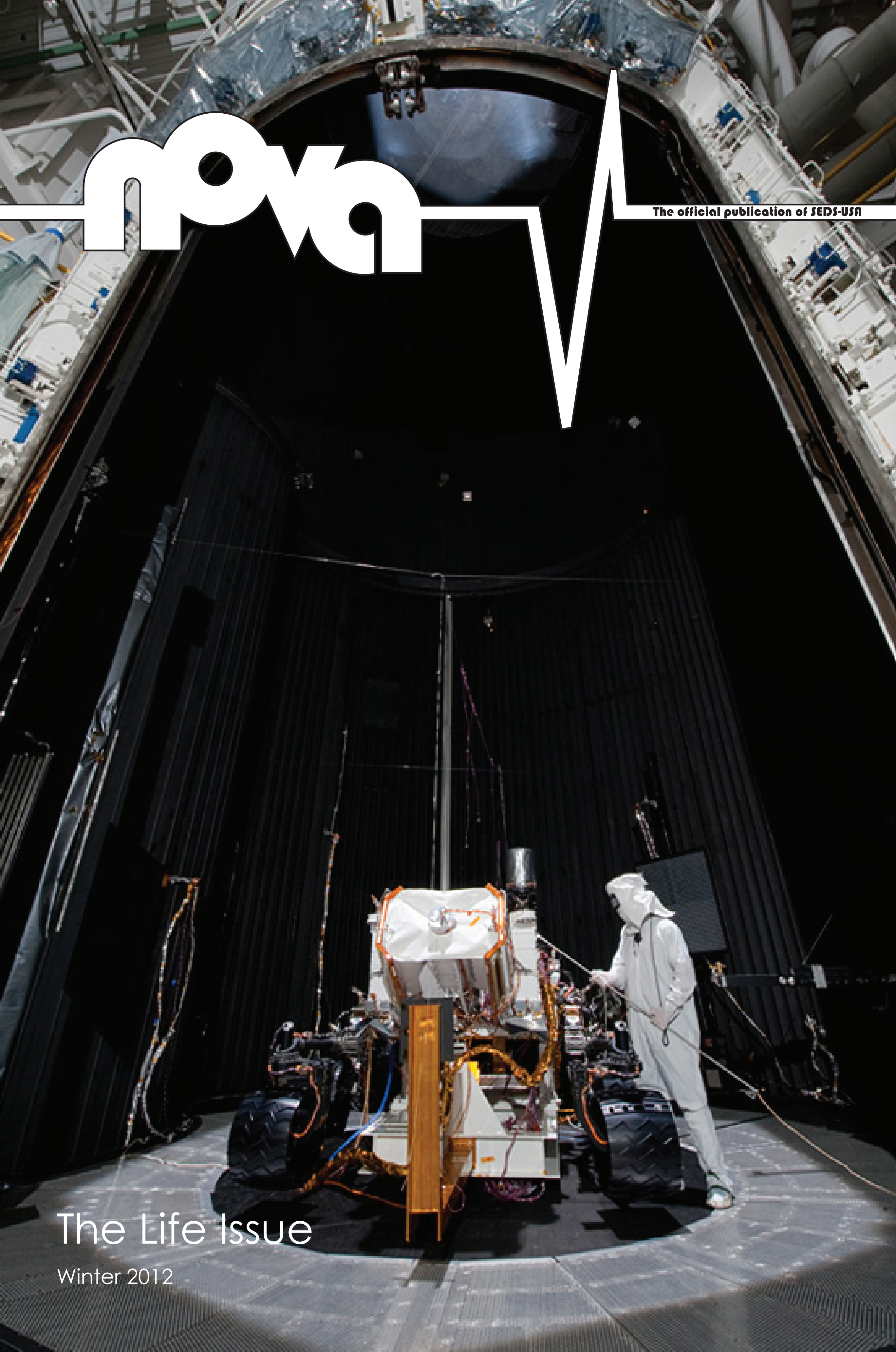
nova

The official publication of SEDS-USA



The Life Issue

Winter 2012

In this issue

In December, we invited the members of SEDS-USA to tweet, facebook, or email their top news stories from 2011 to the editors of this magazine. As turbulent as 2011 was for the space community, I'm glad to see that the robotic exploration of Mars and the achievements of the human spaceflight program ranked so highly in our query. In response to your comments, this issue will focus on the Mars Science Laboratory (MSL), a robotic rover named "Curiosity," which is now on its way to the red planet. In these pages, you will find a discussion of what it is that makes a planet habitable, an overview of the MSL rover and mission architecture, and a review of Gale Crater the landing site selected for this flagship mission.

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Letter from the Chair

Welcome to 2012!

As this latest installment of the NOVA comes out, we cannot help but look back on last year. 2011 was a year of many changes to our nation's space program. The final launch of the Space Shuttle of course will be seen as one of the year's most important events, although not the only. 2011 also saw the launch of Mars Science Laboratory, an exciting next step in our Mars program, as well as for the first time ever we have a satellite in the orbit of Mercury (MESSENGER). We've seen the loss of another scientific mission to Mars, the Russian Phobos-Grunt. Human spaceflight is preparing for its next steps in the form of commercial launch providers and planning for beyond Earth orbit. There will be a great amount of excitement as we venture beyond LEO, and determine what destinations await us. 2012 will see several of these launch service providers doing testing to the International space station and other destinations, proving their capabilities before being put into service.

The next few years will lay the groundwork for our future exploration and development in space, and the students of today will be among the ones that make it happen. This is why involvement in SEDS helps students learn more about what is going on in Spaceflight, and help to build experience working on projects.

When we look at where SEDS is today, we've come a long way as an organization even in the past four years. The number of Chapters across the country is at all-time highs, and we're welcoming more and more chapters in each month. Despite the unknowns about the future, this growth alone shows that there is an incredible amount of interest from students across the country in the future of Space Exploration and Development. Our generation will be the group that makes our future in space a reality.

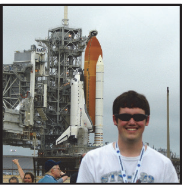
SEDS exists as an organization to help guide students to obtain that future and to get more students (and the general public) involved with the space community. This year, I challenge all members who are involved with SEDS to go out and get your friends involved, be from your own school or from other schools. Through growth each member can make their experience in SEDS that much more.

Finally, we're working on trying to bring our national organization closer together with the members across the country. I strongly encourage those members of SEDS sign up for our national announcement letter (www.seds.org/mail) to hear the latest of what's going on. We'll be sending out updates, opportunities, internships and job postings once or twice a month. I hope this resource will help members from across the country keep in touch with SEDS and give them opportunities that you wouldn't have known about.

Thank You

Dan Pastuf

Chair, SEDS-USA



Chair / Daniel Pastuf
University of Buffalo

I am a senior Aerospace and Mechanical Engineering major at the University at Buffalo, and currently serve as Chairman of SEDS-USA. I joined SEDS in 2007 and immediately got involved with my chapter's propulsion project and a course UB-SEDS sponsored called *Topics in Space Exploration and Development*. I was elected president of UB-SEDS at the end of my freshman year and worked to expand our activities to include events like stargazing, high power rocketry flights, and more. To this day, I hold a TRA level 1 rocket certification and a technician level amateur radio license (call sign: KD2BBZ). One of my biggest tests of leadership was in 2009, UB-SEDS was hosting the Northeast Regional Conference of SEDS (NECOS) and the conference coordinator was forced to resign two weeks before the big event. I stepped up to fill the void and I'm proud to say we were able to pull it off. In 2010, I stepped down as President of UB-SEDS and was elected to the position of Engineering Council Coordinator for the University at Buffalo Student Government. This was also the year I was elected to the SEDS-USA Board of Directors where I served as Director of Chapter Affairs.

