not migrate; it is stuck in what is essentially a stationary position indefinitely. On Earth, hurricanes tend to drift northward because of the forces acting on the fast swirls of wind as the planet rotates. The one on Saturn is already as far north as it can be. The end result is a strong swirling storm, with no place to go.

"The polar hurricane has nowhere else to go, and that's likely why it's stuck at the pole," said Kunio Sayanagi, a Cassini imaging team associate at Hampton University in Virginia.

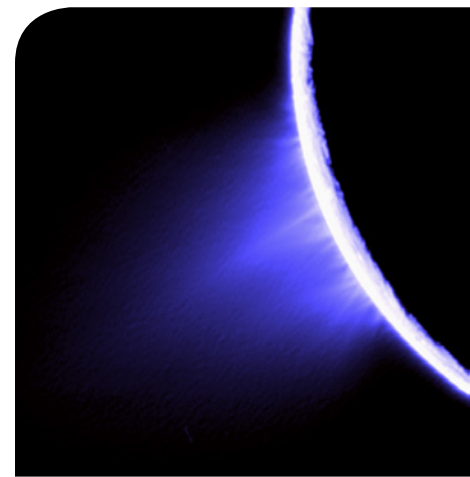
Unrelated to the hurricane in the polar region, a massive thunder and lightning storm was detected in Saturn's northern hemisphere. After forming, the turbulent head of the storm moved west and spawned a clockwise rotating vortex that followed the same path but more slowly. In a matter of just a few months the storm encircled the entire planet, stretching some 190,000 miles, with thunder and



Few sights in the solar system are more strikingly beautiful than softly hued Saturn embraced by the shadows of its stately rings. Despite Cassini's revelations, Saturn remains a world of mystery. Credit: NASA/JPL/Space Science Institute

the spacecraft uses radar to "see" first through the smoggy atmosphere of Titan, and then through the lake itself to find the bottom.

Cassini also discovered a huge hurricane swirling around Saturn's north pole just last year. Even though Cassini has been in orbit since 2004, the polar region was dark due to the northern hemisphere being in winter. The composite infrared spectrometer and the visual and infrared mapping spectrometer detected a massive vortex quite some time ago. However it could not be seen until recently with winter ending in the northern hemisphere. "Such a stunning and mesmerizing view of the hurricane-like storm at the north pole is only possible because Cassini is on a sportier course, with orbits tilted to loop the spacecraft above and below Saturn's equatorial

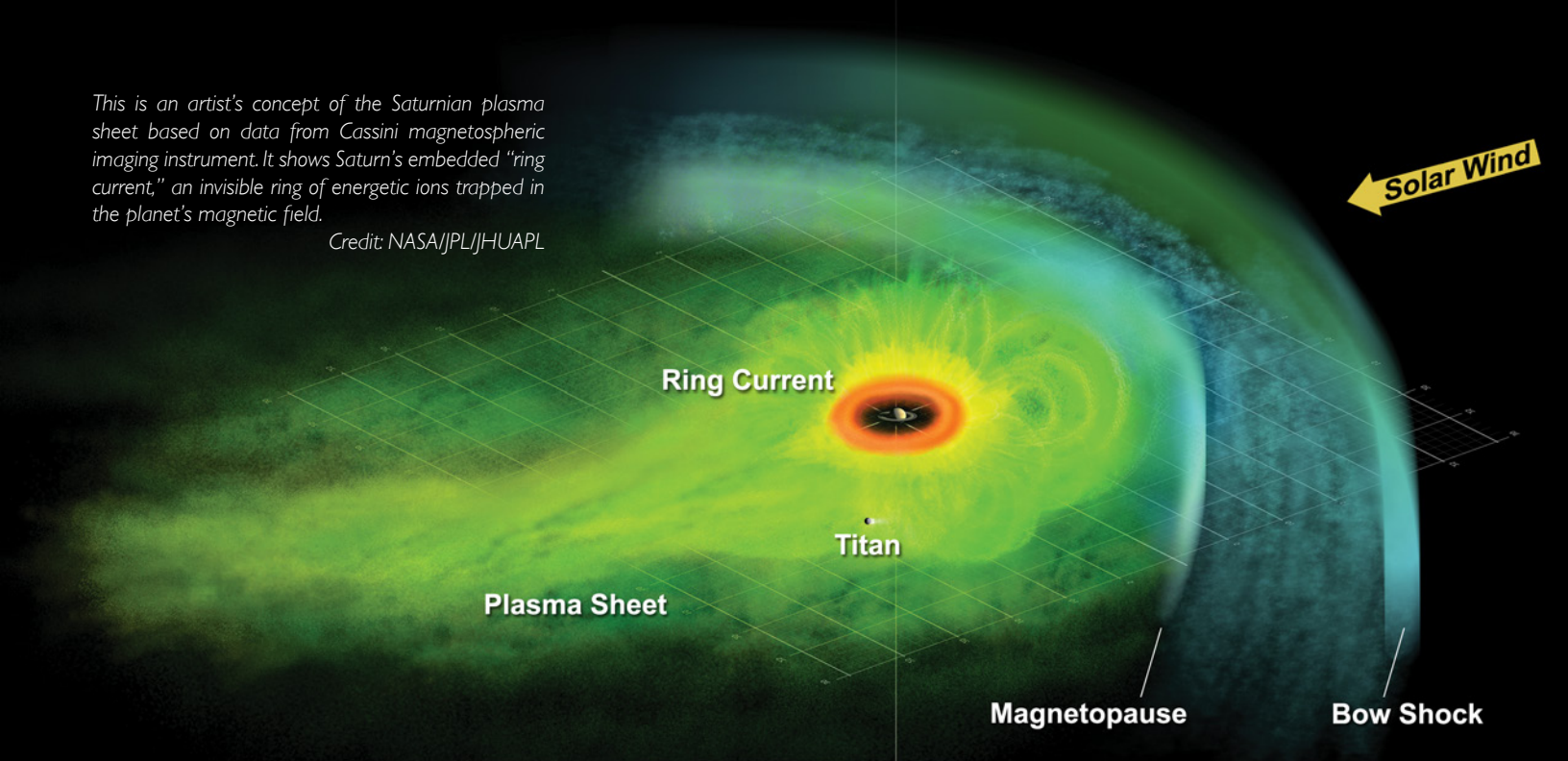


Jets spurt ice particles, water vapor and trace organic compounds from the surface of Saturn's moon Enceladus.

Credit: NASA/JPL/Space Science Institute

This is an artist's concept of the Saturnian plasma sheet based on data from Cassini magnetospheric imaging instrument. It shows Saturn's embedded "ring current," an invisible ring of energetic ions trapped in the planet's magnetic field.

Credit: NASA/JPL/JHUAPL



lightning raining down on the surface the whole time. The storm lasted for 267 days! Along with amazing photographs of the massive storm, Cassini's near infrared camera detected a combination of water and ammonia ice in the storm clouds. The storm ended when the head of the storm ran into its own "tail" after encircling the planet and the circulation eventually came to a stop.

Another recent discovery is that Saturn's moon, Enceladus, has an ocean of liquid water beneath its frozen crust. Scientists first hypothesized the existence of liquid below the surface when a Cassini Flyby in 2005 showed water vapor and ice spewing from vents near the moon's south pole. Scientists recently provided more evidence of this ocean's existence by measuring the gravitational variances of the moon. Utilizing data from three flybys of the 19 close encounters Cassini has made with Enceladus.

The gravitational tug of Enceladus, as with any other celestial body, alters Cassini's flight path. Variations in the gravity field, such as those caused by mountains on the surface or differences in underground composition, can be detected as changes in the spacecraft's velocity as measured from Earth.

The south pole of Enceladus has a surface depression that causes a decrease in the local tug of gravity. However, the decrease is less than expected given the size of the depression.

This leads researchers to conclude the depression's effect is partially offset by a high-density feature in the region, beneath the surface. "The Cassini gravity measurements show a negative gravity anomaly at the south pole that however is not as large as expected from the deep depression detected by the onboard camera," said the paper's lead author, Luciano Iess of Sapienza University of Rome. "Hence the conclusion that there must be a denser material at depth that compensates the missing mass: very likely liquid water, which is seven percent denser than ice. The magnitude of the anomaly gave us the size of the water reservoir."

Of course, with water, the possibility of some sort of life on Enceladus is raised significantly. "Material from Enceladus' south polar jets contains salty water and organic molecules, the basic chemical ingredients for life," said Linda Spilker, Cassini's project scientist at JPL. "Their discovery expanded our view of the 'habitable zone' within our solar system and in planetary systems of other stars. This new validation that an ocean of water underlies the jets furthers understanding about this intriguing environment."

What lies ahead for Cassini? At the time of this writing Cassini just finished its closest remaining flyby of the smoggy moon Titan on April 7. Cassini whizzed by Titan at a targeted 598 miles above the surface while travelling at 13,000 MPH! The close

pass enabled Cassini's Ion and Neutral Mass Spectrometer, or INMS, to get a good whiff of the atmosphere, allowing further analysis of the composition of the atmosphere. Also Cassini's Composite Infrared Spectrometer, or CIRS, continued to map the vertical structure of Titan's atmosphere in far-infrared wavelengths of light. Scientists are watching for seasonal changes as the moon's southern hemisphere heads into its several-years-long winter season. Also the Visible and Infrared Mapping Spectrometer, or VIMS, extended its global and regional map coverage of Titan. VIMS observed the moon's extended atmosphere as it passes in front of the bright red star Antares. These measurements of well-known stars provide a useful probe of the structure and density of the atmospheres of Titan and Saturn. Cassini will fly by Titan again on May 17 and six more flybys of Titan will occur this year.

Cassini, as previously noted, is now in a more polar orbit, and will make passes through Saturn's ring plane many times over the next three-plus years of the Solstice mission. Some of these passes will actually be between the rings and the

the rings during these trips between the planet and its rings.

More flybys of Saturn's moons will occur of course, they will be continued to be used as gravity assists to propel the spacecraft and redirect its flight path of course, but these flybys will also serve scientific purposes.

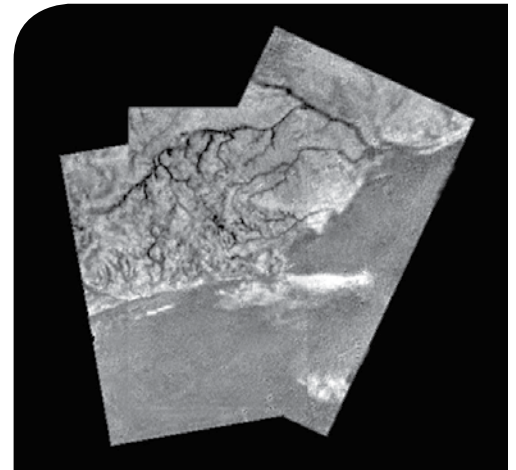
The recent discoveries of the icy plumes shooting from the surface, and possible seas below the surface of Enceladus make it a focal point for further investigation. As noted earlier, investigation of these plumes revealed that the spray contains complex organic chemicals. Tidal heating is keeping Enceladus warm, and hotspots associated with the plumes have been pinpointed. With heat, organic chemicals and, potentially liquid water, Enceladus could be a place where primitive life forms could evolve. Enceladus's "astrobiological potential" are at the heart of many investigations being conducted in the Solstice Mission.

The spacecraft will study the bright and dark surfaces of Dione and Rhea to compare their geological and cratering histories with those of other icy moons. Further analysis of the unique thermal features recently discovered on Mimas will be performed.

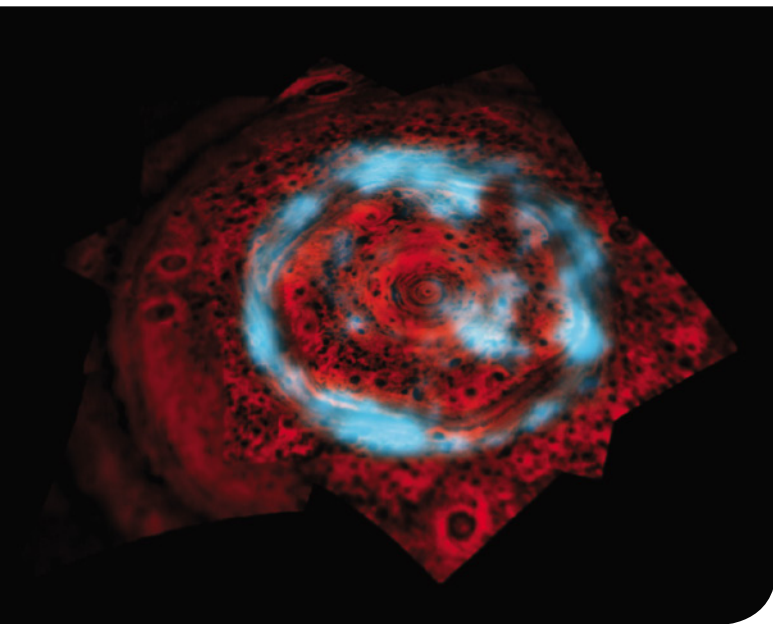
Titan and many other moons will be included in flybys also. Titan remains a top priority as scientists hope to catch the moon's surface features in the act of changing. The spacecraft will look for signs of seasonal climate change such as storms, flooding, or changes in lake levels, as well as evidence of volcanic activity.

All these passes will certainly reveal more secrets of Saturn, its ring system, and its moons. So stay tuned for more amazing photographs and more exciting scientific discoveries over the next three years from Cassini.

To learn more about Cassini's accomplishments visit the mission's website at <http://saturn.jpl.nasa.gov/>.



*Mosaic of river channel and ridge area on Titan
Credit: ESA/
NASA/JPL/
University of
Arizona*



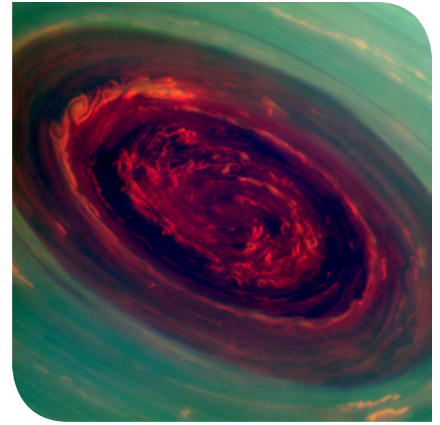
This image of the northern polar region of Saturn shows both the aurora and underlying atmosphere, seen at two different wavelengths of infrared light.

Credit: NASA/JPL/University of Arizona

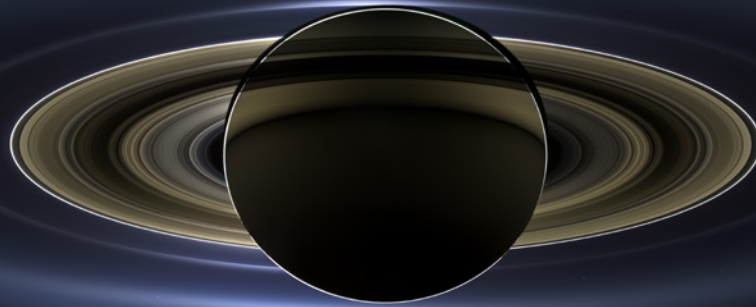
planet, a path no other mission has done before. By diving between Saturn and its rings, the team hopes to obtain in depth knowledge of the gas giant. Cassini will study the internal structure of Saturn, its magnetic fluctuations, and the mass of

The Rose: The spinning vortex of Saturn's north polar storm resembles a deep red rose of giant proportions surrounded by green foliage in this false-color image from Cassini. Measurements have sized the eye at a staggering 1,250 miles across with cloud speeds as fast as 330 miles per hour.

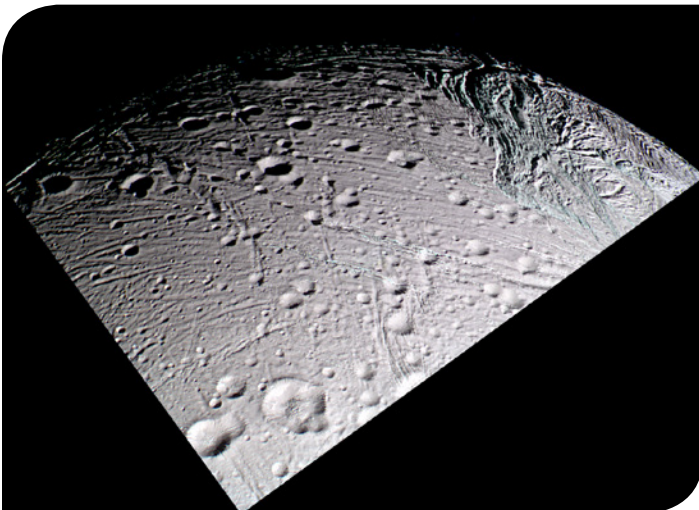
Credit: NASA/JPL-Caltech/SSI



the images of **Cassini**



Credit: NASA/JPL-Caltech/SSI



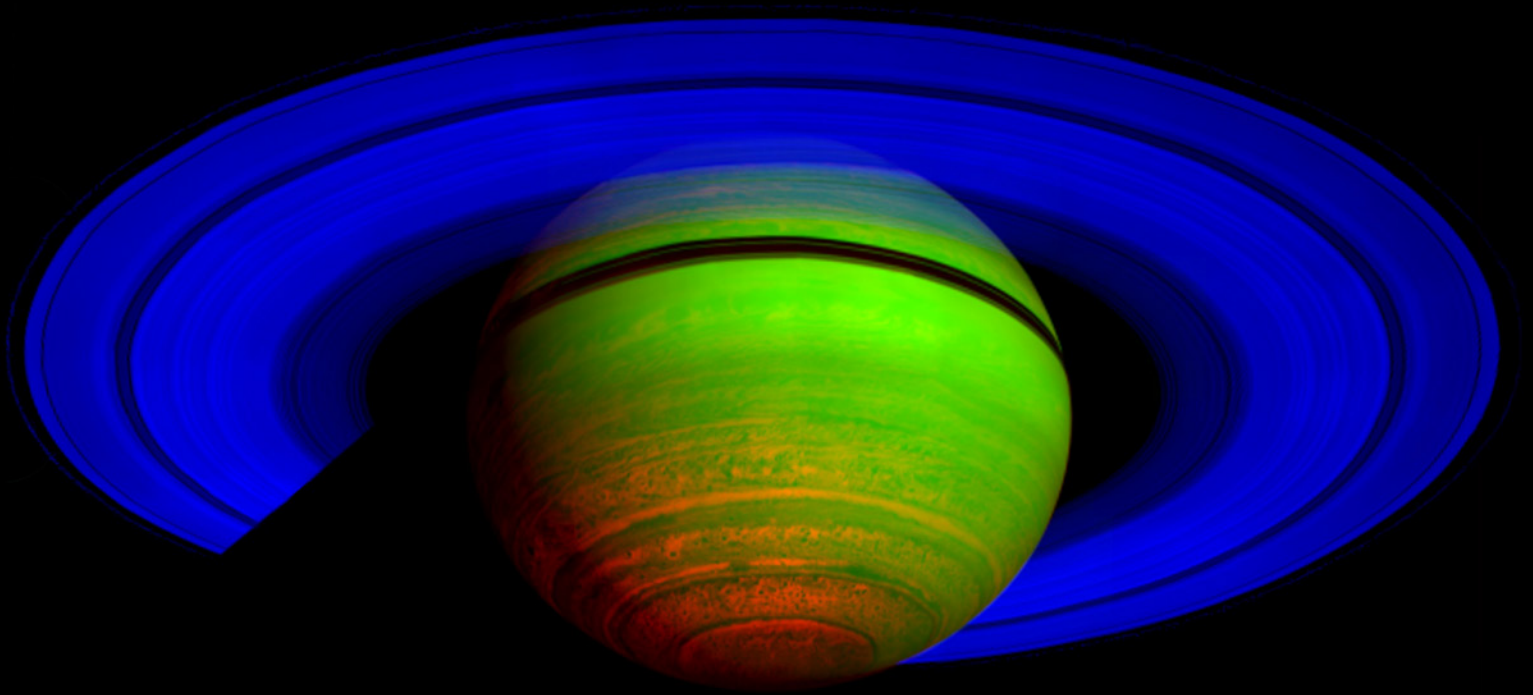
Old and new again: This false-color Cassini mosaic of Saturn's moon Enceladus captures much of the frigid moon's diverse geology. Cratered terrain dominates most of the scene. The relatively dense accumulation of impact craters implies that this terrain is among the oldest on the moon's surface. The entire area is transected by a complex web of fractures and faults. The widely varied appearances of fractures attest to the fact that the surface of Enceladus has been shaped by a long history of intense tectonic activity.