Vice Chair / Sara Meschberger
University of Arizona

I have always been fascinated with space and the world of engineering and science. When I was 11 I started stargazing and brought my telescope out to public events to teach the public about all the wonders that are out beyond our world with a group called Stargazing for Everyone. When I started high school I wanted to launch rockets and received my level 1 and 2 certification for HPR when I turned 18. I also worked for Challenger Space Center in Peoria, AZ doing everything from summer camps to managing the weekends.

Currently I am a senior at the University of Arizona majoring in Linguistics and Communications. I am very active with my SEDS club and have flown on a microgravity flight, launched balloon payloads and done various outreach activities with my SEDS family. I have served on the SEDS-USA board for two and a half years and have acted as Director of Projects and Vice Chair. I look forward to serving the board this year and want to continue the funding of the endowment and work with our Chair to accomplish as much as we can for SEDS-USA.

Director of Finance / Andrew Dianetti
University of Buffalo

I am a junior Aerospace and Mechanical Engineering major at the University at Buffalo, and the new Director of Finance for SEDS-USA. I have been involved with UB-SEDS since my freshman year and have served as chapter president for the past two years. Spaceflight has always been my passion, and I believe that SEDS is an excellent opportunity to bring students who share the same passion for space together. I am excited to serve as Director of Finance this year.


Director of Chapter Affairs / Daniel Zhou
Purdue University

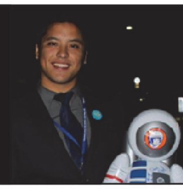
Hi, my name is Daniel Zhou and I am an undergraduate student at Purdue University currently working towards a Bachelor's degree in Aerospace Engineering. I was first interested in space exploration while I was in elementary school, when one day, our teacher showed us fascinating pictures of black holes and nebulae, and asked us the puzzling question of "Are we alone?" From that moment on, I have decided to dedicate my life to aid mankind in answering this question and to allow mankind to capture images of these amazing extra-terrestrial objects not through telescopes, but through our own eyes. My quest eventually led me to Students for the Exploration and Development of Space, or SEDS, where I joined forces with fellow space enthusiasts like myself as we set to answer the mysteries of space together.

Director of Publications / Harvey Elliott
University of Michigan

I am a PhD student in Space and Planetary Science working with Dr. Nilton Renno at the University of Michigan. My research focuses on the planetary conditions for life, with most of that effort going toward the robotic exploration of Mars. As an undergraduate at UM, I was a founding member our SEDS chapter and I am proud to say that I am still highly active on the board. I think one of the most important aspects of SEDS is the opportunity to get outside of your comfort zone and interact with people of very diverse backgrounds. This publication is just another form of that interaction and I would like to hear more about your interests. I ask that you too contribute to NOVA. As scientists and engineers it is easy to slip into our own worlds (complete with our own jargon) and I hope that publications like NOVA will help to bridge that gap between us. It doesn't take much – just send your questions, your comments, and your articles to publications@seds.org

Director of Public Relations / Brandon Seifert
University of Colorado

I am an undergraduate double majoring in Astrophysics and International Economics at the University of Colorado in Boulder. My diverse interests include studying the Russian, Chinese, and Italian languages. I plan to pursue a career in the private space industry, eventually starting my own 'New Space' company, but I would also be interested in the development and utilization of alternative energies in automobiles, airplanes, metro-transit, etc. As you can see from my studies, I am just as passionate about politics and economics as I am about space, and I would someday like to be involved in the American political system.


Director of National Projects / Michael Zwach
Purdue University

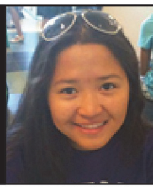
I am a senior at Purdue University studying Electrical Engineering, Astrophysics, and Entrepreneurship and Innovation. Born and raised in Colorado Springs, CO, Mike has been a longtime space supporter and is a avid robotic engineer. Mike has worked on robotic systems since middle school and has many years of competition experience through Science Olympiad and FIRST Robotics. He previously worked for NASA on the Lunar Micro Rover for four years while attending Purdue and is currently the co-founder of the Purdue Lunabotics Team. After graduating in December 2012, Mike plans to investigate getting involved with a commercial space start up company or pursuing his graduate degree. As Director of National Projects, Mike is leading national inter-chapter competitions and is setting SEDS up to have a prosperous future by setting up ambitious but achievable goals.

Director of Educational Outreach / Erik Lopez
University of Illinois

I am an Aerospace Engineering and Engineering Physics major at the University of Illinois originally from Los Angeles, California. Growing up in Los Angeles gave me a great perspective about how fortunate some people were in respect to their circumstance. Even within the same city there were large contrasts between the opportunities people had. My job and dedication as Director of Educational Outreach is to remove this divide and use my position and passion for space to inspire underprivileged youth from all walks of life and hopefully make a difference in their life. My ultimate goal is to become an astronaut and venture into outer space not just because of my desire for exploration but because I know I will be put in a position to improve the lives of youth all over the world.

Director of High School Affairs / Pye Pye Zaw
Arizona State University

I am a current junior studying Earth and Space Exploration with a concentration in Astrophysics at Arizona State University. I have worked for the National Optical Astronomy Observatory (NOAO) in the educational outreach department as a special projects assistant. In addition, I have also worked with NASA Space Imagery Center as a student worker, and taught college level general astronomy observing sessions at University of Arizona Steward Observatory. I have worked with the NASA Lunar Science Institute (NLSI) as an EPO intern. For SEDS USA, I am working as the officer for high school affairs, dealing with high school related matters associated with SEDS. This work includes techniques and options for starting, sustaining, and maintaining SED's interest and association with before university level students interested in STEM. I am working with some high school and middle school teachers to help set a foundation in which SEDS can be a place for students to indulge, learn, and have fun.

Webmaster / Joshua Sosa
University of Arizona

My name is Joshua Sosa and I am the current SEDS.org webmaster. I help manage all seds.org services, including the main site, forums, wiki, gallery, email, and everything in-between. I currently work for the Arizona/NASA Space Grant Consortium in the University of Arizona's Lunar and Planetary Lab. And I have been happily married for over 3 years.

Secretary / Mary Magilligan
University of Buffalo

I am a sophomore from the University at Buffalo majoring in Mechanical and Aerospace Engineering with a minor in Computer Science. I joined the Students for the Exploration and Development of Space at the beginning of my freshman year and currently serve as the UB chapter Secretary.

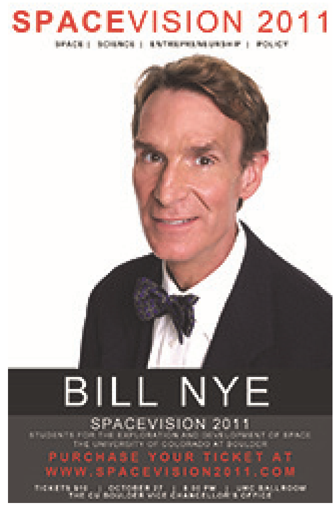

SPACE VISION
2012
November 8-11, 2012
University at Buffalo
Buffalo, NY
Early Bird Registration:
Student - $35
Young Professional - $60
Professional - $225
*Prices increase on May 24
SPACEVISION2012.COM

SpaceVision / A Revelation

by Kaizad Viraf Raimalwala

Last October, I had the fantastic opportunity of attending SpaceVision, by far the largest and most comprehensive student-run conference on space topics in the country, at the University of Boulder in Colorado. After being a member of Purdue SEDS for about 2 years now, I was only recently exposed to the true grassroots space advocacy movement that SEDS really is, and that is all thanks to SpaceVision.

We were treated to a number of inspiring talks by some great speakers and some fun demonstrations all packed in a 3 day convention. The event officially kicked off with quite an entertaining talk by the keynote speaker, Bill Nye, who holds the prestigious position of being the quintessential Science Guy. Oh and he's also the Executive Director of the Planetary Society. He talked about his past experiences, his work with Spirit & Opportunity, and basically persuaded us to change the world a number of times.



Fliers for SpaceVision 2011 keynote speaker Bill Nye.

One of the more interesting talks that weekend was the History of SEDS session. Good ol' Bob Richards, one of the three co-founders of SEDS, our tribe leader and head of the so-called Space Mafia, narrated the early beginnings of our organization and how it took the space community by storm in the early 80s. Peter Diamandis, popularly known as the X-Prize guy, was also one of the three co-founders but wasn't present a t the conference. Todd Hawley was the other co-founder and he unfortunately passed away several years back. These three men have left behind quite an impressive legacy.

Today, SEDS is still expanding, reaching out to anyone and everyone to support the cause of space. Space exploration is no longer the domain of engineers and scientists. Space is for all. Space is our future. Whether you're an artist, a lawyer, a nurse, or a teacher, space will soon just simply be a new habitat for thousands. In a future not too distant from now, astronaut wings will be commonplace among the peoples of the world.

Another interesting panel discussion was hosted by top level employees at three major launch vehicle providers. Kent Rominger, a former veteran astronaut, represented ATK (Alliant Techsystems) as the VP of Advanced Programs. Lawrence Williams represented SpaceX as the VP of Strategic Relations. Lastly, George Sowers, VP of Business Operations at ULA (United Launch Alliance) was present. Each gave a brief presentation of the launch vehicles that their respective companies are responsible for. Unfortunately, I was absent during George Sower's talk, but I got a chance to attend the ATK and SpaceX presentations. The Liberty rocket, under development by ATK, utilizes a modified Shuttle SRB (Solid Rocket Booster) as its first stage and a Vulcan cryogenic engine from Ariane 5 as its second stage. It appeared to be quite a viable competitor as a commercial launch provider for NASA.

One outdoors session in particular was dedicated to hardware exhibitions. Present were Colorado School of Mines' robot from last year's NASA Lunabotics Competition and a functional monopropellant-powered lunar lander prototype designed by SpeedUp, LLC and built/tested with help from Frontier Astronautics. However, the hybrid propellant suitcase rocket demonstration by the Rocket City Space Pioneers definitely drew the largest crowds.

SpaceVision allowed me to really feel the burgeoning need to push for development of space. Benefits lie far above and beyond the realm of just the science and space community. The unique weightless research environment provided at the International Space Station is currently being harnessed for a wide array of fields from biotech to materials science. Alan Stern, VP of R&D at the Southwest Research Institute, described how some bacteria express genes differently in space and how that knowledge base is providing insight into cancer research.

In returning back to the world of engineering classes and routine habits, I felt that intellectual hangover from 'partying' all weekend to the talks of great rock-stars in the space industry. For us space geeks, it was that one convergence point where we could share and discuss our hopes and dreams. Unsurprisingly therefore, I started to look forward to SpaceVision 2012 the moment I boarded my flight out of Denver, CO!

SpaceVision 2011 held by CU-SEDS in Boulder Colorado. SpaceVision is the largest student-run space conference in the nation. It's dedicated to facilitating networking between college students, professionals, and the public, furthering the development of the National Committee (SEDS-USA), and sharing ideas through interactive lectures and workshops.

Top Stories of 2011

We polled the chapters to see what they thought the top news stories of 2011 were and with the drop of the ball - the results are in!

1

Launch of the Mars Science Laboratory, the rover "Curiosity"

The Mars Science Laboratory began its historic voyage to Mars with the Nov. 26 launch of a United Launch Alliance Atlas V. Liftoff from Cape Canaveral Air Force Station occurred at 10:02 a.m. EST (7:02 a.m.) and the car-sized rover is now flying free with an intended arrival date of August 6, 2012.

2

Retirement of the Space Shuttle

After 30 years of spaceflight and more than 130 missions, NASA's Space Shuttle program ended with the landing of Atlantis on July 21, 2011. After undergoing "Transition and Retirement Processing," Atlantis will be moved to public display at the Kennedy Space Center in Florida. Enterprise, the first orbiter, will move to the Intrepid Sea, Air & Space Museum in New York. Discovery, which retired after completing its 39^{th} mission in March, will be on display at the Smithsonian's National Air and Space Museum Steven F. Udvar-Hazy Center in Virginia. Endeavour will go to the California Science Center in Los Angeles.

3

Potential for water and life on Mars

Using the most powerful camera ever to orbit Mars, Alfred McEwen and his colleagues at the University of Arizona are reporting the strongest evidence yet for water on Mars that's flowing, not frozen—and the water is flowing today, not a millennium or an eon ago. At a few spots, the meager warmth of martian summer seems able to coax enough liquid water out of the ground to darken the soil in streaks. The marks, which sometimes number in the hundreds, flow downhill only to fade with the winter cold. Now, as they say, where there is liquid water there could be life.

4

The Mars curse continues, Russia's Phobos-Grunt stuck in LEO

Phobos-Grunt was an attempted Russian sample return mission to Phobos, one of the moons of Mars. This interplanetary probe was successful launched on November 9, 2011, but rocket burns intended to put the craft on a transfer orbit to Mars failed, leaving Phobos-Grunt stranded in low Earth orbit. Weighing13 tons, Phobos-Grunt was the largest interplanetary probe ever built and subsequently became one of the largest pieces of space junk in history. After efforts to reactivate the craft were unsuccessful, it fell back to Earth in an uncontrolled re-entry over the Pacific Ocean west of Chile on January 15, 2012.

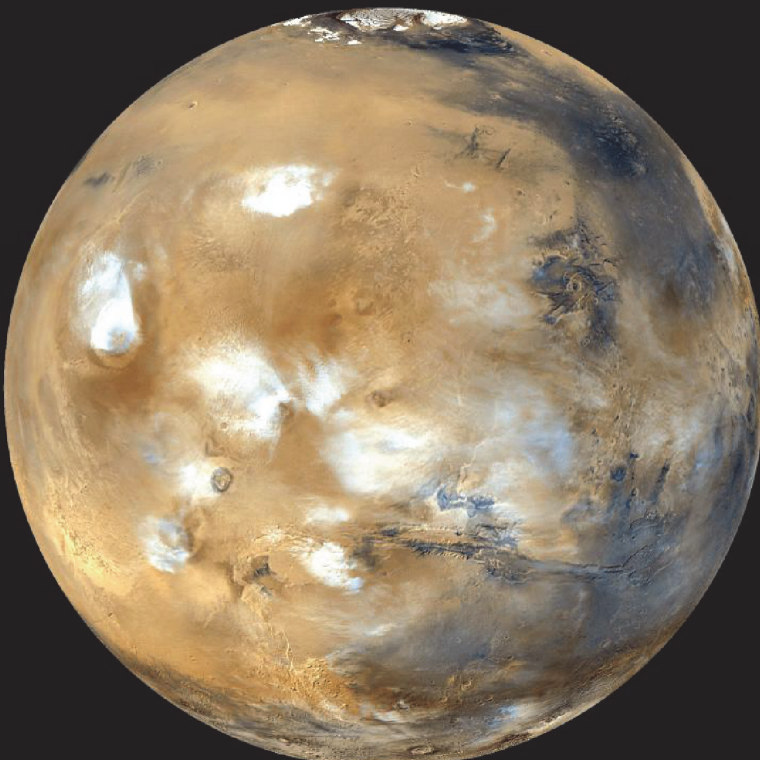
5

50th Anniversary of Vostok 1, Yuri Gagarin's first flight in space

Vostok 1 (Russian: Восток-1, *East 1* or *Orient 1*) carried Yuri Gagarin into history on April 12, 1961. On this date, 50 years ago, he became the first human in space.