Credit: NASA/JPL/Space Science Institute

Liquid Lakes on Titan:

The existence of oceans or lakes of liquid methane on Saturn's moon Titan was predicted more than 20 years ago. But it had not been possible to confirm their presence until the Cassini flyby in 2006. Radar provided evidence for large bodies of liquid. The lakes, darker than the surrounding terrain, are emphasized here by tinting regions of low backscatter in blue.

Credit: NASA/JPL/USGS



Majestic Saturn, in the Infrared: This false-color composite image shows Saturn's rings and southern hemisphere. The composite image was made from 65 individual observations by Cassini's visual and infrared mapping spectrometer in the near-infrared portion of the light spectrum on Nov. 1, 2008. The observations were each six minutes long.

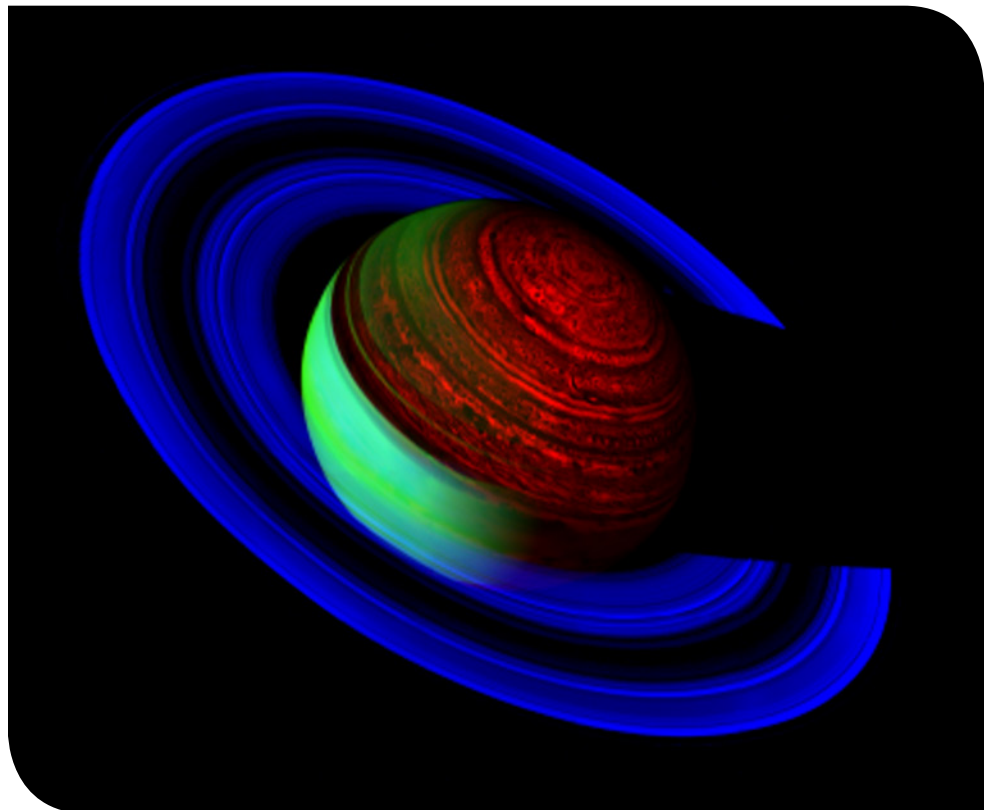
Credit: NASA/JPL/ASI/University of Arizona

Neon Saturn:

Flying over the unlit side of Saturn's rings, the Cassini spacecraft captures Saturn's glow, represented in brilliant shades of electric blue, sapphire and mint green, while the planet's shadow casts a wide net on the rings.

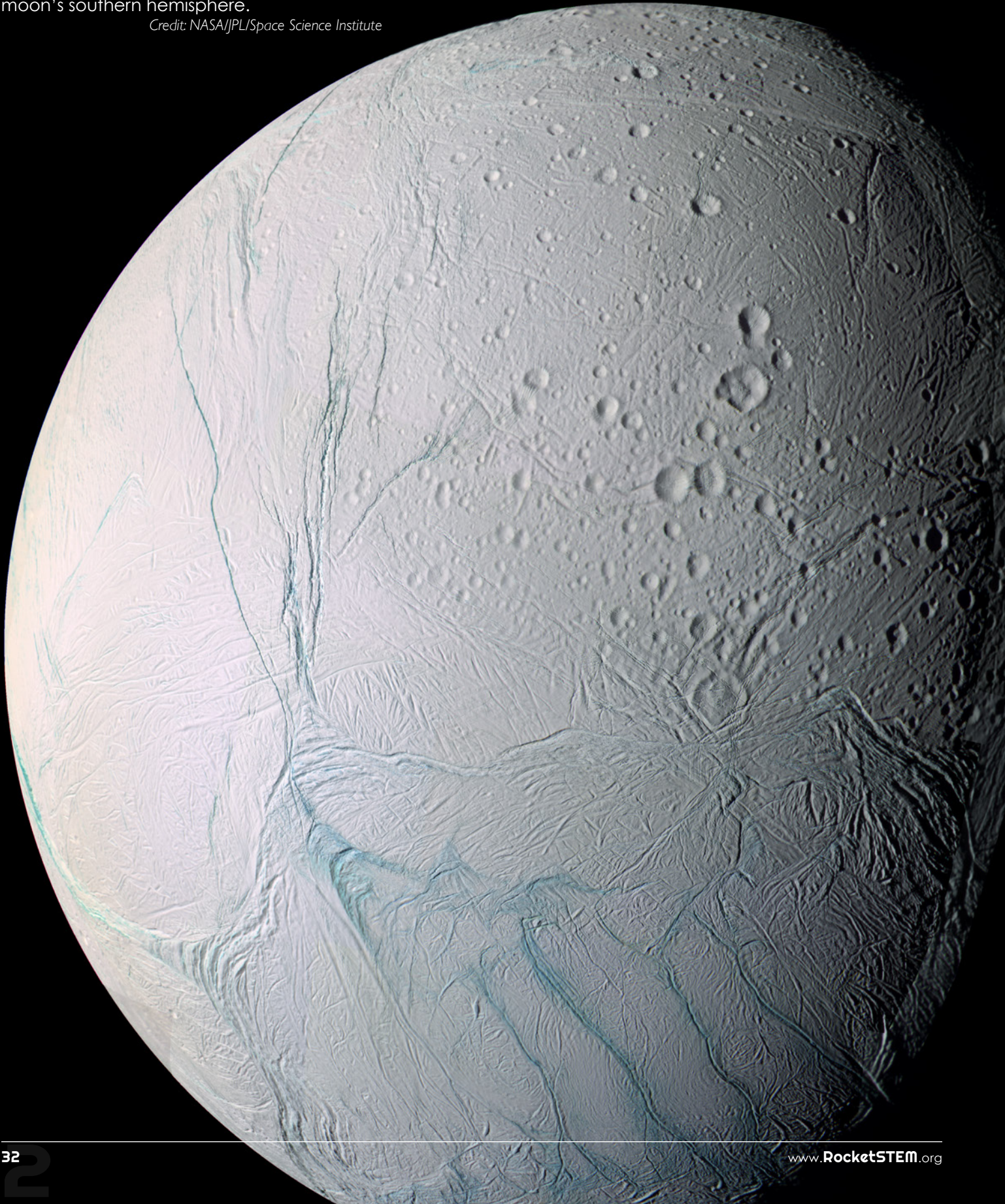
This striking false-color mosaic was created from 25 images taken over a period of 13 hours while the spacecraft was 1.58 million kilometers (1 million miles) from the planet and 34.6 degrees above the ring plane. In this view, Cassini was looking down on the northern, unlit side of the rings, which are rendered visible by sunlight filtering through from the sunlit, southern face.

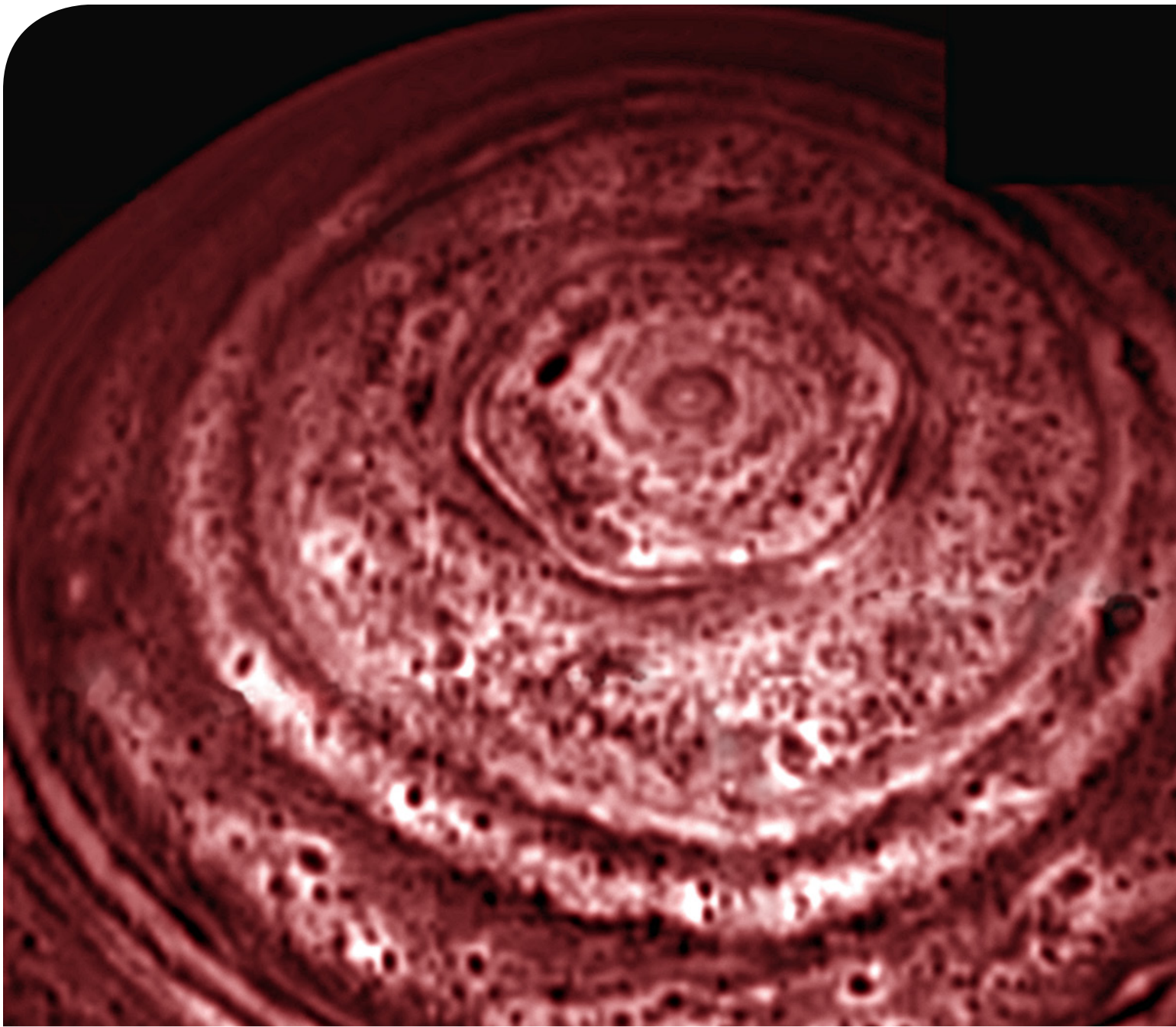
Credit: NASA/JPL/University of Arizona



Enceladus the storyteller: A masterpiece of deep time and wrenching gravity, the tortured surface of Saturn's moon Enceladus and its ongoing geologic activity tell the story of the ancient and present struggles of one tiny world. This enhanced color view of Enceladus is primarily of the moon's southern hemisphere.

Credit: NASA/JPL/Space Science Institute



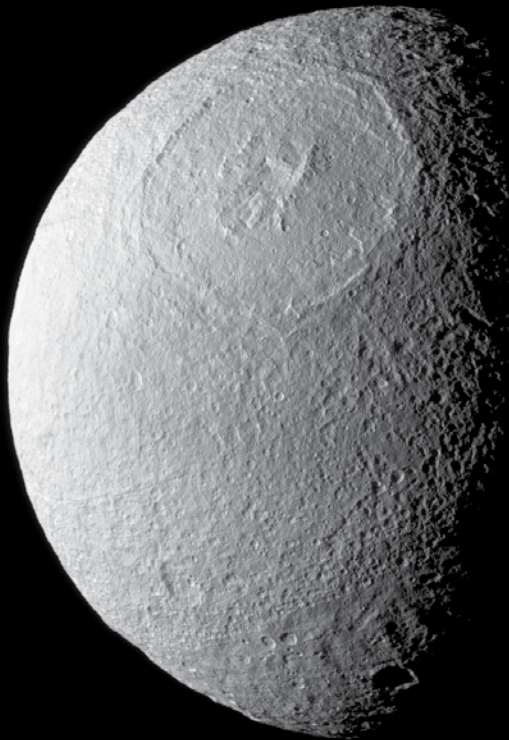
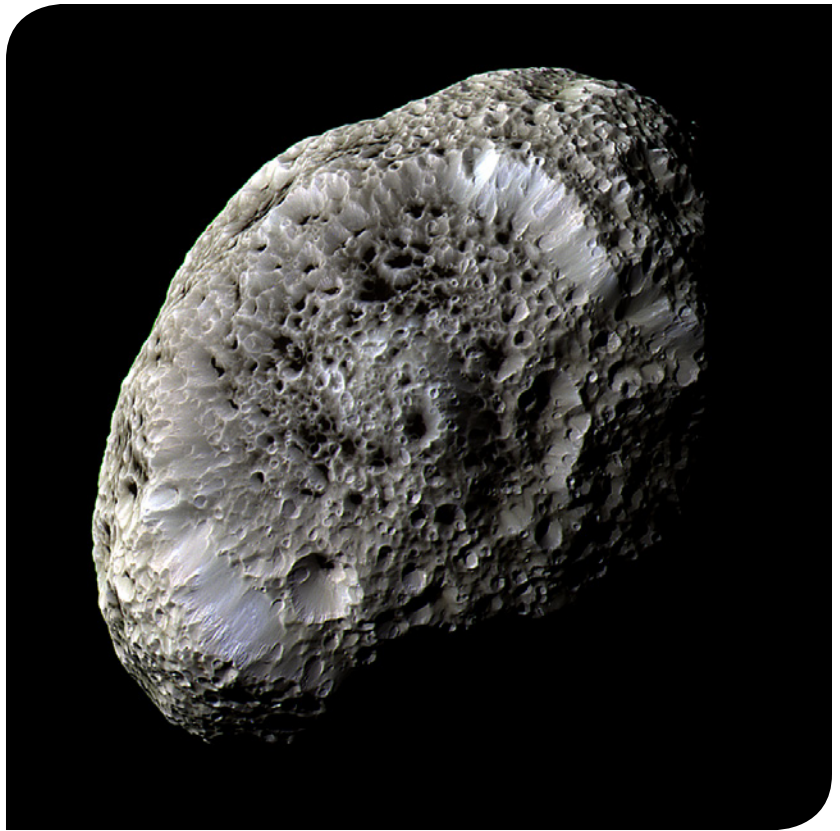


Saturn's active north pole: A bizarre six-sided feature encircling the north pole of Saturn has been spied by the visual and infrared mapping spectrometer on the Cassini spacecraft. This image is one of the first clear images ever taken of the north polar region as seen from a unique polar perspective. Originally discovered during NASA's Voyager flybys of the early 1980's, the new views of this polar hexagon prove that this is an unusually long-lived feature on Saturn. This image is the first to capture the entire feature and north polar region in one shot.

Credit: NASA/JPL/University of Arizona

Odd world: This stunning false-color view of Saturn's moon Hyperion reveals crisp details across the strange, tumbling moon's surface. The view was obtained during Cassini's very close flyby on Sept. 26, 2005. Hyperion has a notably reddish tint when viewed in natural color. Cassini scientists think that Hyperion's unusual appearance can be attributed to the fact that it has an unusually low density for such a large object, giving it weak surface gravity and high porosity. These characteristics help preserve the original shapes of Hyperion's craters by limiting the amount of impact ejecta coating the moon's surface. Impactors tend to make craters by compressing the surface material, rather than blasting it out. Further, Hyperion's weak gravity, and correspondingly low escape velocity, means that what little ejecta is produced has a good chance of escaping the moon altogether.

Credit: NASA/JPL/Space Science Institute



Epic Odysseus:

With an epic size, Odysseus Crater stretches across a large northern expanse on Saturn's moon Tethys. Odysseus Crater is 450 kilometers, or 280 miles, across. The image was taken in visible green light with the Cassini spacecraft narrow-angle camera on Feb. 14, 2010. The view was obtained at a distance of approximately 178,000 kilometers (111,000 miles) from Tethys. Image scale is about 1 kilometer (about 3,485 feet) per pixel.