Tracers of Habitability /

Looking for signs of life on Mars



by Harvey Elliott

The possibility of life on Mars is arguably one of the most intriguing topics of modern science - it's practically a modern day quest for the holy grail. While abundant work has been done in an attempt to settle the question, it seems likely that we'll need boots (or bots) on the ground to answer this one. MSL is the next, but likely not the last in a series of missions to "follow the water" and search for signs of life on Mars. In this article we will review what we know and what we need to know about the habitability of our nearest planetary neighbor.

What do you need for life?

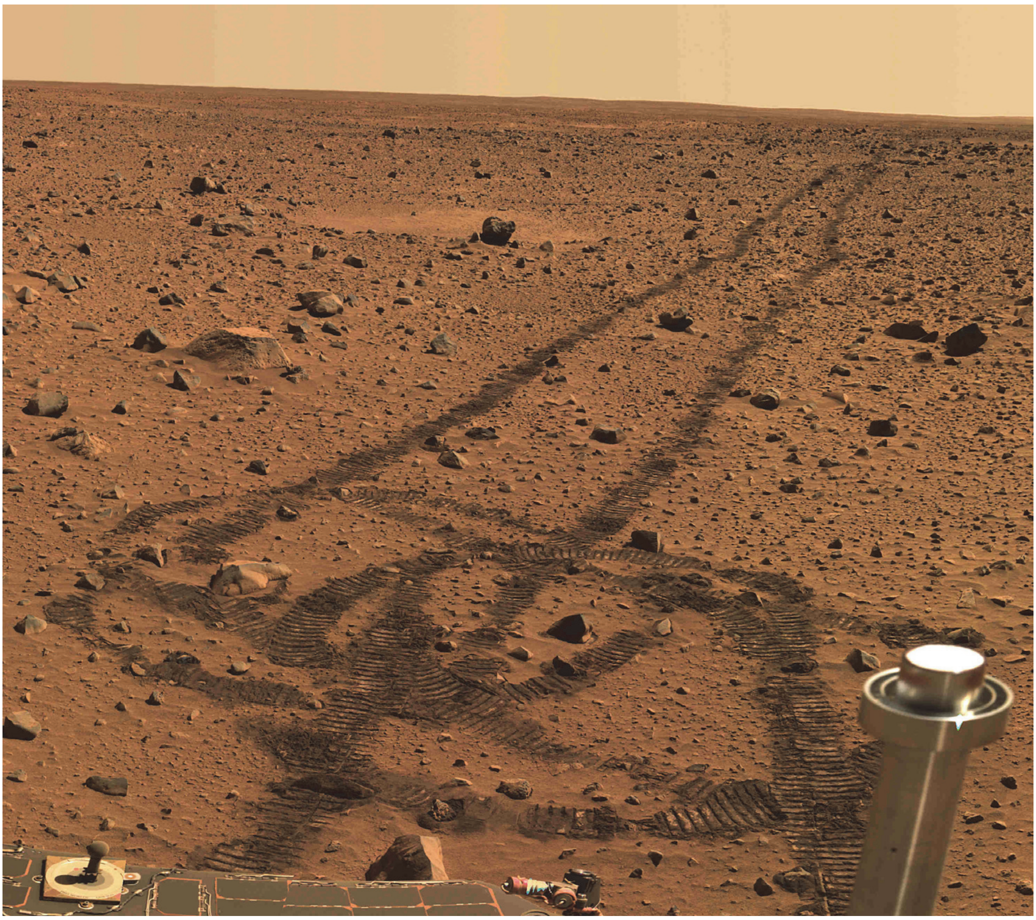
Since there is no unequivocal definition of life, one might start looking for life by searching for the requirements of life here on Earth. We know of four basic prerequisites for the existence of life as we know it: (1) chemical building blocks, (2) presence of an energy source, (3) liquid water (or alternative liquid environment), and (4) time, i.e. the stability of these conditions in the environment.

For number one, life as we know it is based on "CHNOPS" carbon, hydrogen, nitrogen, oxygen, phosphorus, and sulfur. Although more than 25 types of elements can be found in biomolecules, these six elements are most common. This is convenient because the first four are also the most common in cosmic abundance. Thinking of the Earth and Mars as comparatively similar planets, it's reasonable to assume all these elements would be readily available on both worlds.

For the second point, Mars is the Earth's closest neighbor and receives a similar amount of Solar flux. The planet also shows signs of geothermal activity and volcanism in its past. It is reasonable to assume that life on Mars would have access to similar power sources as life on Earth.

The third point here is really critical as it plays a role in organic chemistry and the transport of molecules within the cell. That is why we often define the habitable zone of a solar system as the goldilocks region that is not too hot or too cold for liquid water to be stable on planetary bodies. This is where Mars falls short. While there is evidence for the presence of liquid water on ancient Mars, the atmosphere today is too thin and too cold for the stability of pure liquid water. Small microhabitats may exist, but these habitats would likely be in flux which brings us to #4 - time.

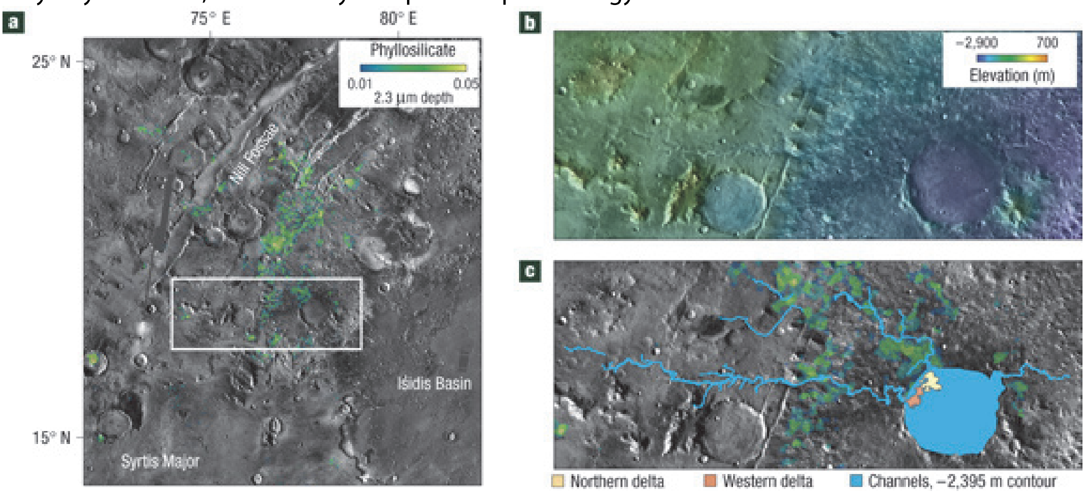
Life needs time and stable habitats to develop. We do not know how long it takes life to develop, but we do know it is not instantaneous. The real question about life on Mars is did it have enough time to develop - and if it did - are there still signs of it there today?



The Mars Exploration Rover "Spirit" looking back at its tracks while enroute to the Columbia Hills. As you can see - modern Mars is not a very hospitable place - but new research may change the way we look at the red planet. (NASA/JPL-Caltech)

Stability of Paleontological life

Research suggests that the Noachian period (4.1-3.7 Ga) on Mars provided the best chance for life to develop on Mars. This claim is supported by satellite observations, rover measurements, and laboratory models that suggest the four requirements for life could have been satisfied on early Mars. Overwhelming geomorphological and geochemical evidence for the presence of liquid water has been consecutively confirmed by several missions, such as Mars Express and Mars Odyssey's THEMIS, as well as by comparative planetology.



Mars Odyssey THEMIS day infrared image with overlain OMEGA phyllosilicate detections. (Ehlmann et al., 2008)

The availability of organic carbon and biologically essential elements could be supplied by volcanic sources, and silicified volcanic sediments have been detected. At the same time, surface water requires a relatively dense atmosphere, most likely consisting of primarily CO_2 with mixed greenhouse gases, such as methane, thus the first condition could also be an indication of the second one. Simulation results indicate that the increased atmospheric pressure in the Noachian period would have diminished harmful radiation, thereby providing for more habitable conditions. (Ehresmann et al., 2011) However, all of the above conditions come from the derivations about the historical Mars according to the current observations; the existence and stability of these conditions are still in question.

Stability of Extant life

In the view of possible reaction for life emergence on Mars, the interaction between volcanic activity and ice can generate substantial quantities of liquid water, together with steep thermal and geochemical gradients typical of hydrothermal systems. (Cousins and Crawford, 2011). Since there has been widespread evidence of putative volcano-ice interaction on Mars throughout its history it is possible that life had a chance to take hold in one of these environments. Another critical feature of these environments is the presence of sedimentary and mineralogical deposits that could potentially preserve any indigenous microbial populations, or the evidence that extant life formed in early Mars. The recent discovery of liquid brine flows on the surface of Mars provides another intriguing possibility for the existence of extant life - which we will discuss more in this article. That means that a future surface mission could potentially unearth and find evidence of extant life.

Martian Methane? Where did it come from? Where does it go?

One of the most puzzling aspects of Mars is that organics haven't been found on the surface. The existence and behavior of methane on Mars is of great significance as methane is a potential biomarker. Here we first review the current understanding of possible sources and sinks of methane and then discuss the temporal and spatial variability of methane on Mars. Methane can be produced from exogenous sources, internal sources, or biological sources.

Exogenous Sources

Meteorites are an exogenous but unlikely source of methane. Comets on the other hand have a little more potential as a likely source. An impact by a few hundred meter comet on Mars in the recent past is possible but would only count for a small fraction of the observed methane at best.

Internal Sources

Volcanic origin of methane is unlikely as an internal source since SO_2 has not been readily detected on Mars. On the contrary, hydrogeochemical sources at relatively low temperatures (~40° C - 90° C) are a more likely scenario. On Mars such temperatures are reached at a depth of ~2 km below the surface. The serpentinization reactions (low-temperature metamorphic processes involving heat and water) for methane require an aqueous phase. In these reactions H_2(aq) reacts with carbon grains or CO_2 of the crustal rocks/pores to produce methane or higher order hydrocarbons. (Atreya et al., 2007) Either of these processes could have happened in the past. The produced methane could have been stored as stable methane hydrate in subpermafrost aquifer and gradually released to the surface. There could exist regions of soil ideal for these methane- producing serpentinization reactions to take place.

Biological Sources

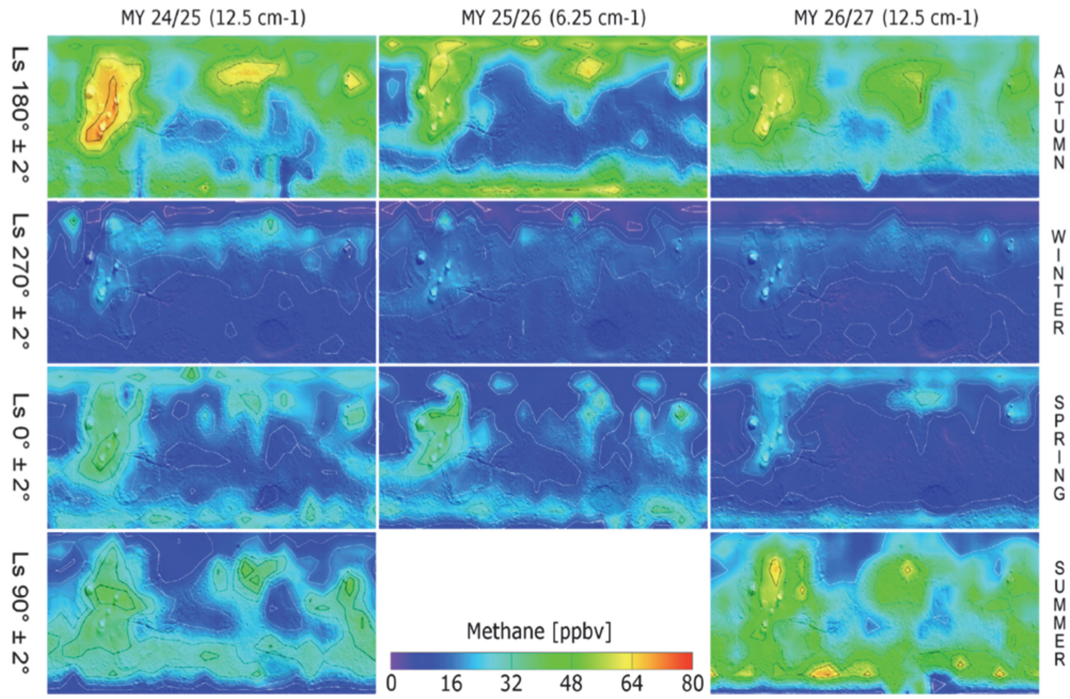
Methanogens that use CO or H_2 for energy are candidates for current biogenic sources. Microbial colonies could exist in the subpermafrost aquifer environment on Mars and produce methane by utilizing CO and/or H_2. This would provide an adequate source for current levels of observed methane. It is also possible that methane could have been produced in the past by microorganisms living on Mars during an epoch when conditions were more favorable. This methane could then be stored in methane-hydrates and gradually released. (Atreya et al., 2007)

Possible Sinks

The conventional loss mechanism of methane in the Martian atmosphere is photochemistry. It includes UV photolysis in the middle and upper atmosphere and oxidation by O(1D) and OH below. (Atreya et al., 2007) Furthermore there exists the possibility of heterogeneous loss to the surface. For this process, hydrogen peroxide (H_2O_2) is essential, which was only recently detected in 2003. The presence of this oxidizer can lead to a reactive Martian surface, which could remove methane much more efficiently than the photochemical loss processes. However, this faster loss would imply a faster production rate and greater non- uniformity in methane, which places a greater burden on the source.

Spatial and Temporal Variation

The spatial distribution of methane on Mars is not uniform. The three broad regions where the concentration of methane is systematically higher are Tharsis, Arabia Terrea and Elysium. The higher concentration of methane around Elysium and Tharsis is related to the geological and hydrological activity in this region. Arabia Terrea has an extensive subsurface deposit of permafrost, which is enriched in hydrated silicates. (Fonti et al., 2009) For both the geological and biogenic processes, an underground aquifer would be a necessary condition.