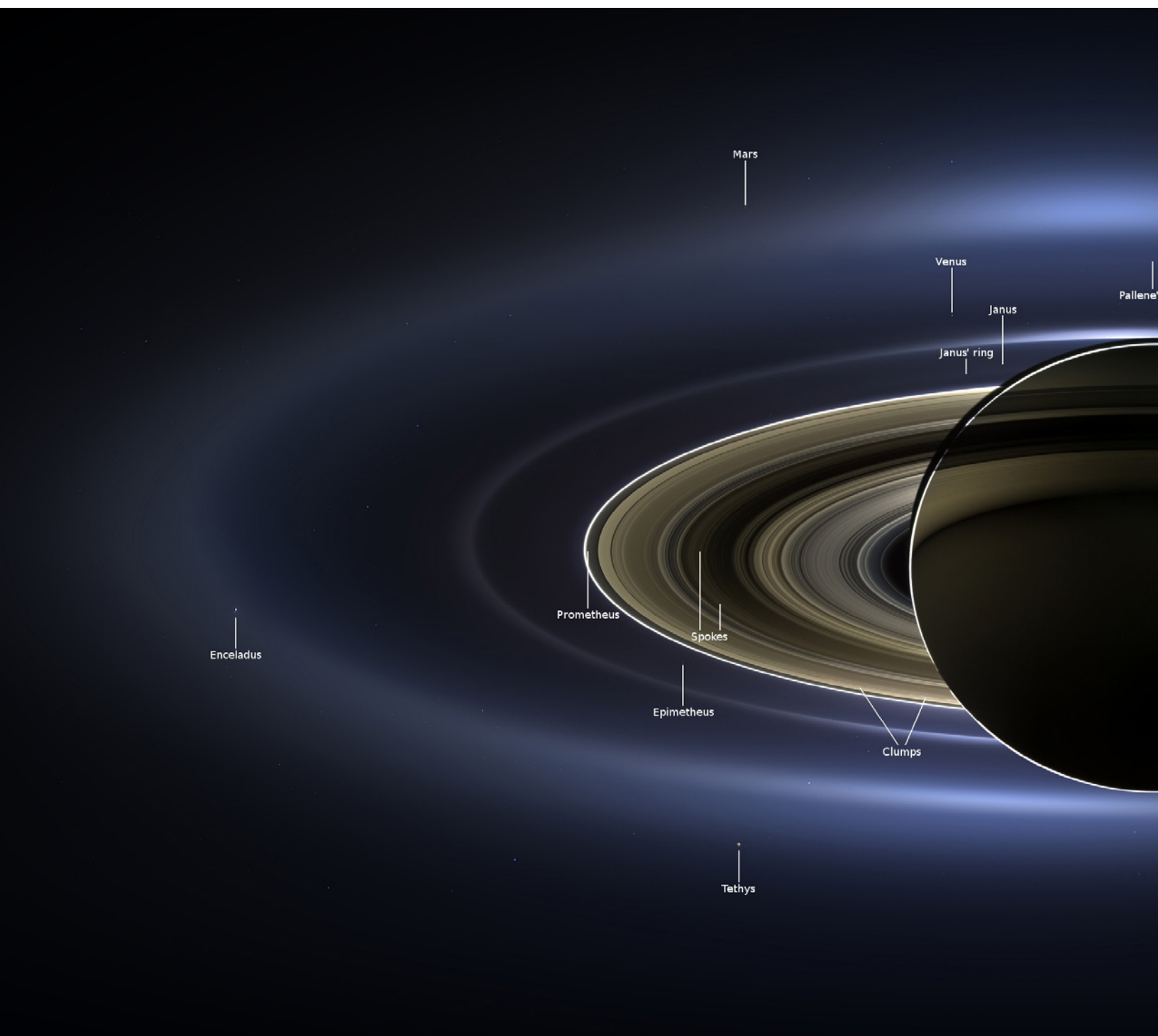
Credit: NASA/JPL/Space Science Institute

High resolution Phoebe:

Cassini captured a series of high resolution images of Phoebe during a close encounter. The surface shows many craters. The moon might have been part of an ancestral population of icy, comet-like bodies, some of which now reside in the Kuiper Belt.

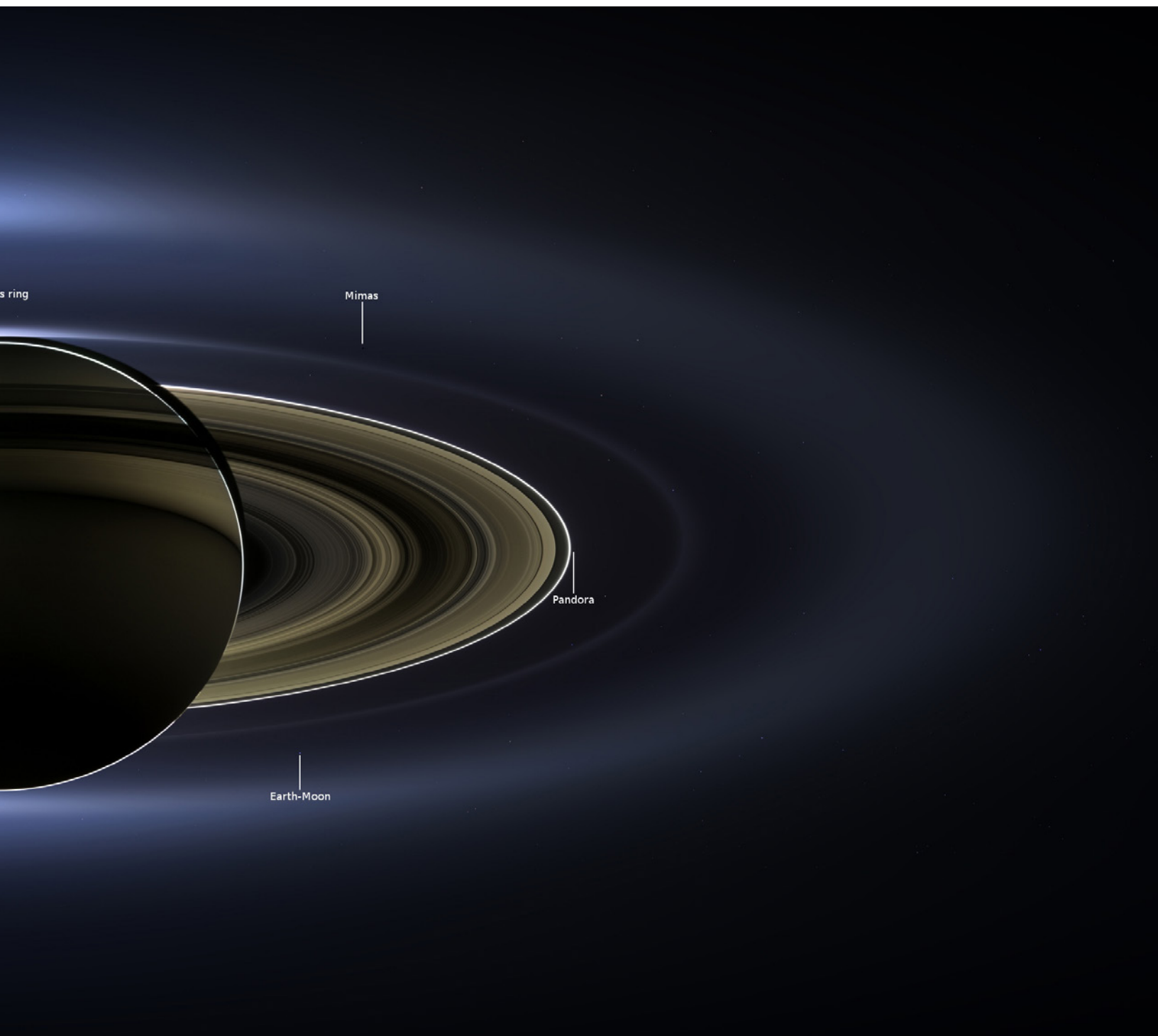
Credit: NASA/JPL/Space Science Institute





The day the Earth smiled: On July 19, 2013, in an event celebrated the world over, NASA's Cassini spacecraft slipped into Saturn's shadow and turned to image the planet, seven of its moons, its inner rings -- and, in the background, our home planet, Earth. With the Sun's powerful rays eclipsed by Saturn itself, Cassini's onboard cameras were able to take advantage of this unique viewing geometry to acquire a panoramic mosaic of the Saturn system that allows scientists to see details in the rings and throughout the system as they are backlit by the sun. This mosaic is special as it marks the first time ever that inhabitants of Earth were made aware in advance that their photo would be taken from such a great distance.

Credit: NASA/JPL-Caltech/SSI





Credit: Nicole Solomon

Jim Adams:

Keeping NASA's technology on the right track

Interview by Chase Clark

After sitting inside a Mercury capsule during a Family Day at NASA's Goddard Space Flight Center in the 1960s you would think that W. James (Jim) Adams was destined to seek out a career with the space agency. Turns out that Adams, now NASA's Deputy Chief Technologist, originally had another career path in mind, one that might not have ever intersected with space exploration. Fortunately, destiny had another path in mind for him. During an exclusive interview with RocketSTEM, we conversed with Adams about his background, his career at NASA and his thoughts on the future of space travel.

RocketSTEM: You were exposed to space at an early age, weren't you?

Jim ADAMS: "I was born just before Sputnik launched. A couple of times I've referred to myself as a Sputnik baby. So yes, the space race and space program have always been a presence in my life. I came up in a household where space was just sort of common.

My father was an aerospace engineer. He started working for Rocketdyne in California, which was where I was born, designing rocket motors. And then we came East to Virginia so Dad could work at a small company on the Saturn V and the Apollo Lunar Excursion Module, the LEM.

In 1967 we moved to the Philadelphia area where he worked in the defense aerospace business. I never really learned much of what he did because a lot of it was classified, weapons and stuff. But from time to time he would work on these really crazy

I was born just before Sputnik launched. I've referred to myself as a Sputnik baby.

things. Like ocean based farms to grow giant sea kelp for advanced energy production or sometimes some NASA projects.

He came home one day with a pack full of Apollo astronaut food that he wanted my sisters and I to see. He'd been working on better ways to package it. Then one time I remember he brought home some experimental methods of attaching Space Shuttle tiles. This was while the Space Shuttle was being designed, before it ever flew the first time. They were trying to avoid using glues, but the final design ended up going with an adhesive. There were a number of really interesting projects like that. He had a patent on an extendable boom to rescue astronauts in the event their tethers broke. Just a really interesting mix of things.

When I went to college I studied physics at a small liberal arts school in western Pennsylvania. I became interested in satellite communication because of some of the interests that my professor had. He was a ham radio operator and he wanted to design an antenna that could track the OSCAR satellites as they went overhead. So that was one of my projects when I was in college. I came up with a system that would use common television antenna gear to track a satellite.

At the same time, the microchip had just become practical. I wouldn't say powerful, but useful. This was 1977 or so and I had played with them making the satellite communication controllers plus a few other things. My idea for a career was that these chips

were going to be very popular and since National Cash Register, NCR, was just down the road I wanted to work there designing cash registers. That was my goal.

My mistake was that NCR was hiring electronics engineers, not physicists.

I ended up going with my second choice, which was aerospace.

I was offered a job at General Electric working out of Philadelphia and Valley Forge, Pennsylvania. I

spent 10 years working for GE in Pennsylvania, until one

day I was working on what was then called 'Space Station

Freedom' and NASA made me an offer I couldn't refuse. Within a couple

of weeks I was working at NASA Goddard Space Flight Center on the space station in Maryland."

RS: Since going to work for NASA, you've been involved in the development of more than two dozen satellites and other spacecraft?

ADAMS: "I remember when NASA put that factoid together the count was 26. It's probably gone up now,



but that's right. Many, many communication satellites. Some pieces of the Space Shuttle, the kitchen and the waste collection system. I've got some really funny stories about the Space Shuttle toilet. Let's see. Some military systems. Some international collaborations. I worked on the Upper Atmosphere Research Satellite, if you remember that. It was up there for years and years. Various versions of Landsat, the Wind and Polar satellites, those were space physics missions looking at the sun, as well as GOES weather satellites. The Earth observing system Aura spacecraft was also one of mine. STEREO, the pair of spacecraft we launched to image the Sun's coronal mass ejections in 3D, I worked on that. I don't know that I can list them all. And then I got into planetary science, where I was privileged to be a part of Dawn, MESSENGER, Phoenix, Juno, GRAIL, MSL and LADEE."



Then NASA Deputy Director of Planetary Division Jim Adams, center, and NASA Administrator Charles Bolden, right, review incoming data during the countdown to launch of the twin GRAIL spacecraft in 2011 at the Cape Canaveral Air Force Station. Credit: NASA/Bill Ingalls

RS: While working for NASA, you've been involved in the development of several different systems to power and to propel a spacecraft around the solar system. What are some of your favorite technologies?

ADAMS: "The Dawn spacecraft uses an ion propulsion that puts out a steady stream of xenon ions which slowly changes the velocity of the spacecraft. It's an extremely efficient way of executing propulsion if you have the system right. Because it is so mass efficient we were able to actually send one spacecraft to two different destinations in the asteroid belt. Dawn visited Vesta in 2011 and is now on its way to arrive at Ceres in 2016. If we were using conventional propulsion – chemical propulsion – we would not have been able to launch a single satellite to both of those destinations. Radioisotope power systems, those are the things

that have been used since the Voyager days that take the heat generated from the radioactive decay of plutonium 238 and make electricity. Then that electricity is used to run the spacecraft. Voyager uses one and that's why we are still talking to Voyager today, because it is still chugging away and making power that allows us communicate with the spacecraft.

Two years before I joined the space program NASA launched Voyager 1 and 2. They are a little bit older than my career. An amazing factoid is that just now, after 37 years of traveling to the outer reaches of our solar system, they are reaching what some people call the edge of the solar system. It is the edge of space where the pressure from the gases released from our Sun is roughly equivalent to the tenuous pressure of the inter-stellar wind. But that point is just five percent of the way to the outer reaches of the Sun's gravity. The

Sun's gravity goes much, much further out. Twenty times further out than Voyager has been is this region that we believe is the Oort Cloud. Those are the leftover pieces of the earliest formation of our solar system and the birthplace of many of the comets we see. We live in a vast place."

After 37 years of traveling to the outer reaches of our solar system, they are reaching what some call the edge of the solar system. But that point is just five percent of the way to the outer reaches of the Sun's gravity.

RS: From being involved with developing and utilizing new technology for science missions, it was no surprise that you moved up to the position of Deputy Director of the Planetary Science Division at NASA Headquarters, only to then later be promoted to the position of the Deputy Chief Technologist for all of NASA. What exactly does the Deputy Chief Technologist do?

ADAMS: "What we do in the office of the Chief Technologist for NASA is we look at the goals of the agency. For example, we want to put humans on Mars in 2035. That is one of the things the President has asked for. We want to find all the asteroids that could threaten human populations here on Earth. That's another thing the President has asked for. We look at our entire bag of tricks, everything from ion propulsion and radioisotope power systems, to advanced communications, sky cranes and rockets and such. We say to ourselves 'what are we going to need in 2035 in order to make 'boots on Mars' happen?'

The job of the Office of the Chief Technologist is to make sure that the dollars we invest in technology stay well aligned with the objectives of the agency. That's a difficult job because we don't actually control the dollars. What we do is we influence the investment of the dollars. The other mission directorates, like the Human Exploration Mission Directorate, is investing technology dollars in what they believe are the right places so that NASA can accomplish the goal as well. We work with them making sure that the investments we're making are the most effective so that when General Bolden (NASA Administrator Charles Bolden) is in front of Congress and says 'Yes, we're on track to put humans on Mars in 2035,' that it will become a reality."



*Jim Adams has been involved with the development and launch of more than two dozen spacecraft during his career at NASA.
Credit: Nicole Solomon*

RS: Of course getting to Mars depends on more than technology. It also requires a Congress and President who support the project and give NASA the financial resources through its annual budget that will allow NASA to reach those longterm goals. Something that you and the rest of the employees at NASA understand all too well as part of the process.

ADAMS: "Yeah. That has very little to do with my career. I think it is important for readers, especially of RocketSTEM, to understand that it is a privilege for anybody to work for NASA. And that what we are doing is helping to make history for the United States, and for the world at large. Often that involves some rather heated and certainly public debate. I think the public is entitled to that debate. People have opinions on what we ought to do, and it's not easy coming to those decisions. I feel pretty strongly that even though sometimes the debate may look ugly, it's worth having. That's just a bit of Adams' philosophy."

RS: Some people may feel that NASA has two distinct divisions – a manned and an unmanned space program

– but from your viewpoint they are a complementary necessity if humans are to reach out and touch the stars one day.

ADAMS: “We did not send humans to the Moon without robotic precursor missions. People tend to forget that we sent the Ranger and Surveyor missions to the Moon first. The first lunar landers were robots. They were crude robots, but they told us about the surface and what we could expect. We could have not been successful on Apollo if we had not sent robots first.

Today, robots are a lot more capable. You look at what Robonaut can do, or the Curiosity rover, or one of our spacecraft in orbit around Mercury or Mars, or the New Horizons probe on its way to Pluto. Or even the satellites we have orbiting the Earth. Those are all robots today. They are unmanned and much more capable than the early ones that we launched. However, they are still robots. They don’t carry the cognizance and the presence the human being does.

As an example, Spirit and Opportunity are the two rovers that landed using airbags on Mars in January 2004.

Spirit lasted seven years even though it was designed for 90 days. And Opportunity is still going. Yet, Steve Squyres, the principal investigator for those missions, said that everything those rovers accomplished could have been accomplished by humans on the surface of Mars in about a week.

And so it’s an important thing to remember that robots are still robots. There is nothing that beats the presence of a human brain in order to make judgments and decisions on the spot in a new environment. That’s the first reason why I think we need to see a blend of robots and humans.

The second reason is I really believe it is humanity’s destiny to move off this planet. We aren’t going to do it without the help of robots. Humanity someday will move toward the stars. We’ve started already, we have a constant presence in space with human beings aboard the International Space Station. I am hopeful that very soon we will have a constant presence of human beings deeper into space. We have to conquer a lot of things in order to be able to do that. Like living in space with the radiation, and being able to move around and communicate back home, and deciding what to do when you are short on resources, and that sort of thing.

But in fact, I believe human beings someday will be living on Mars and looking outward into the solar system wondering how they could put a space station in orbit around Saturn or Jupiter ... and ultimately

journey to the closest star to explore the worlds that we are now just finding exist around those. I think we need both. Because I don’t believe as humans we will ever be able to accomplish our destiny without the aid of robots. And I don’t believe it is an accomplishment for humanity fully unless we send ourselves.”

RS: **With colonizing Mars and eventually journeying to the Stars the ultimate goal, is the need for new propulsion systems greater now than at any point in the last three decades?**

ADAMS: “I think that’s right. We need forward thinkers. We need people that can conceive of ideas, run experiments and decide that this is a viable new way of looking at things. We need physicists that are going to challenge the fundamental laws of physics and say ‘well is warp drive possible?’ We need people be thinking about that without getting laughed out of a room. I think it is possible that people could at least begin to contemplate those sorts of ideas.

And along the way we’ll learn stuff. We may not ever accomplish warp drive, but along the way we will learn about moving around the solar system.”

I believe human beings someday will be living on Mars and looking outward into the solar system wondering how they could put a space station in orbit around Saturn or Jupiter ... and ultimately journey to the closest star.

RS: **With the convenience of modern technology, answers to almost any question are just seconds away via a web search. The need to understand how something works and to be able to fix it yourself is becoming a rarer trait in today’s disposable economy.**

Encouraging children to learn problem solving skills may be harder now than at any time in the past, but why is it still a necessity to try?

ADAMS: “I think one of the most important lessons for a child today is what happens when the cell phone doesn’t work? What do you do? What is a pay phone? Or if the microwave ceases to function, how do you cook on a stove? You ask these questions and people come to appreciate the technology in their lives. I think there will be a few, not everybody, but a few that will want to know how that works.

I believe most human beings are curious and it is just a matter of catching the kids at the right age and ask wouldn’t you like to know how your Nintendo DS actually functions? It’s fun playing the game but how about if you wanted to be part of the team that designs the next game system? I think that challenges people. How would you get by if you didn’t have the technology? And what do you think you need to know if you want to help make the next one? Those I think are valuable questions for kids.”

RS: Curiosity is just the first step to pursuing a career in space exploration, whether it be from terra firma or from the zero-G environment of space itself. What is your advice for those dreaming of going into space themselves?

ADAMS: "Two things. In the short term if you want to be an astronaut for NASA, make sure you study math, science and engineering. It is incredibly important. It develops the discipline of thinking that is extremely helpful for people who want to be astronauts. Which by the way I should go on record as saying I am not an astronaut, but I know a lot of them."



Jim Adams speaks during a news briefing to discuss the Dawn spacecraft's year-long visit to the asteroid Vesta, the first prolonged encounter with a main belt asteroid and the first trip to a protoplanet. Credit: NASA/Paul E. Alers

Second is as humanity moves further out into space, beyond just astronauts, but the general populace as people begin to go to hotels orbiting the Earth on vacation, all kinds of people from diverse backgrounds are going to be needed. Everything from operations specialists, to construction engineers who operate things in space and construct things in space, to hotel stewards, and police officers, and cooks and cleaners. Everything that you can image that is in society today will be contained in a microcosm if you have even a low Earth orbiting hotel for tourists. What I really see happening is the tools necessary to go to space will be enabled by the opening of the commercial space industry, especially space tourism."

RS: When it comes to memorable moments, you don't really seem to need time to reflect and rank moments do you? What are the most exciting parts of every space mission?

ADAMS: "Anytime I see something take off. Any launch. Even if it's not mine."

The launch of the STEREO mission in 2006 was extremely poignant for me, because of just how hard everyone had worked to get those two satellites to Kennedy Space Center, then on the Delta to launch, and just how outrageously successful they were. It is the effort and the energy and the intention of people, a team, that goes into those machines that ride on top of the rocket. At the launch you remember everybody and everything that brought you to the moment of overcoming Earth's gravity. As soon as the flames start at the bottom of the rocket, you realize there is not

Investment in space creates innovation that allows us to have things like cell phones, lasers, lightweight blankets, advanced materials, and a variety of robotics. The list just goes on and on. I believe that NASA is crucial to the advancement of technology right here on Earth, even though we're working on things in space.

anything you can do anymore. It's like watching your child go off to college. It is on the ride, alone. You hope you raised it well and along the way you might get to help it make a course correction. The launch just brings everything you've done to a head.

Then getting the data back. Once the mission unfurls its solar array, gets to its destination, and we actually start to see the data from the mission accomplishing what it was supposed to do in the first place, whether it is looking for water on Mars, or mapping Mercury, or surveying the vegetation canopy on the Earth. That's a moment where you begin to understand that all that effort you put into it became not only a moment in history when you launched it, but now that the data is coming back you are adding to the body of human knowledge about the world that we live in. We begin to be able to understand where we came from as a race, or where we are going as a society, or maybe even whether or not we are alone in the universe."

RS: During the past five decades, technologies

developed by NASA have led to many advances here on Earth, including some that we now take for granted in our everyday life such as cell phones and fire-resistant clothing. Informing the general public of these 'spinoff' technologies isn't always the easiest thing, but one that NASA tries to do anyway.

ADAMS: "There is a book we put out each year called Spinoffs. The 2013 book just came out. It is an amazing book of NASA in your life. Things that NASA has invested in for missions that have direct application right here on Earth. The innovation that NASA brings to bear on accomplishing these extremely hard missions – landing a ton of robot on the surface of Mars safely, or getting to be able to sense the ozone layer and watch it open and close, or keep human beings in space for six months at a time – those are extremely hard problems that require a great deal of fresh thought and innovation. When we think that way there's always stuff that applies to our lives here terrestrially on Earth. That innovation primes an economic pump that creates businesses and sub economies here on Earth that pay dividends many, many times over.

Investment in space creates an economy here on Earth of innovation that allows us to have things like cell phones, lasers, lightweight blankets, advanced materials, and a variety of robotics. The list just goes on and on. I believe that NASA is crucial to the advancement of technology right here on Earth, even though we're working on things in space.

You can get a summary of these innovations via an app in the iTunes store for your iPad and iPhone called NASA Spinoffs. You can download it and read the NASA spinoffs for yourself.

I'd also pose a thought question for people. Think about what it would be like if there was no NASA. If there was no NASA where would that spirit of innovation come from? How would we begin to think about ourselves as a nation, earthbound, constantly looking at the stars and wondering what's out there? I think the investment that the United States public sacrifices to make in NASA is worth every dime of it. And we need to spend it wisely answering those fundamental questions: Where did we come from? Where are we going? And are we alone?"

Spinoff 2013 shows how much space is in our lives

Water filtration bottles, comfortable car seats and remote medical monitoring devices all have one thing in common -- they all have benefited from NASA technology.

These products are featured in Spinoff 2013, an online publication now available that highlights commercial products created using NASA-developed technology, including some developed at the agency's Jet Propulsion Laboratory in Pasadena, Calif. Also featured in the 2013 edition is an air purification system that can sustain miners in the event of a disaster, a solar-powered vaccine refrigerator saving lives in remote areas throughout the world, and a powerful heat shield used on the first commercial spacecraft to successfully achieve orbit and return to Earth.

"NASA develops technologies to push the boundaries of what's possible in space, but those same tech-



NASA-developed space technologies benefit those of us here on Earth. Credit: NASA

nologies also make life better here on Earth," said Daniel Lockney, NASA's Technology Transfer program executive. "Spinoff 2013 is filled with examples of how NASA technology benefits our lives every day."

NASA has a long history of transferring technologies from their original mission applications to secondary uses. For example, Mars continues to be a rich destination for scientific discovery and exploration, and NASA's missions there have inspired a variety of practical, terrestrial ben-

efits. Spinoff 2013 features stories about some of these technologies, including a wind turbine that could one day be used to provide energy for a human exploration mission on the Red Planet, and is being used today in harsh environments here on Earth.

New to Spinoff this year is a section called "Spinoffs of Tomorrow," which showcases 18 NASA technologies currently available for licensing and partner-

ship opportunities.

NASA's Technology Transfer Program is charged with finding the widest possible applications of agency technology. Through partnerships and licensing agreements with industry, the program ensures NASA's investments in pioneering research find secondary applications that benefit the economy, create jobs, and improve quality of life.

Spinoff 2013 is available online at: <http://spinoff.nasa.gov/>.

NASA testing supersonic parachute

By Brenden Clark

Force equals mass times acceleration – or in the case of NASA and JPL planning for a landing on Mars – deceleration. JPL is currently in the testing phase of the LDSD (Low-Density Supersonic Decelerator) for future, larger load trips to the Red Planet. The current limit of parachute and deceleration technology has been reached with the most recent rover programs, Curiosity being the largest at about the size of a small SUV. For the future, we need to be able to land much larger objects on Mars safely so that we can build habitats for the first manned missions. This first step in increasing payload options is a small step, only increasing the payload from the current 1.5 metric tons to 2-3 metric tons. But considering the current deceleration system is the same one we've been using since the Viking days forty years ago, it's time for an upgrade.

The larger the mass, the greater the force needed to slow it down. The engine of that force is friction or "atmospheric drag". While Mar's atmosphere is much thinner than our own, it does exist. And so JPL is working on much larger parachutes. The larger the parachute, the more surface area to create more friction and deceleration.

It seems like such a simple thing; just build a bigger parachute. Well, sadly, it's not. The parachutes JPL needs to build and test are too big for wind tunnels and so they have to work out inventive and complex ways to test the new chutes and make sure they work out any flaws.

The first test involves flying the parachute, attached to a line, over a kilometer above the ground via helicopter, releasing the parachute where a rocket sled explodes to life, pulling the parachute back down to ground at great speed and force. And it's a good thing JPL is testing this, as the first run through showed a flaw when the parachute split open on one side.

But the parachute test is only half of the LDSD program. The other half is the first stage of deceleration, the inflatable aerodynamic decelerators. Basically a large balloon structure inflates around the circumference of the payload, sort of like a donut ring or inner-tube that increases the surface area of the payload, causing more friction. This first stage is projected to slow the payload down from Mach 3-4, down to Mach 2 when the parachute deploys, further slowing the vehicle down to subsonic speeds.

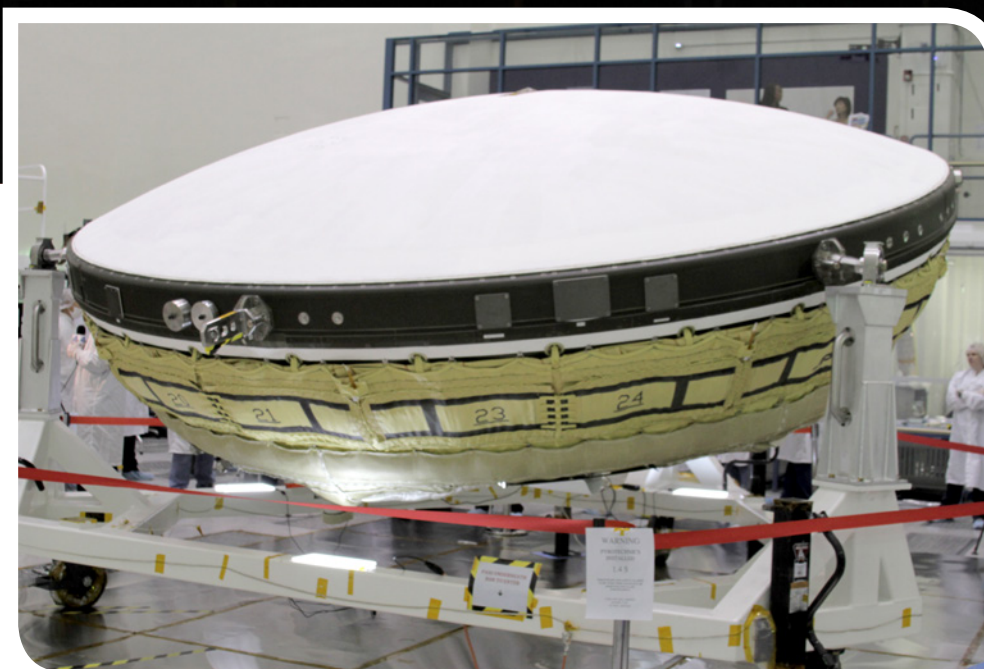
The two stages together will be tested next month in Hawaii and if every everything goes well, there are hopes that they will be ready for missions starting in 2018. Click the link to watch video of the test: www.youtube.com/watch?v=9h1NtQJ59kM.



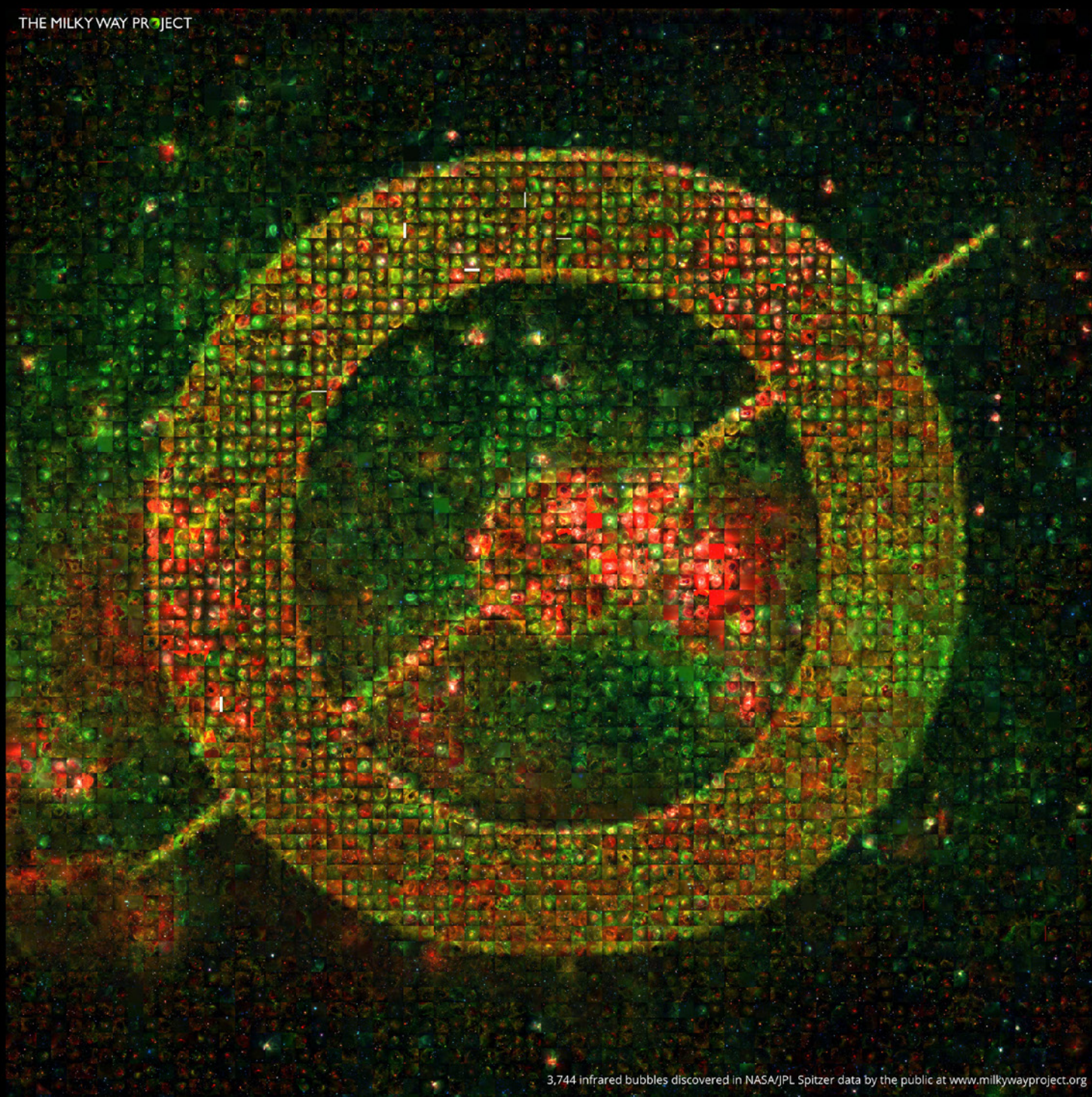


With larger robotic probes and even humans one day being sent to the surface of Mars, NASA is hard at work on the Low-Density Supersonic Decelerator Project to develop new ways to safely land on the Red Planet. A 110-foot diameter parachute (above) and an inflatable decelerator (right) are being test at JPL.

Credit: Brenden Clark



THE MILKY WAY PROJECT



3,744 infrared bubbles discovered in NASA/JPL Spitzer data by the public at www.milkywayproject.org

One million strong:

Zooniverse enables anyone to participate in science

By Amjad P. Zaidi

The advent of faster, digital data capture and processing has been a boon in astronomy but created a problem of too much data to analyse with too few professional astronomers.

In July 2007 University of Oxford based astronomer and BBC Sky at Night presenter Chris Lintott and a team of astronomers from the University of Oxford tackled this enviable problem. Their goal was to detect the positions and classify the morphology of a million galaxies captured from the Sloan Digital Sky Survey (SDSS) in New Mexico, and compare those to their positions in the early universe. This would build a picture of the universal expansion of galaxies in the 13.7 billion years since the Big Bang.

The solutions were to crowd source the problem and release this data to the public. The Sloan data sets were made available online for volunteers. Their task: to sort, classify and examine these individual galaxies into distinct types (e.g. disks, ellipticals, mergers, warped and spirals).

This small online citizen science project was named Galaxy Zoo. Unexpectedly, the overwhelming volunteer response to the project made it incredibly popular, with global input contributing to the wealth of real scientific discoveries through real research. Over 70,000 classifications were received each hour within 24 hours of Galaxy Zoo's launch, with multiple independent classifications verifying the results. By the project's first birthday over 150,000 volunteers had contributed to over 50 million classifications.

Discovering the strong uptake of interest in citizen science and delivery of scientific results, Lintott and the Galaxy Zoo team saw an untapped reserve of global talent to leverage for use in citizen science projects. The Citizen Science Alliance was born and Zooniverse was created shortly after.

Compiling dozens of projects maintained and developed by the Citizen Science Alliance partners, Zooniverse focuses a global network of talented

volunteers in sifting through the massive amounts of collected data. Essentially this approach has sped up the rate of scientific discovery and saved hundreds of years of human effort through global cooperation. As a result the benefits assist scientists and researchers in achieving many science goals and discoveries that would otherwise take years with less human analysis and pattern recognition. Furthermore the data analysed from a variety of projects has led to the publication of over 50 scientific papers. Primarily, academic research is the main goal of all Zooniverse projects. As a hugely

positive side effect, the enlistment of a global community of citizen science volunteers has, by its very nature, supported STEM outreach for formal and informal education.

Today, almost 30 citizen science projects exist in Zooniverse. Uniquely these all need the active participation of human volunteers to complete research tasks across many disciplines such as astronomy, ecology,

nature, cell biology, humanities and climate science. As of February 2014 there are over 1 million registered volunteers in the Zooniverse community (see image #1) who are known as "Zooites" working on projects in many languages. There are over 17.7 classifications per minute by volunteers across all these fields showing the vast power of citizen science. The spread of global Zooites is clear.