The spatial and temporal distribution of methane on Mars (Fonti et al., 2010)

Turning to the temporal evolution of methane abundance, we note a seasonal cycle and year-to-year variation. Additionally, the distribution of methane varies from one year to the next. For seasonal cycles, methane gets the maximum relative abundance in autumn, a sharp decrease in winter, a slight increase in spring and a further increase in summer. It is evident that the highest concentrations are related to the warmest seasons. The high energy in these seasons could trigger both geological processes and an outbreak of biological activity. (Fonti et al., 2009)

For either biologic or geologic origin of methane, liquid water is essential. If methane is actively being produced on Mars, this would imply that there are underground aquifers. If methane was produced during a past warm period, when liquid water flowed on the surface, it could have been stored as a clathrate compound, and is being released from time to time when the clathrate source becomes unstable. In order to better understand the production mechanism of methane on Mars, more information is required, especially on the distribution of water.

Water on Mars?

Both hydrogeochemical and biological process that produce methane require the presence of water. Liquid water is also a necessary ingredient for life as we know it. Here we will look at evidence for ancient water on Mars, how water may have been lost in the past, and evidence that water is still there today.

Evidence for Ancient Water – Minerals

Evidence for an ancient wet environment on Mars includes ground based observation of minerals that can only form in the presence of liquid water. It has been inferred that the landing site of the Martian rover Opportunity was once saturated for a long period of time with high salinity, acidic liquid water. Evidence for this is supported by the observed presence of cross- bedded sediments, spheroids (aka blueberries) which appear in concretions, vugs inside rocks, and the presence of large amounts of sulfate-rich minerals such as jarosite and magnesium sulfate (Forget et al., 2008). Opportunity has continued to find further evidence of past liquid water throughout the course of its 8 year journey. Just recently, at the 2011 AGU fall meeting it was announced that Opportunity's latest discovery is an observation of veins of gypsum near the rim of Endeavour Crater, 33 kilometers from its original landing site. The presence of this mineral suggests that liquid water flowed through underground fractures in the rock in which it formed (Phillips, 2011).

Evidence for Ancient Water - Martian Orbiters

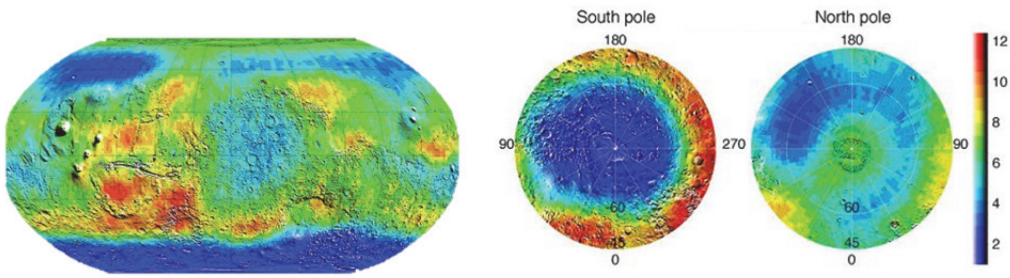
Despite observational clues suggesting that there were once large quantities of liquid water on the surface of Mars, it is certainly not easy to locate surface water today. This raises a simple yet significant question: Where did all the water go? The answer appears to be that it went... up. Water vapor is dissociated by high-energy photons in the Martian atmosphere, after which a portion of its constituent atoms (H and O) are stripped from the upper atmosphere by the solar wind, an effect that occurs more readily in Mars' atmosphere than Earth's due to the absence of a strong protective magnetic field around Mars. This process has dealt a one-two blow to the Martian water supply. In addition to Mars having lost much of its water in this manner, it is this atmospheric loss, resulting in a thin atmosphere unable to provide a large greenhouse warming effect, which has left the surface of Mars with temperatures and pressures insufficient for the remaining water to exist as a liquid on the surface.

D/H Ratios Implying Atmospheric Loss of Ancient Water

Evidence that vast quantities of water have been lost in this way come in the form of measurements of the ratio of deuterium (D) to hydrogen (H). Because Deuterium has roughly twice the mass of the dominant isotope of hydrogen, the atmospheric mixing ratio of deuterium falls off more rapidly above the homopause. Hydrogen, on the other hand, which has a much larger scale height, remains relatively abundant at the high altitudes at which atmospheric loss takes place. We would expect, therefore, that far more hydrogen is lost than deuterium, resulting in enhanced D/H ratios on Mars. This is, in fact, exactly what has been observed. The first measurements of this kind came from ground-based observations in the late 1980s (Owen et al., 1988). Results of spectral analysis showed that the Martian atmosphere has a D/H ratio six times that found on Earth. Highly accurate measurements of both the D/H ratio and the loss rate of hydrogen, which will be used to calculate the amount of water lost, will be provided by MAVEN, which is scheduled to launch in late 2013.

Evidence for present day water on Mars - Martian Orbiters

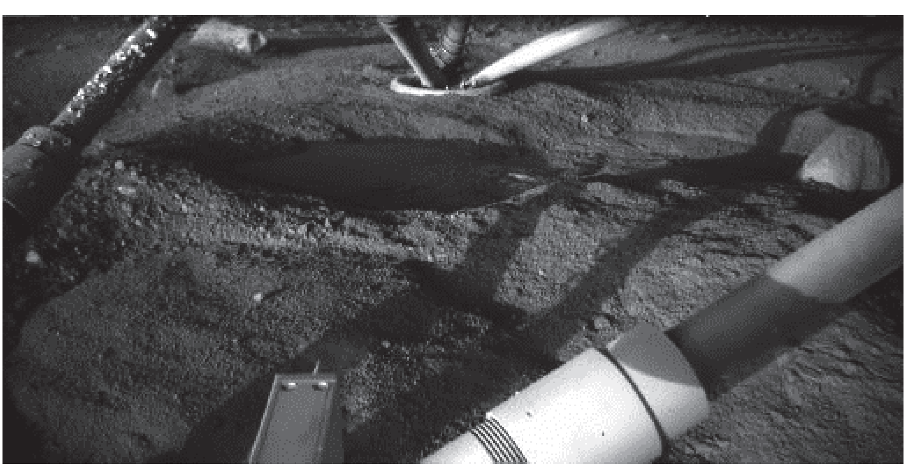
Water cannot be a liquid on the surface of Mars, but it can and does exist as ice. Mars Odyssey has two instruments that have been used to locate water on Mars. One is the Thermal Emission Imaging System (THEMIS), which collects data on the temperature of the Martian surface. Different temperatures correspond to different materials. In Mars' polar regions, this has allowed THEMIS scientists to distinguish between CO_2 ice, H_2O ice, and dry soil. It has been known for some time that H_2O ice exists on the north polar cap, but THEMIS revealed that water ice is present in the south as well. During southern summer, when melting causes the CO_2 ice cap to recede, a layer of H_2O appears as a region whose temperature seems to indicate water ice (Titus et al., 2003). Another instrument aboard Odyssey capable of detecting the presence of water ice is the Gamma Ray Spectrometer (GRS). Penetrating one meter into the Martian surface, GRS is able to identify the composition of near-surface materials. Where large amounts of hydrogen is seen, the presence of H_2O is inferred. In this way GRS supports THEMIS data in identify water ice around the south pole. The layer of H_2O ice at the north pole, though present, is currently hibernating beneath a layer of CO_2 ice too thick for GRS to penetrate.