Among the active space themed projects are:

- **Galaxy Zoo** (Launched 12 July 2007): The latest Galaxy Zoo project. Users view galaxy images and are asked questions to determine its morphology. The current sample includes high red-shift galaxies taken from the Hubble Space Telescope and low red-shift galaxies from the Sloan Digital Sky Survey.
- **Moon Zoo** (Launched 16 February 2009): High resolution Lunar Reconnaissance Orbiter photos of the Moon's surface are used for detailed crater counts and mapping lunar rocks ages.
- **Solar Stormwatcher** (Launched 21 December 2009): Video imagery data from the twin STEREO spacecraft

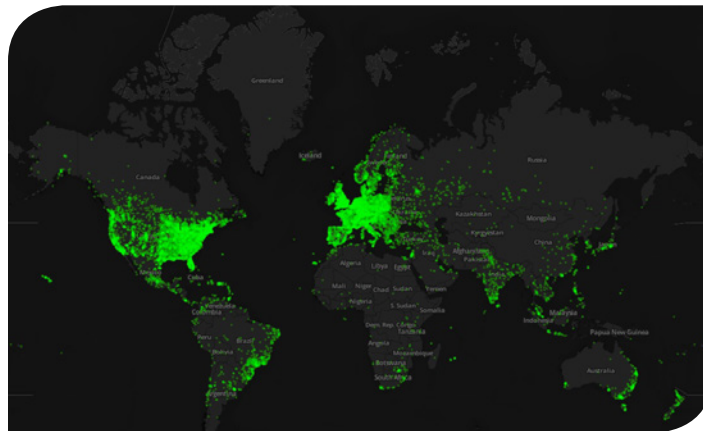


Image #1: Map of the global Zooite community. Credit: ttfrob/Zooniverse

are used to track the formation and evolution of Coronal Mass Ejections.

- **The Milky Way Project** (Launched 7 December 2010): Spitzer & Herschel Space Telescopes data are used to infer regions where early stages of star formation are occurring.
- **Planet Hunters** (Launched 16 December 2010): Zooites identify extra solar planets from the light curves of star data recorded by the Kepler Space Telescope.
- **Planet Four** (Launched 8 January 2013): Mars Reconnaissance Orbiter images of the surface of Mars are reviewed by volunteers, classifying fans and blotches caused by gas and geysers under CO2 ice.
- **Radio Galaxy Zoo** (Launched 17 December 2013): Zooites identify radio waves of astrophysical jets powered by accretions onto a black hole.
- **Disk Detective** (Launched 30 January 2014): NASA's WISE telescope data is analysed to identify dusty debris in the Milky Way that indicate stars forming planetary systems.
- **Sunspotter** (Launched 30 January 2013): Zooites examine sunspots and rank them according to complexity, to understand their evolution and how they produce eruptions.

A full exploration of each of these projects and others not listed would take up several volumes of this magazine. Instead, here is a preview of two of the citizen science projects above that you can directly contribute to and play a big role in.

Our story in starlight: Galaxy Zoo

"In many parts of science, we're not constrained by what data we can get; we're constrained by what we can do with the data we have. Citizen science is a very powerful way of solving that problem." - Chris Lintott



Image #2 Results of citizen science outreach. Credit: Kevin Schawinski/Galaxy Zoo

The long running Galaxy Zoo is now into its fourth incarnation. With a minimum of a septillion stars in the observable universe (that's approximately 1 followed by 24 zeroes), there will be many more incarnations of this long lived project to come. By having multiple volunteers come to independent conclusions on the type of galaxy observed, a built in cross check enables a high level of confidence in the results. This further allows scientists and researchers to more finely target a test population of spiral galaxies, merger galaxies and other types using the classifications made by volunteer

Zooites. Examples of some of the successfully classified galaxies by Zooites are shown in image #2.

At the time of Galaxy Zoo's inception in 2007 and faced with classifying over a million galaxies, the team found that about 70% of galaxies were classified correctly by computers, but the 30% of incorrect classifications were never known. Some computer programs have been unreliable when it comes to

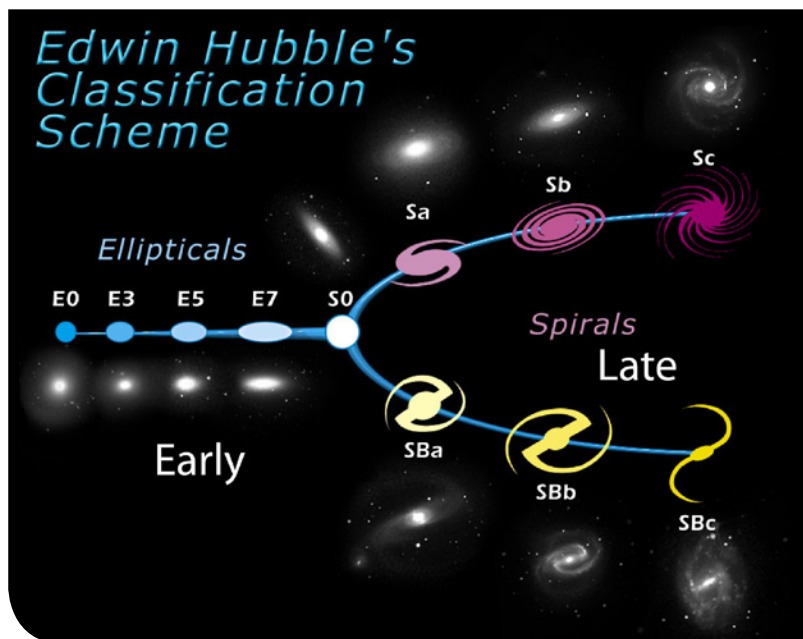


Image #3: Tuning the volunteers in via Hubble's classification of galaxies. Credit: STScI

classifying galaxies. Another member of Galaxy Zoo, Kevin Schawinski recognises the advantages humans have over computers; "the human brain is actually much better than a computer at these pattern-recognition tasks."

Due to the data deluge problem created by modern data collection methods, it would take years for astronomers to sift through the entire set of results but with even as few as 10,000 to 20,000 volunteers giving time to classify galaxies, this process could be finished within months. By more speedily classifying the types of galaxies observed, their shapes tell the tale and the history of each galaxy's lifetime.

The key aspect of Galaxy Zoo (and indeed any Zooniverse project) is that no previous subject matter expertise is needed. Simple tutorials are included on the site guiding volunteers with previously worked examples. Once registered, volunteers can begin accessing the vast amounts of images captured by all the telescopes Galaxy Zoo employs. The vast majority of these are all robotic, as is the subsequent automated processing. The first Galaxy Zoo referred to astronomer Edwin Hubble's famous "Tuning Fork Diagram" (as seen in image #3) as a simple guide for galaxy classification.

The successful results from the first Galaxy Zoo allowed the founders, astronomers and scientists to win valuable observing time on some of the most powerful telescopes in the world. Galaxy Zoo discoveries have

been followed up on the Isaac Newton and William Herschel Telescopes on the island of La Palma in the Canaries, Gemini South in Chile, the WIYN telescope on Kitt Peak, Arizona and the IRAM radio telescope in Spain's Sierra Nevada.

Galaxy Zoo has also won precious observing time and gained data from orbiting space telescopes including Swift, GALEX, Chandra, XMM-Newton Suzaku and perhaps most excitingly the Hubble Space Telescope. Thus, in addition to the original SDSS data there are high chances that volunteers will be looking at remote galaxies and parts of space never seen before by human eyes.

The second and third iterations of Galaxy Zoo further extended the range of surveys and what was asked of the Zooite population. More detailed observations and classifications were made; Galaxy Zoo 2's survey generated over 60 million classifications in 14 months. Colour observations of galaxies were made which deduced recent star formation history. For example



Image #4: A montage of volunteers' classified overlapping galaxies.

Credit: Galaxy Zoo Forum

blue stars are the "rock stars of the cosmos" as they live fast and die young, burning up their fuel in only 100 million years or so.

The third project, Galaxy Zoo: Hubble involved Zooites looking back to the distant past. Drawn from Hubble surveys, the light from galaxies billions of years old was compared to light from galaxies now to determine the footprints that influence their shape and growth (active black holes, mergers, star formations).

The current and fourth iteration, Galaxy Zoo: CANDELS adds the most up to date and distant images of our local cosmos to the mountain of available data than ever. In addition to images from Sloan, Hubble's newest Widefield Camera 3 installed during the Shuttle Atlantis' Hubble Servicing Mission 4 (STS-125), has provided data for the CANDELS (Cosmic Assembly Near-Infrared Deep Extragalactic Legacy) survey. Zooites can look back into history farther than before.

Installed in 2009, the Widefield Camera 3 (WFC3) is



Image #5: But for the absence of gravity, astronaut Andrew Feustel, perched on the end of the remote manipulator system arm, would be a bit top heavy as he helps to install the Wide Field Camera 3 (WFC3) during a May 2009 spacewalk to upgrade the Hubble Space Telescope. Out of frame is veteran astronaut John Grunsfeld, his spacewalking crewmate. The pair kicked off five back to back days of extravehicular activity for the STS-125 crew.

Credit: NASA

a highly sensitive camera able to peer deeper into the depths of space and through galactic dust at infrared wavelengths. Surveying wider fields of view during the CANDELS program, never before seen pictures of distant galaxies have been obtained. These are far older and more distant than anything seen before.

The infra-red images are very different from those taken in the visible light spectrum showing distinctive hidden structures of these galaxies (see image #6). However there are so many pictures available from the CANDELS Survey that Zooites have been called upon again for their help in closely inspecting and classifying them. The advantages of global citizen science outreach can be leveraged again with built in independent cross checks in classifying newly discovered and far distant galaxies. The Zooite community is instrumental in adding to our sum knowledge of the observable universe.

Serendipitous and unexpected discoveries lie at the heart of each Galaxy Zoo project. Undoubtedly one of the most surprising and now famous discoveries made in recent years was by a volunteer citizen scientist and classifier, a Dutch school teacher called Hanny Van Arkel. Going beyond the obvious classifications that would have been made by an automated computer programme, Ms Van Arkel spied an unknown object below her target classified galaxy IC2497. She alerted the Galaxy Zoo team to this discovery, now named "Hanny's Voorwerp", and they immediately began to observe this mysterious green object with other colleagues and even employed the Hubble Space Telescope itself (see image #7).

The conclusion was that this object is an intensely hot cloud of gas of around 50 thousand degrees Kelvin but rather puzzlingly with very few stars. The hottest stars are very young, probably only a few million years old and lie at the top most and brightest part of the cloud, closest to IC2497. Coincidentally this part of the "voorwerp" or green cloud lies on the trajectory of outflowing gas from IC2497 seen by radio telescopes, so it has been theorised that the star formation in the

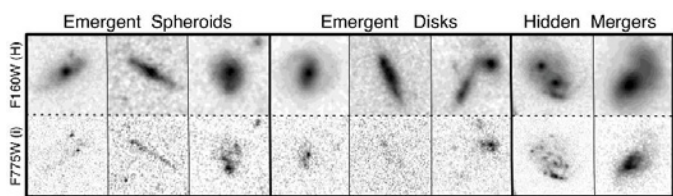


Image #6: Older, distant and 'hidden' galaxies. Credit: NASA/Boris Haeussler

cloud has been from the interaction of outflowing gases from IC2497 and Hanny's Voorwerp too. But what of the cloud itself?

Data from Hubble has been analysed and suggest a traumatic merger of two or more galaxies formed IC2497 perhaps a billion years before our current view. Out of this, a colossal tail of gas stretched a million light years around IC2497. During this time material rapidly accreted around the new galaxy's central black hole, enough to form a quasar. This illuminated and ionized

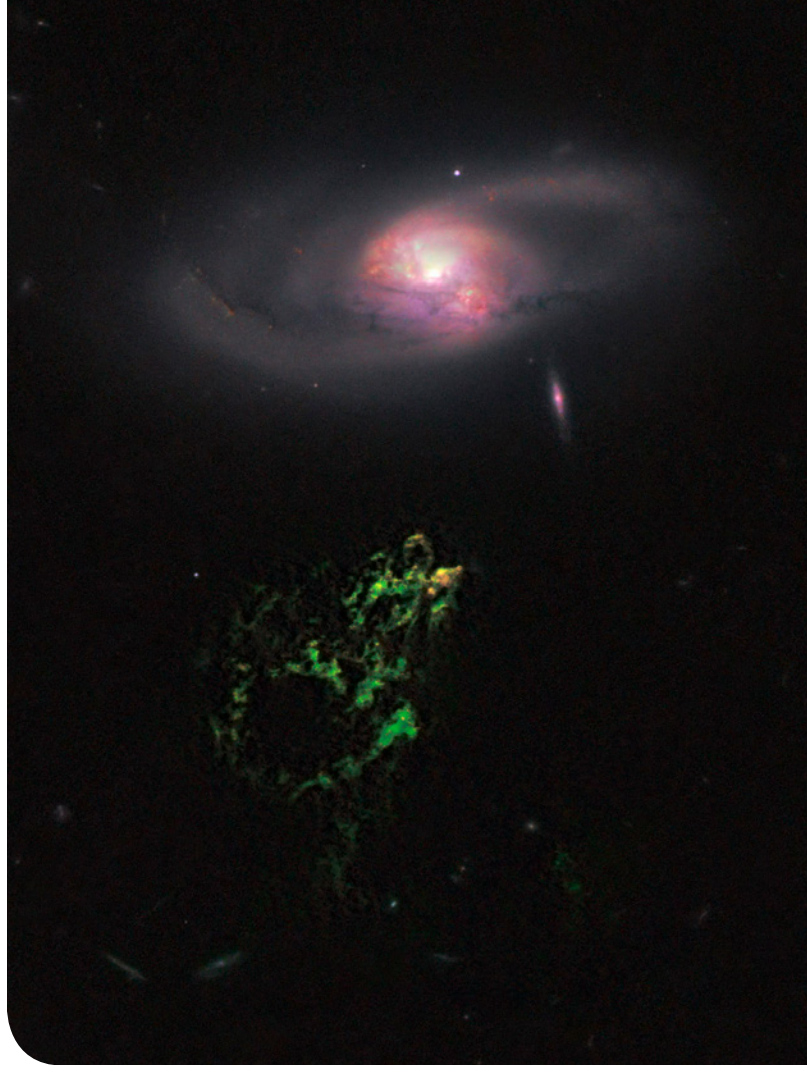


Image #7: A Zooite discovery and a mysterious object: Hanny's Voorwerp which can be seen below spiral galaxy IC2497.

Credit: NASA/ESA/W. Keel/Galaxy Zoo Team/Hubble Space Telescope

the gas creating the Voorwerp cloud. A million years ago, it blew the material adrift as the galaxy core began to fade. The Voorwerp is now a castoff, a ghostly survivor of the past.

This story illustrates the power of outreach and citizen science. One person's serendipitous discovery has directed the attention of world astronomers, scientists and marshalled their tools to examine an object that would otherwise have been missed if we relied solely on computers. The community of Zooites has many more discoveries to be found.

This global community of citizen scientists can connect with the project team leaders on their blog (<http://blog.galaxyzoo.org/>), in Google + Hangouts and Twitter (@galaxyzoo). There is also a Galaxy Zoo forum available for everyone to discuss any and all topics (www.galaxyzooforum.org/). Talk Galaxy Zoo is another place for Zooites to gather share and discuss their data (<http://talk.galaxyzoo.org/>). More universal mysteries than we know are being gathered, more questions are being asked about the history and evolution of galaxies and the stars within. You could be one of those million or so volunteers helping and find the answers and solve mysteries as old as the cosmos itself.

Strange new worlds: Planet Hunters

"... the ways by which men arrive at knowledge of the celestial things are hardly less wonderful than the nature of these things themselves" – Johannes Kepler

Perhaps the most exciting and fast growing field in the space sciences is that of exoplanetology. This is the search for worlds other than the eight in our own solar system (sorry Pluto!), orbiting distant stars. This interdisciplinary field mixes astrobology, astrophysics, astronomy, planetology, geochemistry, astrochemistry and astrogeology in the effort to find so called "exoplanets". Multiple planet hunting and detection methods have been developed and refined, and these are listed in image #9. This image lists the multiple detection methods (top left) and shows how the transit method has greatly increased the number of detections - far right bar. The "transit method" has recently contributed greatly to the rate of exoplanet discoveries as seen during the "Kepler Planet Bonanza" announcement in February.

As of May 2014, NASA's Exoplanet Archive reports there are 1,713 confirmed planets. 443 star systems have multiple planets. The Kepler Space Telescope has 3,845 candidates and 962 confirmed exoplanets making it responsible for 56% of all confirmed discoveries to date.

Most excitingly there are 21,267,575 Transit Survey Light Curves. These are the results of exoplanet searches by astronomers via photometric transits of potential planets around host stars. The number of detections by this "transit method" has exploded in the first quarter of 2014 as seen in images #8 and #9. This

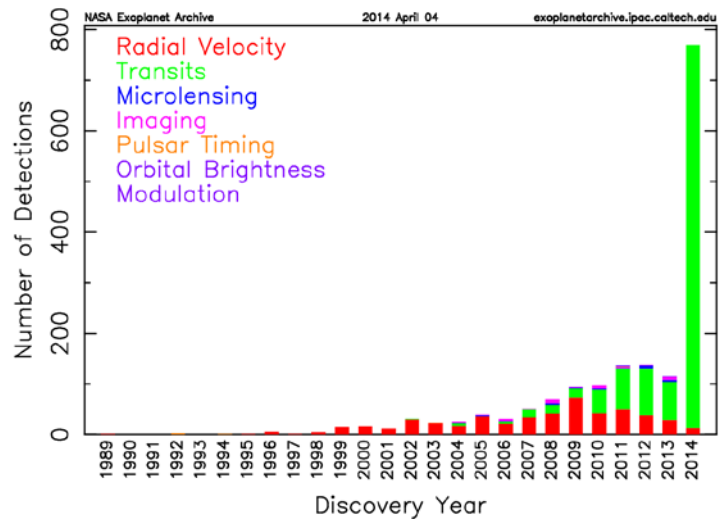


Image #9: Exoplanet detection methods. Credit: NASA's Exoplanet Archive

supposition further, the search for extra-terrestrial intelligence is another related and attractive field. Intelligence seeks out intelligence.

The Kepler Space Telescope was launched in March 2009 to look for exoplanets by using the transit method. Kepler stares at the Cygnus constellation in its Field of View every thirty minutes looking for such transiting planets that slightly dim their parent star's starlight, as viewed by the space telescope. Smaller planets similar to Earth's size will dim their parent star's brightness only slightly. Larger planets also known as "Super Jupiters" will also dim their parent's star's brightness but not as much as a smaller Earth size planet would.

These time series "snapshots" of changing brightness in these stars are called "light curves" and data for over 150,000 stars is sent to Earth regularly. The light curves provided on the Planet Hunters site are publicly available from the Kepler mission.

Clearly, the huge amounts of precise data coming from Kepler have awed astronomers and needs to be analysed. Rooms full of super computers could do the job efficiently and quickly, but limited by their programming, can also miss the non-standard signs of an exoplanet or its cosmic footprints.

Building on the success of Galaxy Zoo, the talent for a large global resource of human pattern recognition was recognised once more. A new Zooniverse project, Planet Hunters was conceived in collaboration with Yale University.

A simulation of a light curve is shown in image #10. This uses a star about the same size as our Sun and different sizes of planets that pass in front of that star. The distributions of white dots represent uninterrupted starlight, as if no planets were transiting in front of that star. However, what would happen if a planet the size of Jupiter would pass in front of that star? The light would noticeably dip for the period that planet was in front of that star, as seen by the dip of the blue dots over a day and a half of observation. This is shown to scale as a Jupiter size planet 11.2 times Earth's diameter and a tenth the diameter of the Sun.

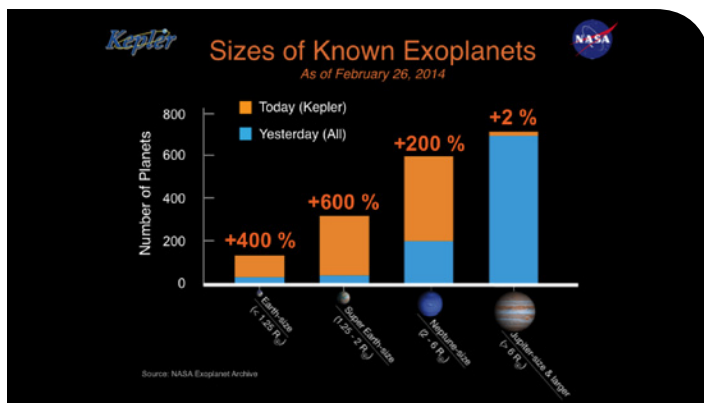


Image #8: The blue bars show those exoplanets known by size before the Kepler Planet Bonanza announcement earlier this year. The gold bars show Kepler's newly verified planets. Credit: NASA Ames/W Stenzel

has vastly outstripped the combined discovery rates of the last 25 years. The inferred conclusion means that there are billions of worlds in our own galaxy, many of which could be capable of supporting life, and just perhaps many where life may have developed just as it has done on Earth. Astronomers dating back to antiquity have long held this view. Extending this

A Neptune sized planet, 3.9 times the radius of Earth, would still block some starlight but not as much as represented by the distribution of green dots. An Earth size planet would decrease the starlight by a fraction of an amount as seen by the distribution of red dots. This is an imperceptible difference to the untrained eye and less sensitive telescopes, but with the advent of Kepler and refined data sifting methods, finding near Earth sized worlds is becoming more frequent.

You can also simulate this transit method at home by taking different sized balls and passing them in front of a lit bulb (but wear sunglasses!). The light emitted from the bulb will dip by varying amounts according to the size of the ball passing in front of it and the length of time the ball takes to pass in front of the bulb.

Human pattern recognition is being relied upon to spot those patterns in the Kepler data that have been missed by the computers back on Earth. Firstly volunteers are being asked to check for data offsets that look like errors that could be corrected. Secondly, volunteers can check for variability in star data, i.e. if a star's data looks scattered but constant, or if there are cyclical variations in the star. Lastly, volunteers can highlight any "transit events" they have found in the Kepler data which will look like low points or a low spike in a data set.

As a registered volunteer citizen scientist you can corroborate observations along with other volunteers and claim credit for your own discoveries on Planet Hunters (see image #11).

Already we have begun to see a large increase in the rate of discovery of worlds closer to our own solar system, hence the need for a united Earth of citizen scientists.

The race is on between man and machine. This is a great experiment for an interconnected **human** super computer of voluntary citizen scientists versus the interconnected **machine** super computers. The goal is to see which side will find the most exoplanets. Planet hunting volunteer citizen scientists can interact

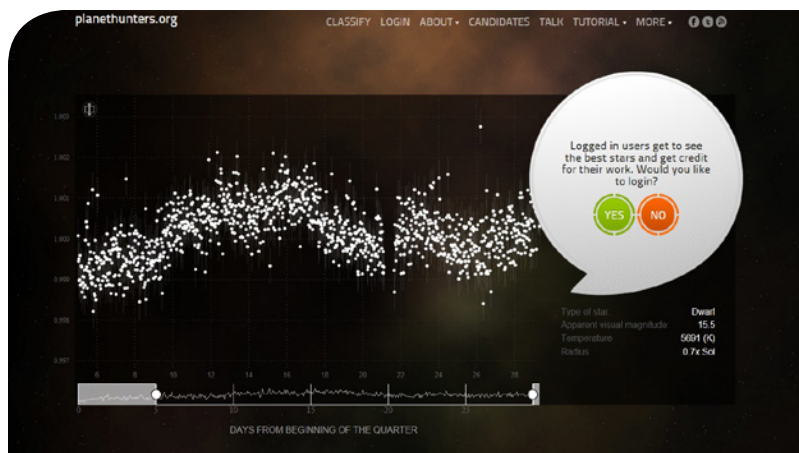


Image #11: Perhaps you can help discover the next exoplanet from real Kepler data.
Credit: www.planethunters.org

and share ideas at Planet Hunters Talk (<http://talk.planethunters.org/>). Actively involving volunteer citizen scientists in real research will enhance our knowledge of the universe and our place in it. The ultimate prize will be to find that one elusive exoplanet; Earth sized, rocky, in its parent's star's habitable zone, with the right atmospheric conditions and the signatures of liquid water. Could life evolve there? The age old question "are we alone?" has never been more ready for an answer. Perhaps a volunteer citizen scientist, a Zooite will help find that answer.

News flash: Kepler discovery

Using the Kepler Space Telescope data NASA announced the discovery of the first Earth sized exoplanet "Kepler-186f" 500 light years from Earth in its parent M dwarf star's Habitable Zone where liquid water could exist on its surface. Previous research suggests this world is likely to be rocky but we have yet to determine its mass, density, the signatures of liquid water and its atmosphere. Perhaps Kepler's successors, like the James Webb Space Telescope, can uncover this. This is a remarkable scientific breakthrough and it brings us even closer to the ultimate prize and answer for that age old question. Yet more strange new worlds await our discovery and exploration.

Galaxy Zoo and Planet Hunters are only two of the space themed projects in the Zooniverse you can participate in. Other non-space projects include:

- **Climate: Cyclone Center** - Classify over 30 years of tropical cyclone data with scientists at NOAA's National Climatic Data Center
- **Nature: Sea Floor Explorer** - Help explore the ocean floor with the HabCam team and Woods Hole Oceanographic Institution
- **Nature: Whale FM** - Help marine researchers understand what whales are saying by grouping similar sounding whale calls together

Students, teachers, in fact everyone and anyone can become a volunteer citizen scientist and participate in any Zooniverse project.

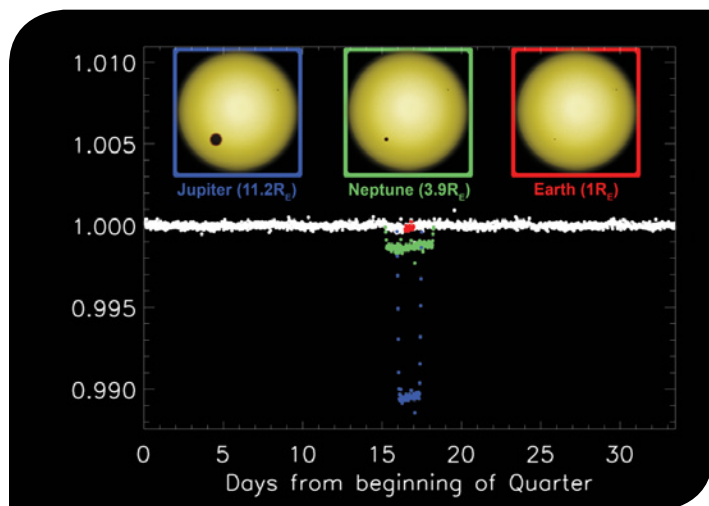


Image #10: Light curves explained for finding an exoplanet.
Credit: The Zooniverse

Zoo Teach: Classes for the curious minded

As an educational outreach tool Zooniverse projects engage with a wide population across all age ranges and encourage meaningful science research. Zoo Teach (www.zooteach.org/) is a tool for educators to share lessons that complement the Zooniverse projects in the classroom. Searches can be done by age range, subject and recent additions of lessons and resources as seen in image #12.

Galaxy Zoo is available to educators and students via an interactive tool called Navigator (www.galaxyzoo.org/#/navigator/home) where groups can classify galaxies, compare and investigate their characteristics.

Planet Hunters also has well developed set of tutorials and guides at www.planethunters.org/site_guide.

Humans have always been curious explorers. We have searched for new sustenance, new lands, crossed oceans and the void of space in search of new cultures and knowledge. Today this curious exploration gene continues to thrive as we search for knowledge to give insight into our existence, whether it is on the ocean floor, on Earth or among the stars.

While some of the above quests show the exciting projects available for you to participate in, this is just the tip of the iceberg. There is a whole universe – a “zooniverse” of discoveries out there waiting for you to find. All you have to do is take that first step on the journey.

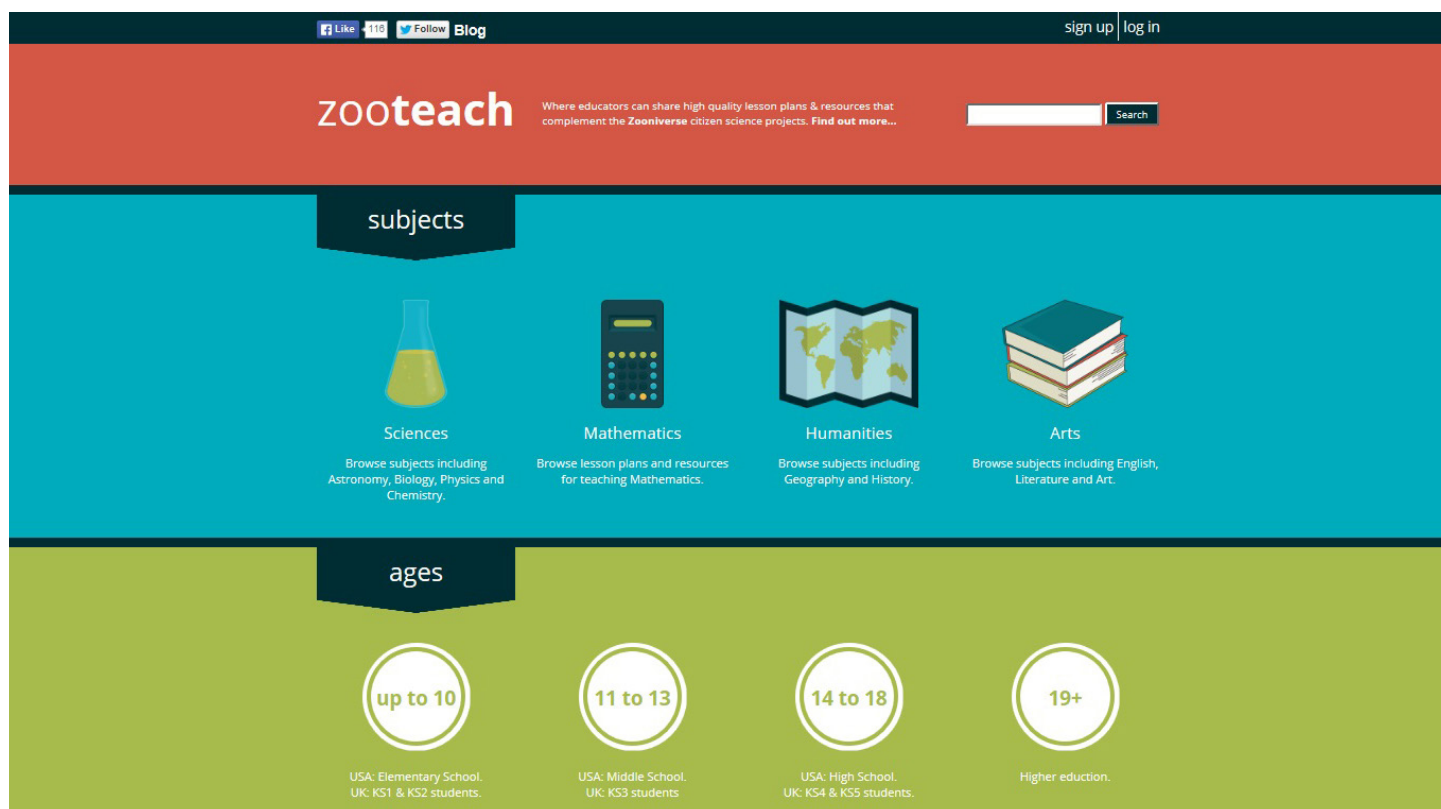


Image #12: Classes for the curious minded at the www.zooteach.org.

Sources:

Citizen Science Alliance

<http://www.citizensciencealliance.org/>

Zooniverse

<https://www.zooniverse.org/>

Zoo Teach

<http://www.zooteach.org/>

Galaxy Zoo

<http://www.galaxyzoo.org/>

Galaxy Zoo Navigator

<http://www.galaxyzoo.org/#/navigator/home>

Galaxy Zoo: A Zooniverse Project Blog

<http://blog.galaxyzoo.org/>

Sloan Digital Sky Survey / Sky Server

<http://skyserver.sdss.org/dr1/en/proj/advanced/galaxies/tuningfork.asp>

Chris Lintott on The Galaxy Zoo (Video)

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NASA Exoplanet Archive

<http://exoplanetarchive.ipac.caltech.edu/>

Planet Hunters

<http://www.planethunters.org/>

Planet Hunters Tutorial and Guides

http://www.planethunters.org/site_guide

Planet Hunters: A Zooniverse Project Blog

<http://blog.planethunters.org/>

NASA Ames Research Center: Kepler A Search For Habitable Planets

<http://kepler.nasa.gov/>

Kepler 186-f Discovery

<http://kepler.nasa.gov/news/index.cfm?FuseAction=ShowNews&NewsID=330>

'Club sandwich' of oceans & ice may exist within Jovian moon

The largest moon in our solar system, a companion to Jupiter named Ganymede, might have ice and oceans stacked up in several layers like a club sandwich, according to new NASA-funded research that models the moon's makeup.

Previously, the moon was thought to harbor a thick ocean sandwiched between just two layers of ice, one on top and one on bottom.

"Ganymede's ocean might be organized like a Dagwood sandwich," said Steve Vance of NASA's Jet Propulsion Laboratory in Pasadena, Calif., explaining the moon's resemblance to the "Blondie" cartoon character's multi-tiered sandwiches. The study, led by Vance, provides new theoretical evidence for the team's "club sandwich" model, first proposed last year.

The results support the idea that primitive life might have possibly arisen on the icy moon. Scientists say that places where water and rock interact are important for the development of life; for example, it's possible life began on Earth in bubbling vents on our sea floor. Prior to the new study, Ganymede's rocky sea bottom was thought to be coated with ice, not liquid -- a problem for the emergence of life. The "club sandwich" findings suggest otherwise: the first layer on top of the rocky core might be salty water.

"This is good news for Ganymede," said Vance. "Its ocean is huge, with enormous pressures, so it was thought that dense ice had to form at the bottom of the ocean. When we added salts to our models, we came up with liquids dense enough to sink to the sea floor."

NASA scientists first suspected an ocean in Ganymede in the 1970s, based on models of the large moon, which is bigger than Mercu-

ry. In the 1990s, NASA's Galileo mission flew by Ganymede, confirming the moon's ocean, and showing it extends to depths of hundreds of miles. The spacecraft also found evidence for salty seas, likely containing the salt magnesium sulfate.

Previous models of Ganymede's oceans assumed that salt didn't change the properties of liquid very much with pressure. Vance and his team showed, through laboratory experiments, how much salt really increases the density of liquids under the extreme conditions inside Ganymede and similar moons. It may seem strange that salt can make the ocean denser, but you can see for yourself how this works by adding plain old table salt to a glass of water. Rather than increasing in volume, the liquid shrinks and becomes denser. This is because the salt ions attract water molecules.

The models get more complicated when the different forms of ice are taken into account. The ice that floats in your drinks is called "Ice I." It's the least dense form of ice and lighter than water. But at high pressures, like those in crushingly deep oceans like Ganymede's, the ice crystal structures become more compact. "It's like finding a better arrangement of shoes in your luggage -- the ice molecules become packed together more tightly," said Vance. The ice can become so dense that it is heavier than water and falls to the bottom of the sea. The densest and heaviest ice thought to persist in Ganymede is called "Ice VI."

By modeling these processes using computers, the team came up with an ocean sandwiched between up to three ice layers, in addition to the rocky seafloor. The lightest ice is on top, and the saltiest liquid is heavy enough to sink

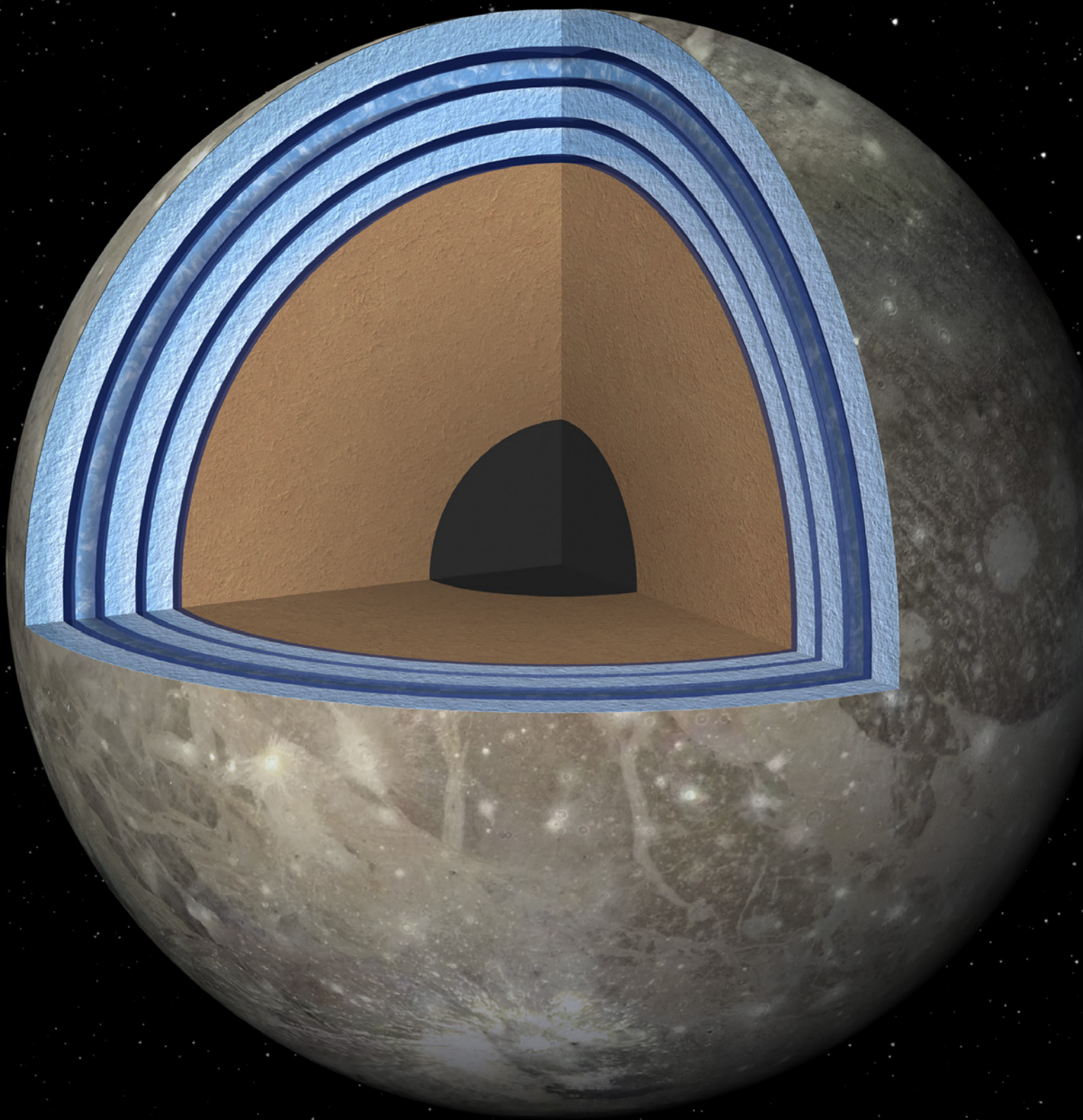
to the bottom. What's more, the results demonstrate a possible bizarre phenomenon that causes the oceans to "snow upwards." As the oceans churn and cold plumes snake around, ice in the uppermost ocean layer, called "Ice III," could form in the seawater. When ice forms, salts precipitate out. The heavier salts would thus fall downward, and the lighter ice, or "snow," would float upward. This "snow" melts again before reaching the top of the ocean, possibly leaving slush in the middle of the moon sandwich.