In these false--color maps of the Martian surface, deep--blue indicates soil enriched by hydrogen. The South pole is surrounded by icy terrain. The North pole contains water--ice, too, but it is hidden for the moment by a wintertime layer of carbon dioxide frost. (NASA/JPL-Caltech/Los Alamos National Laboratory)

Evidence for present day water on Mars – Phoenix

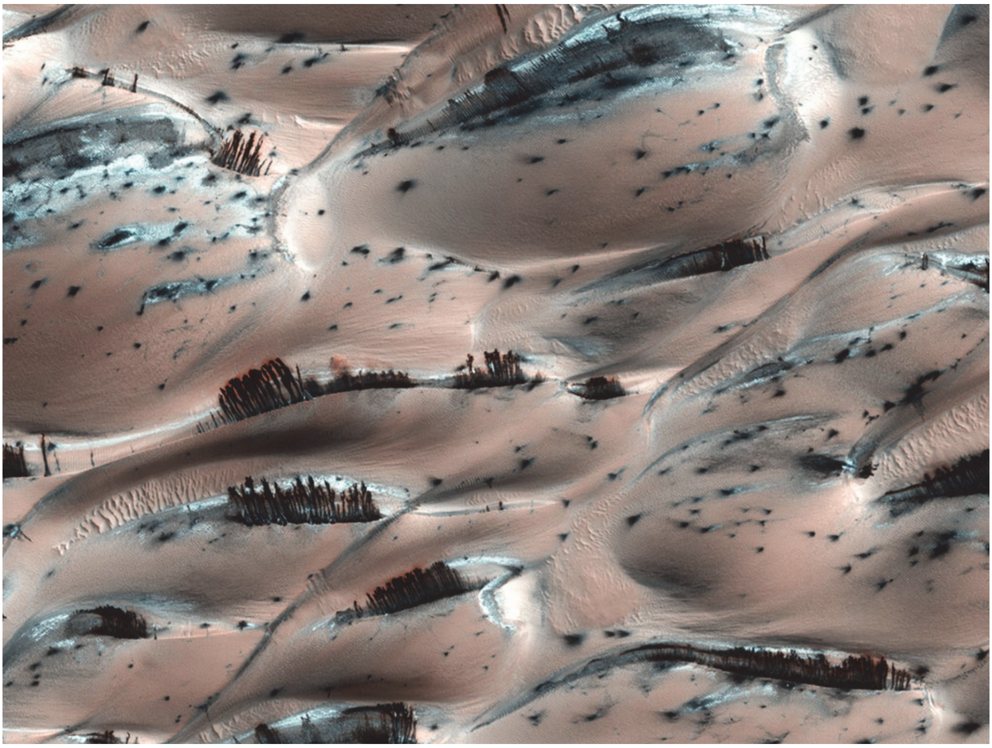
In 2008 the Phoenix Mars lander set down near the Martian north polar region. Its objective was to see if the polar region could support life. During landing its thrusters removed the top soil revealing subsurface water ice. It is believed that without this layer of soil, the water ice will sublimate under the Martian atmospheric conditions. However the wet chemistry lab (WCL) on board Phoenix found large amounts of perchlorates and magnesium ions in the soil at the landing site. When exposed to the atmosphere these salts become efficient at absorbing large amounts of water. This lowers the freezing point temperature and vapor pressure of aqueous solutions. In theory this provides support for the possibility that liquid saline- water can actually exist on the surface under Martian atmospheric conditions (Renno et al., 2009). Some images may show signs of liquid water condensing on the lander's legs, however, this claim remains hotly contested.



The Robotic Arm Camera on the Phoenix Mars Lander took this view under the spacecraft on Sept. 1, 2008, the 97th Martian day of the mission after landing. The lander leg strut at upper left features clumps larger than those seen three months ago. Also, exposed patches beneath the lander are darker than they used to be. (NASA/JPL-Caltech/University of Arizona/Max Planck Institute)

Liquid Water and Mars Today

McEwen et al. 2011 describes recurring slope linea (RSL). RSL's are found in the mid-high latitudes (~48°S to 32°S) and occur on bedrock slopes. They are about 0.5 to 5 meters in width and on the order of ~kilometer in length. Repeat observation by the High Resolution Imaging Science Experiment (HiRISE) instrument on board the Mars Reconnaissance Orbiter has shown that these markings incrementally grow during warm seasons and then slowly vanish during cold seasons. Their location and the fact that RSL's tend to occur during seasonally high surface temperatures supports the idea set forth by Renno et al. (2009) that the mixing of perchlorates with water causes it to liquefy. This briny fluid can then seep out of the bedrock onto the surface.

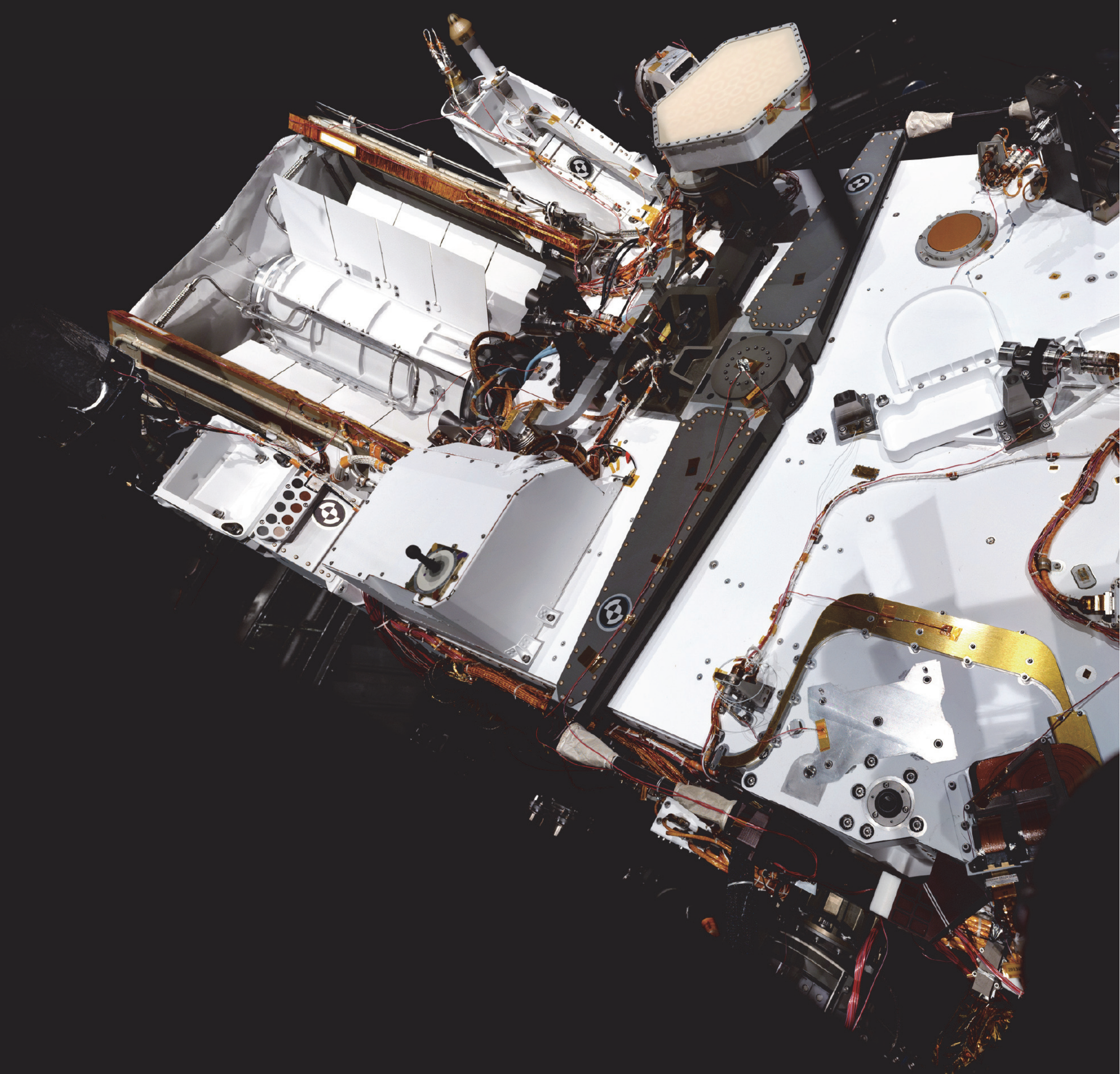


There is a vast region of sand dunes at high northern latitudes on Mars. In the winter, a layer of water and carbon dioxide ice covers the dunes, and in the spring as the sun warms the ice these slope streaks appear. This is a very active process, and could be a sign of liquid brine flows on Mars. (NASA/JPL-Caltech/University of Arizona)

So, is Mars habitable?