"We don't know how long the Dagwood-sandwich structure would exist," said Christophe Sotin of JPL. "This structure represents a stable state, but various factors could mean the moon doesn't reach this stable state."

Sotin and Vance are both members of the Icy Worlds team at JPL, part of the multi-institutional NASA Astrobiology Institute based at the Ames Research Center in Moffett Field, Calif.

The results can be applied to exoplanets too, planets that circle stars beyond our sun. Some super-Earths, rocky planets more massive than Earth, have been proposed as "water worlds" covered in oceans. Could they have life? Vance and his team think laboratory experiments and more detailed modeling of exotic oceans might help find answers.

Ganymede is one of five moons in our solar system thought to support vast oceans beneath icy crusts. The other moons are Jupiter's Europa and Callisto and Saturn's Titan and Enceladus. The European Space Agency is developing a space mission, called JUPITER ICy moons Explorer or JUICE, to visit Europa, Callisto and Ganymede in the 2030s.



Credit: NASA/JPL-Caltech

www.RocketSTEM.org

Fly me to the Moon



Vocabulary

- **Crew Module (CM):** The part of the spacecraft where the astronauts live and work
- **Crew Module Weight:** The total weight of the CM including provisions and the crew
- **Crew Size (Crew):** The total number of astronauts needed to conduct a specific space mission
- **Dry Weight (m_d):** The weight of the spacecraft fully loaded excluding the propellant
- **Engine Module (EM):** The part of a spacecraft that holds the propellant tanks and the rocket engine
- **Exhaust Velocity (v_{exh}):** The speed of the escaping gas exiting a rocket engine
- **Gross Weight (m_g):** The weight of the spacecraft fully loaded including the propellant
- **Inert Weight:** The empty weight of the EM
- **Lunar Orbit Insertion (LOI):** The rocket burn that places a spacecraft into Low Lunar Orbit (LLO)
- **MidCourse Correction (MCC):** The rocket burn that keeps the spacecraft on course
- **Mission Duration:** The total time needed to accomplish a specific space mission
- **RL10 Engine:** The name of the rocket engine used in the Engine Module (EM)
- **Standard Gravity (g_0):** The acceleration due to free fall on Earth, equal to 9.80665 m/s^2
- **Specific Impulse (I_{sp}):** The force with respect to the amount of propellant used per unit of time
- **TransLunar Injection (TLI):** The rocket burn that places a spacecraft on a trajectory to the Moon

Narrative

A long time ago, in a galaxy very near our own, there once existed a wondrous vision of the future, where

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

spacecraft were bountiful, and imaginations could soar.

Given our astronautics concepts for S.T.E.M. education projects, the Boeing Space Tug Study (circa 1971) exemplifies this penultimate vision. Notably, it was a complete design that not only included a Crew Module (CM), but also an Engine Module (EM).

The CM would have housed the astronauts and all of their supplies, including food, oxygen, science equipment, etc.

The EM would have contained the rocket engine, propellant, tanks, electrical supply, etc.



Illustration of the Boeing Space Tug.

Credit: Mark Wade

The CM and EM were to be attached together, and the two would have become one, as they say. The design was very much similar to the Apollo spacecraft that heralded NASA's endeavors in the so-called space race of that era. Hence, a near twin to the Apollo design.

It really would have been quite an awesome machine, because the EM could have been able to carry any type of payload, whether it was the CM or satellites or whatever. Overall, the Boeing Space Tug design was inspirational as well as functional. Remarkable for the year 1971!

That being said, the spacecraft was never built! However, we can still make something good out of its advanced design. Namely, our S.T.E.M. classroom projects geared to this study posits our students working on real space missions using a real spaceship model and real numbers. In short, there are realworld implications in our applied concepts and mathematics.

So can we make this space vehicle finally fly in space; all the way to the Moon? You bet your last rocket!

Analysis: CM

Spacecraft habitat weight depends on many factors, such as the number of astronauts needed or the duration of the mission. Some CM component weights will vary depending on these factors (such as Environmental Control and Life Support Systems), while others will weigh the same no matter what (such as the CM structure itself).

The Space Tug CM graphic shows that a crew of fifteen would have allowed for a two-day mission, and the CM would have weighed 9,386 pounds, whereas a crew of three would have yielded a fifty-day mission and would have weighed 9,755 pounds (all figures would have included the weight of the crew). These numbers look suspiciously like points on a Cartesian graph, which means that they may be linear equations.

We'll make the Crew Size (Crew) the independent variable. Therefore we get the points (3, 50) & (15, 2) and (3, 9755) & (15, 9386). We can thus calculate the slope and the y-intercepts of the two linear equations.

$$\text{Slope}_1 = \frac{2 - 50}{15 - 3} = \frac{-48}{12} = -4$$

$$y - \text{int}_1 = 2 - (-4)(15) = 2 + 60 = 62$$

$$\text{Slope}_2 = \frac{9386 - 9755}{15 - 3} = \frac{-369}{12} = -30.75$$

$$y - \text{int}_2 = 9386 - (-30.75)(15) = 9386 + 461.25 = 9,847.25$$

Therefore, the two linear equations for the Boeing Space Tug CM are:

$$\text{Mission Duration} = 4\text{Crew} + 62$$

$$\text{Weight}_{\text{CM}} = -0.75\text{Crew} + 9847.25$$

Example

Suppose you want to take a crew of 10 astronauts on a space mission to the Moon. What would be the Mission Duration of the spaceflight? More importantly, what is the weight of the CM?

Using the linear equations that we just derived, we plug in Crew = 10 into the equations.

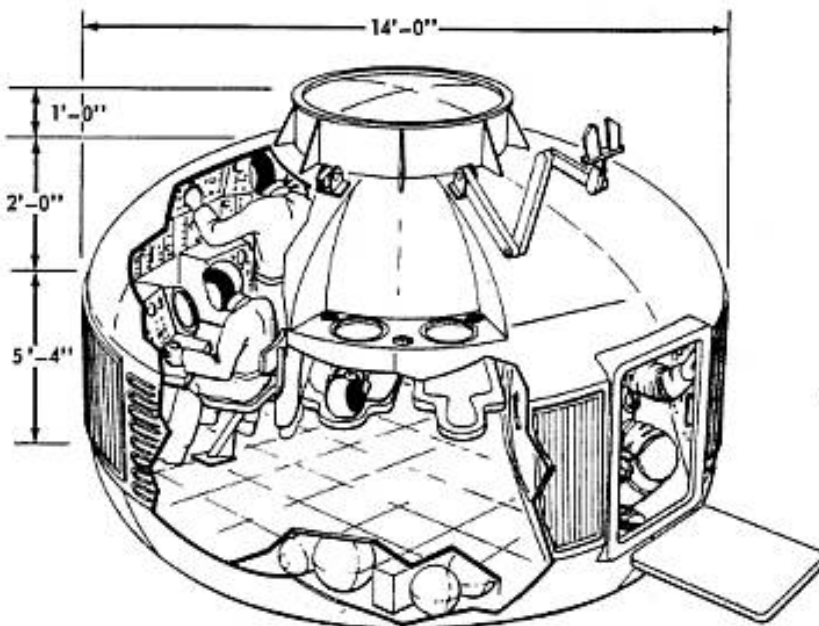
$$\text{Mission Duration} = -4(10) + 62 = 22 \text{ Days}$$

$$\text{Weight}_{\text{CM}} = -30.75(10) + 9847.25 = 9,540 \text{ lbs}$$

So for this particular design, a crew of ten would have allowed the spacecraft to stay aloft for about three weeks, and would have weighed under 10,000 pounds. Very nice!

Diagram of the Boeing Space Tug Crew Module (CM).

Credit: Boeing



● SYSTEMS DESCRIPTIONS

- EC/LSS – CABIN PRESSURIZATION, O₂/N₂, WATER, WASTE MANAGEMENT, ETC.
- ELECTRICAL POWER – BATTERIES, REGULATORS, JUNCTION BOXES, WIRES, CABLES, POWER DISTRIBUTOR
- COMMUNICATION & DATA MANAGEMENT – TV, AUDIO, ANTENNA
- INSTRUMENTATION – DISPLAYS, CONTROLS, WIRING LIGHTING
- CONTROLS – RCS, EXPENDABLES, LINES, INST.

● WEIGHTS

	15 MAN 2 DAY	3 MAN 50 DAY
● STRUCTURE	2497	2497
● CREW SYSTEMS	3689	1705
● EC/LSS	1267	2602
● ELECTRICAL POWER	130	130
● COMMUNICATIONS	327	327
● INSTRUMENTATION	188	188
● CONTROL	60	60
● MISCELLANEOUS EQUIP.	80	80
● EXPENDABLES	295	1279
● CONTINGENCY	853	887
TOTAL	9386	9755

● VOLUME – 1260 CU FT

● ATMOSPHERE – 7–14.7 PSIA

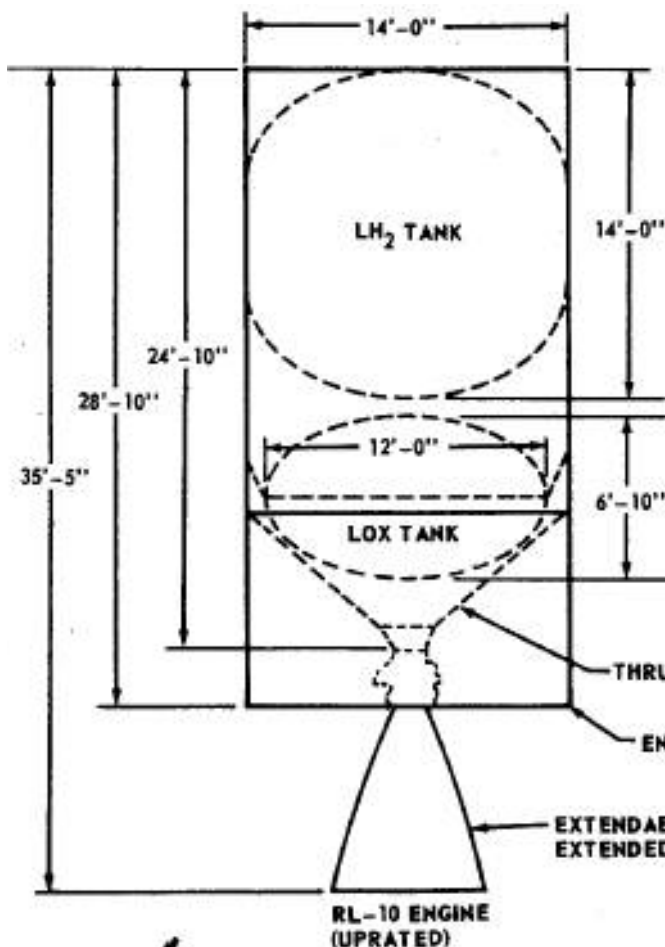
● SYSTEMS DESCRIPTION

- STRUCTURE – 2219 T87 SHELL, 7075 T6 LOAD CARRYING STRUCTURE, – 2219 T87 MICROMETEOROID SHIELD WITH HEXCEL FILLER
- SUPER INSULATION, RADIATORS, LOUVERS, PANELS, FLUIDS, PUMP HEAT EXCHANGER, ACCUMULATOR
- AIRLOCKS AND DOCKING PORTS

- CREW SYSTEMS – BUNKS, SEATS, FOOD, MEDICAL, CLOTHING, HYGIENE, CREW, EVA SUITS, PLSS

- MISC. SYSTEMS – MANIPULATOR ARMS DISPLAYS AND CONTROLS, MAINTENANCE EQUIPMENT, ETC.

- INCLUDES WEIGHT OF CREW



- PROPELLANT WEIGHT – 39,800 LBS
- INERTS WEIGHT – 5,610 LBS
- STAGE WEIGHT – 45,410 LBS
- MASS FRACTION – 0.876
- NO. OF ENGINES & THRUST – (1) ENGINE – 23,300#
- LOX/LH₂ I_{sp} – 460 SEC
- EXPANSION RATIO – 225
- SUBSYSTEMS & CONSTRUCTION MATERIALS
 - STRUCTURES – 2219 T87 AL, 7075 T6 AL
 - THERMAL – SUPERINSULATION
 - MICROMETEOROID – HEXCEL FILLER, 2219 T87 SHIELD
 - ENGINES – RL-10-3-8 (UPRATED RL10)
 - PRESSURIZATION – GH₄ FOR LOX; GH₂ FOR LH₂
 - ACTIVATION – ELECTRICAL ACTUATORS
 - RCS – SUPERCRITICAL LOX/LH₂
 - ELECTRICAL – BATTERIES AND ELECTRICAL NETWORKS

* BASED ON SYNCHRONOUS MISSION

Diagram of the Boeing Space Tug Engine Module (EM).

Credit: Boeing

Analysis: EM

The CM wouldn't have gone anywhere unless there was a way to make it go. Enter the Engine Module (EM). This machine would have had everything you needed to go on a space mission: propellant tanks, a Reaction Control System (RCS), batteries, and of course, the reliable RL10 rocket engine. This rocket engine was useful in that it could have been *restarted* many times, burning the highly efficient Liquid Hydrogen (LH₂) fuel. This meant that the EM could have been *reused* many times, reducing the cost of flying in space!

Speaking of flying in space, the most useful equation in all of rocketry is appropriately called the Rocket Equation, also known as the "Tsiolkovsky Equation" named after its discoverer.

$$\Delta v = v_{EXH} \cdot \ln\left(\frac{m_0}{m_1}\right)$$

It tells rocketeers how much of a change in velocity (Δv) is available given the payload weight, the propellant weight, and the exhaust velocity (v_{EXH}) of the gasses being expelled by the rocket. The exhaust velocity of a rocket is the engine's Specific Impulse (I_{sp}) multiplied by the standard gravity of Earth.

Using the information from the Space Tug EM image,

we see that the RL10 (with the rocket nozzle extended) had an I_{sp} of 460 s. We can thus calculate the rocket engine's Exhaust Velocity (v_{EXH}).

$$v_{EXH} = I_{sp} \cdot g_0 = (460)(9.80665) = 4,511 \text{ mps}$$

The EM graphic also tells us that the Inert Weight of the EM was 5,610 lbs. If we carry a CM with a crew of 10 astronauts on a 22-day mission that weighs 9,540 lbs, and we also carry, for instance, 8,000 lbs of scientific and other payload, the Dry Weight can be calculated.

$$m_1 = \text{Weight}_{INERT} + \text{Weight}_{PAYLOAD} + \text{Weight}_{CM} \\ = 5610 + 8000 + 9540 = 23,150 \text{ lbs}$$

Finally, the EM graphic shows that the propellant would have weighed 39,800 lbs. We now have everything we need to solve the rocket equation.

$$m_0 = m_1 + \text{Weight}_{PROPELLANT} = 23150 + 39800 = 62,950 \text{ lbs}$$

Putting everything together, we get

$$\Delta v = (4511) \cdot \ln\left(\frac{62950}{23150}\right) = (4511) \cdot \ln(2.72) \\ = (4511)(1.000346) = 4,513 \text{ mps}$$

Example

The students at The Learning Community Charter School (www.tlcnm.net) have designed a mission to go one-way from a Bigelow space station in Low Earth Orbit (LEO) to a Bigelow space station in Low Lunar Orbit (LLO) (we'll assume that the spacecraft propellant tanks will be replenished at the lunar space station for the return trip home). The spaceflight would resemble the first leg of the historic Apollo 8 lunar orbit mission. Will they make it?

Looking up the Δv requirements for the Trans Lunar Injection (TLI), the Mid-Course Correction (MCC), and the Lunar Orbit Insertion (LOI) rocket burns, we can calculate the total Δv Budget needed to go to the Moon and enter lunar orbit.

$$\Delta v \text{ Budget} = TLI + MCC + LOI = 3205 + 19 + 881 = 4,105 \text{ mps}$$

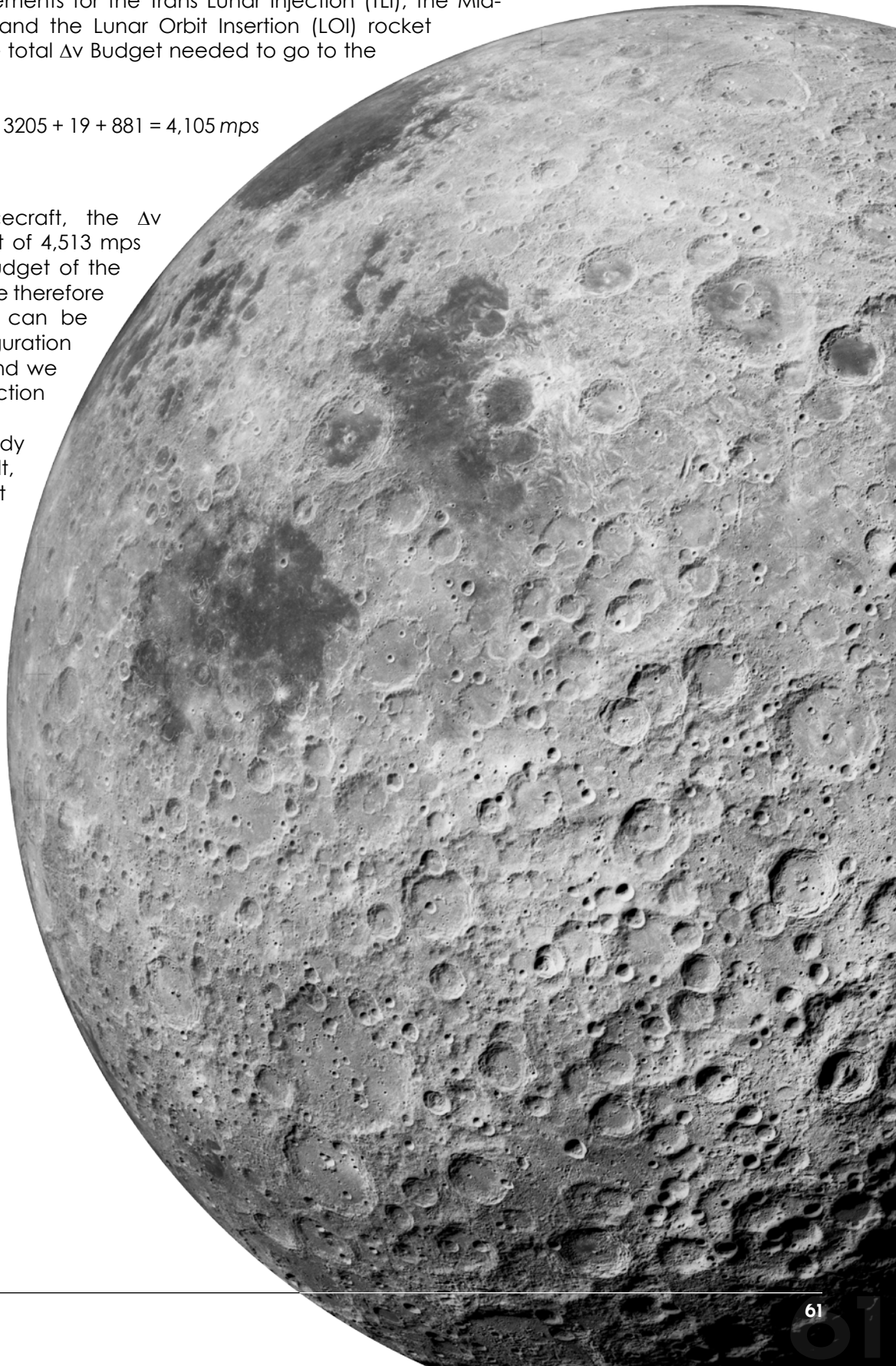
Conclusion

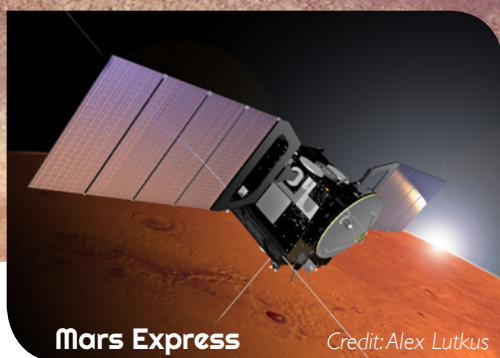
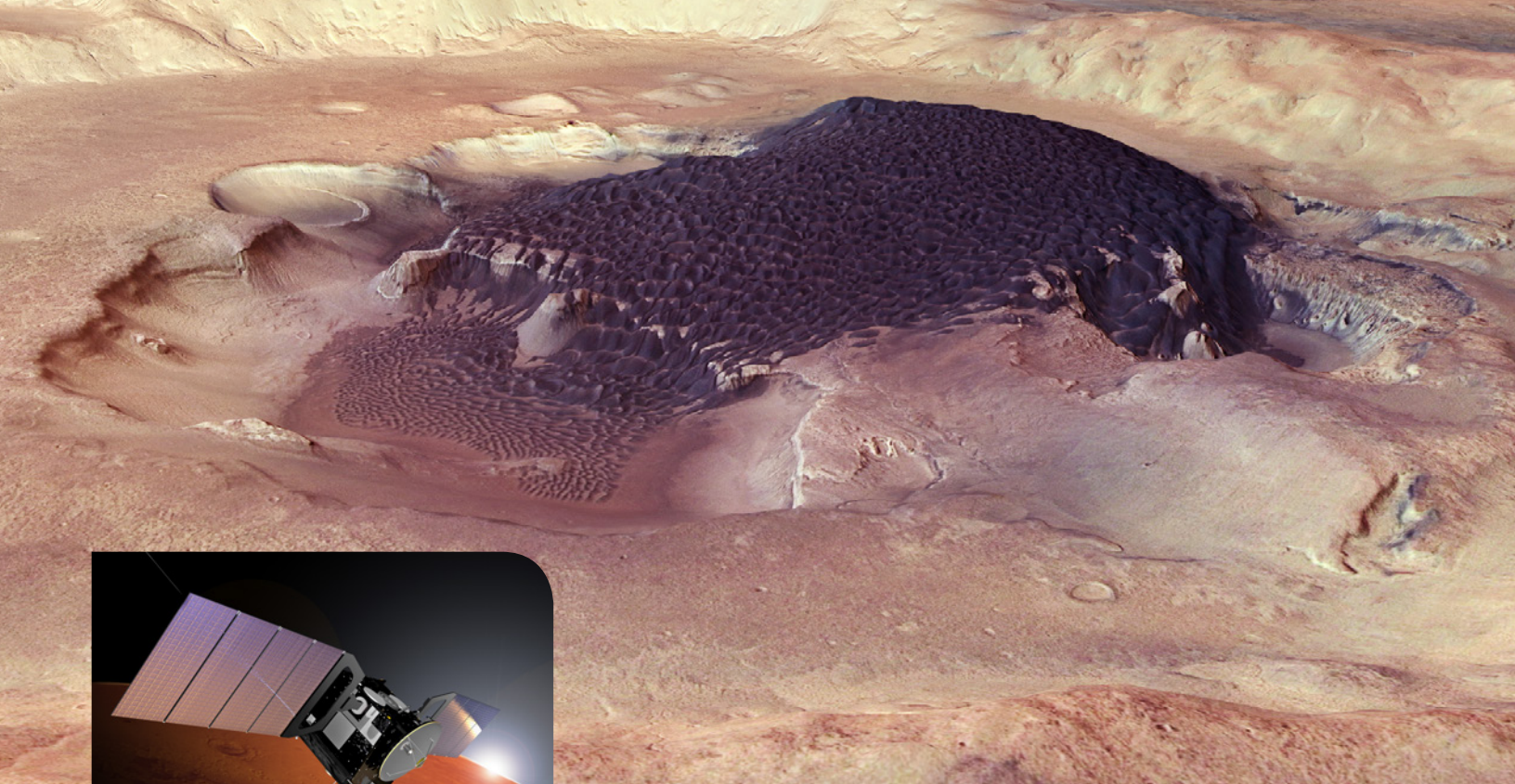
For this particular spacecraft, the Δv capability of the spacecraft of 4,513 mps exceeds the required Δv Budget of the lunar mission of 4,105 mps. We therefore conclude that the mission can be safely flown in this configuration all the way to the Moon, and we recommend that crew selection begin immediately!

The Boeing Space Tug Study spacecraft, had it been built, would have been a most formidable and versatile ship, well ahead of its time. They truly had an astonishing space vehicle on the drawing board back in the day, no?

So why are we not building reusable spaceships en masse again?

Note: In the next issue of *RocketSTEM* magazine, we will continue the human adventure by working out the mathematics for a landing on the Moon. Stay tuned!





Rabe Crater is a 108 km-wide impact crater with an intricately shaped dune field. The dune material likely comprises locally eroded sediments that have been shaped by prevailing winds. The image resolution is about 15 m per pixel.

Credit: ESA/DLR/FU Berlin

Cascading dunes in a Martian crater

A breathtaking new mosaic from ESA's Mars Express shows a stunning swirling field of dark dunes cascading into sunken pits within a large impact crater.

The mosaic was created from two images and focuses on the 108 km-wide Rabe crater. The region is 320 km to the west of the large Hellas impact basin, about halfway between the planet's equator and south pole.

Rabe crater has an interesting topography: its flat floor has a number of smaller craters and large sunken pits within it. The bulk of the dune material sits atop the flat remnant of the original crater floor, but then some of it spills dramatically down into the pits below.

The dunes stand some 150-200 m tall and their swirling patterns indicate the prevailing direction of the winds that have whipped across the crater over time. The dunes are made of basaltic material, a common volcanic rock. In the region shown here, it was subsequently covered over by other layers of material, uncovered by erosion within the crater itself.

Zooming in on the western portion of the crater reveals distinct layers of dark material exposed in the crater walls. One possible interpretation is that the impact crater punched through the top surface to reveal these otherwise hidden layers. Over time, this material has been eroded and swept up by wind to form the dunes seen towards the centre of the crater.

Similar dark material can also be seen in several of the smaller craters surrounding Rabe, with streaks stain-

ing the surface in between, most notably in the left-hand side of the image above. It is possible that some of the dune material was lifted out of Rabe by strong winds and spread locally.

Other nearby craters look degraded, their once-distinct rims and internal features crumbling over time. This 'terrain softening' process is often associated with the presence of ice just below the surface: this can facilitate the slow and steady creep of material downslope, resulting in a smooth appearance.

Material deposited from the atmosphere, perhaps during sand storms, can also contribute to an apparent softening of features over time.

By contrast, one crater to the upper left of Rabe shown here retains a sharper appearance. A closer examination of this relatively deep crater reveals fresh-looking channels and grooves in the crater walls.

Grooves like these are often associated with erosion by liquid water but, regardless of their formation history, they can also expose underlying layers, such as the dark material common to this region. Furthermore, a dense patch of this material is seen concentrated in the deepest part of the crater floor.

Impact craters like Rabe offer a window into the past by exposing ancient rocks that would otherwise remain hidden from view. Meanwhile, the dunes show the important continuing role played by wind in shaping the martian landscape.



NASA's Administrator, Charles Bolden (left), Marillyn Hewson, President/CEO of Lockheed Martin (right), and astronaut Rex Walheim (back) stand with Team ARES, from the Governors School for Science and Technology in Hampton, Va., winners of the Exploration Design Challenge high school competition. Credit: NASA

Students create winning design for Orion

After a year-long competition among high school teams across the country, evaluators from NASA, Lockheed Martin and the National Institute of Aerospace have selected Team ARES, from the Governor's School for Science and Technology in Hampton, Va., as the winner of the high school portion of the Exploration Design Challenge (EDC).

The EDC was developed to engage students in science, technology, engineering and math (STEM) by inviting them to help tackle one of the most significant dangers of human space flight – radiation exposure.

"This is a great day for Team ARES – you have done a remarkable job," said NASA Administrator Charles Bolden, who helped announce the winning team. He continued, "I really want to congratulate all of our finalists. You are outstanding examples of the power of American innovation. Your passion for discovery and the creative ideas you have brought forward have made

us think and have helped us take a fresh look at a very challenging problem on our path to Mars."

Team ARES now will work with the NASA and Lockheed Martin spacecraft integration team to have the product of their experimental design approved for spaceflight. Once the equipment is approved, engineers will install it onto Orion's crew module. Later this year, when Orion launches into orbit during Exploration Flight Test-1 (EFT-1), Lockheed Martin will host Team ARES at NASA's Kennedy Space Center in Florida to watch their experiment launch into space.

During the EFT-1, Orion will fly through the Van Allen Belt, a dense radiation field that surrounds the Earth in a protective shell of electrically charged ions. Understanding and mitigating radiation exposure during Orion's flight test can help scientists develop protective solutions before the first crewed mission. After EFT-1, the students will receive data indicating how well their de-

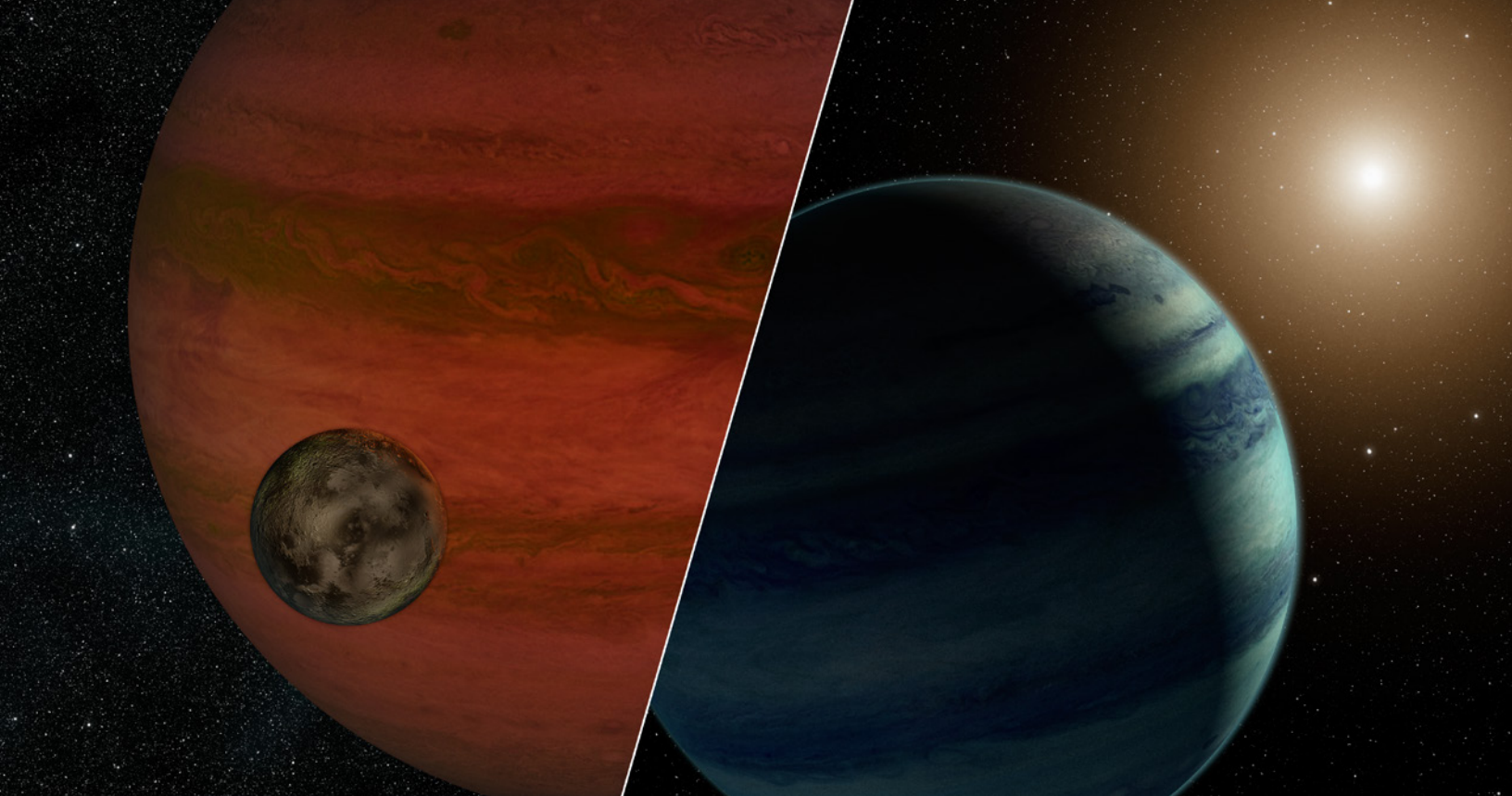
sign protected a dosimeter, an instrument used for measuring radiation exposure.

Speaking at the U.S.A Science and Engineering Festival, Lockheed Martin Chairman, President and CEO Marillyn Hewson said, "The Exploration Design Challenge has already reached 127,000 students worldwide – engaging them in real-world engineering challenges and igniting their imaginations about the endless possibilities of space discovery."

Students around the world in grades K-12 still can be part of Orion's first flight by completing an on-line radiation shielding activity. Students who complete the activity by June 30 will have their names flown aboard Orion.

To learn more about the EDC and related activities, visit: www.nasa.gov/education/edc.

To learn more about Orion and the EFT-1 mission, visit: <http://lockheedmartin.com/orion> and www.nasa.gov/orion.



Researchers have detected the first “exomoon” candidate – a moon orbiting a planet that lies outside our solar system.

Credit: NASA/JPL-Caltech

First exomoon possibly found

Titan, Europa, Io and Phobos are just a few members of our solar system’s pantheon of moons. Are there are other moons out there, orbiting planets beyond our sun?

NASA-funded researchers have spotted the first signs of an “exomoon,” and though they say it’s impossible to confirm its presence, the finding is a tantalizing first step toward locating others. The discovery was made by watching a chance encounter of objects in our galaxy, which can be witnessed only once.

“We won’t have a chance to observe the exomoon candidate again,” said David Bennett of the University of Notre Dame, Ind. “But we can expect more unexpected finds like this.”

The international study is led by the joint Japan-New Zealand-American Microlensing Observations in Astrophysics (MOA) and the Probing Lensing Anomalies NETwork (PLANET) programs, using telescopes in New Zealand and Tasmania. Their technique, called gravitational microlensing, takes

advantage of chance alignments between stars. When a foreground star passes between us and a more distant star, the closer star can act like a magnifying glass to focus and brighten the light of the more distant one. These brightening events usually last about a month.

If the foreground star – or what astronomers refer to as the lens – has a planet circling around it, the planet will act as a second lens to brighten or dim the light even more. By carefully scrutinizing these brightening events, astronomers can figure out the mass of the foreground star relative to its planet.

In some cases, however, the foreground object could be a free-floating planet, not a star. Researchers might then be able to measure the mass of the planet relative to its orbiting companion: a moon. While astronomers are actively looking for exomoons – for example, using data from NASA’s Kepler mission – so far, they have not found any.

In the study, the nature of the foreground, lensing object is not

clear. The ratio of the larger body to its smaller companion is 2,000 to 1. That means the pair could be either a small, faint star circled by a planet about 18 times the mass of Earth -- or a planet more massive than Jupiter coupled with a moon weighing less than Earth. The problem is that astronomers have no way of telling which of these scenarios is correct.

The ground-based telescopes used in the study are the Mount John University Observatory in New Zealand and the Mount Canopus Observatory in Tasmania.

Additional observations were obtained with the W.M. Keck Observatory in Mauna Kea, Hawaii; European Southern Observatory’s VISTA telescope in Chile; the Optical Gravitational Lens Experiment (OGLE) using the Las Campanas Observatory in Chile; the Microlensing Follow-Up Network (MicroFUN) using the Cerro Tololo Interamerican Observatory in Chile; and the Robonet Collaboration using the Faulkes Telescope South in Siding Spring, Australia.

Land ho!

Support personnel prepare to exact the crew from the Soyuz TMA-11M spacecraft shortly after it landed with Expedition 39 Commander Koichi Wakata of the Japan Aerospace Exploration Agency (JAXA), Soyuz Commander Mikhail Tyurin of Roscosmos, and Flight Engineer Rick Mastracchio of NASA near the town of Zhezkazgan, Kazakhstan on May 14. Wakata, Tyurin and Mastracchio returned to Earth after more than six months onboard the International Space Station.

Credit: NASA/Bill Ingalls





SLS engine prepared for the Test Stand

Formerly known as the Space Shuttle Main Engine, the RS-25 accumulated more than one million seconds – or almost 280 hours – of hot fire experience during 135 missions and numerous engine tests like the one pictured here. Four RS-25 engines will power the core stage of NASA's Space Launch System (SLS) and the engine will go back in the stand for testing this summer at NASA's Stennis Space Center.

Credit: Aerojet Rocketdyne