The possibility of the presence of life on Mars is a tantalizing one. What if Earthlings (to use the term broadly) are not alone in our solar system? Mars is at the top of a very short list of solar system bodies that may yet be found to harbor life. Though the odds against it are great, current observations have not been able to rule out the possibility of past–or even present–life. Methane, which on Earth is produced primarily through biological processes, has been detected in the Martian atmosphere, often in regions that also display traces of water. Because the production of methane (if current) implies the presence of liquid water, and because water is paramount among the requirements for life, an intense search for water has been underway by the scientific community for over a decade. Mars is thought to have once been home to vast quantities of water. Measurements made of water in its gaseous and solid forms indicate that a portion of this water still remains. Most exciting of all, high-resolution imaging is beginning to detect what may well be flows of salty water in warmer regions of the Martian surface. These flows could have as their source large underground aquifers that are – as of yet – undiscovered.

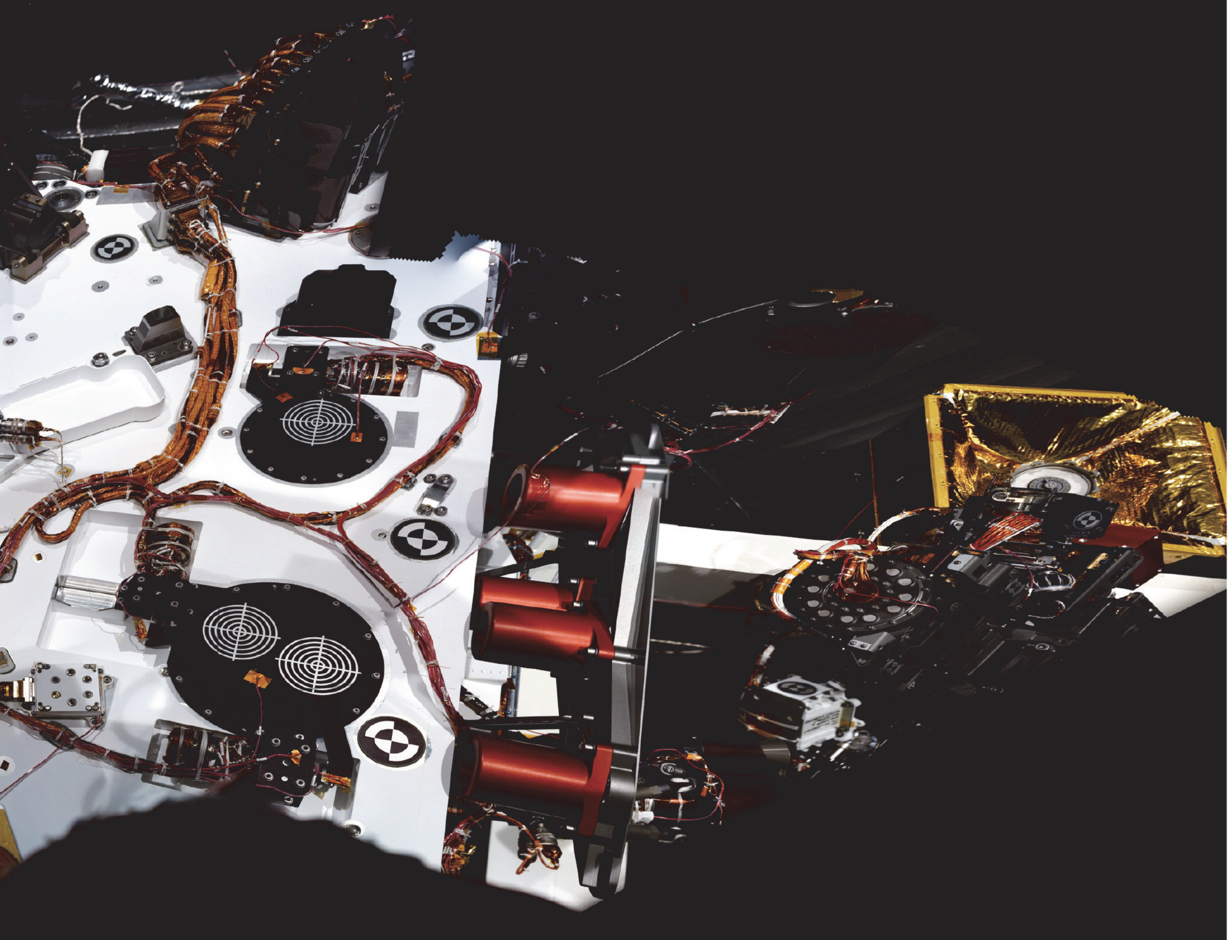
Meet "Curiosity" the



Mars Science Laboratory

by Harvey Elliott

10:02EST on November 26, 2011 – An Atlas V-541 blasted off from Florida's Cape Canaveral Air Force Station starting the Curiosity rover on the first leg of its 8 month journey to Mars. While 8 months in interplanetary space may seem like a long time, it's nothing compared to the decade many scientists, engineers, and technicians have already spent preparing for this moment. This state of the art rover, representing investment of over $2.5 billion dollars, took a herculean effort to build. So, what's the payoff? When this "scientist's dream machine" lands in Gale crater later this year, it stands to answer some of the key questions regarding the past and present habitability of the Red Planet.



Specifications – *from Wikipedia*

Dimensions: The rover Curiosity is 10 ft (3.0 m) in length, and weighs 1,984 lb (900 kg) including 176 lb (80 kg) of scientific instruments. That means it's approximately the size of a Mini Cooper.

Speed: Once on the surface, Curiosity will be able to roll over obstacles approaching 75 cm (30 in) high. Maximum terrain-traverse speed is estimated to be 90 m (300 ft) per hour by automatic navigation, however; average traverse speeds will likely be about 30 m (98 ft) per hour, based on variables including power levels, terrain difficulty, slippage, and visibility. MSL is expected to traverse a minimum of 12 mi (19 km) in its two-year mission.

Power: Curiosity's power generator is the latest RTG generation built by Boeing, called the "Multi-Mission Radioisotope Thermoelectric Generator" or MMRTG. Based on classical RTG technology, it is designed to produce 125 watts of electrical power from about 2000 watts of thermal power at the start of the mission. The MMRTG produces less power over time as its plutonium fuel decays: at its minimum lifetime of 14 years, electrical power output is down to 100 watts. MSL's MMRTG will generate 2.5-kilowatt hours per day compared to the Mars Exploration Rovers (MER) which can generate about 0.6 kilowatt hours per day. The MMRTG aboard Curiosity is fueled by 32 pellets each about the size of a marshmallow.

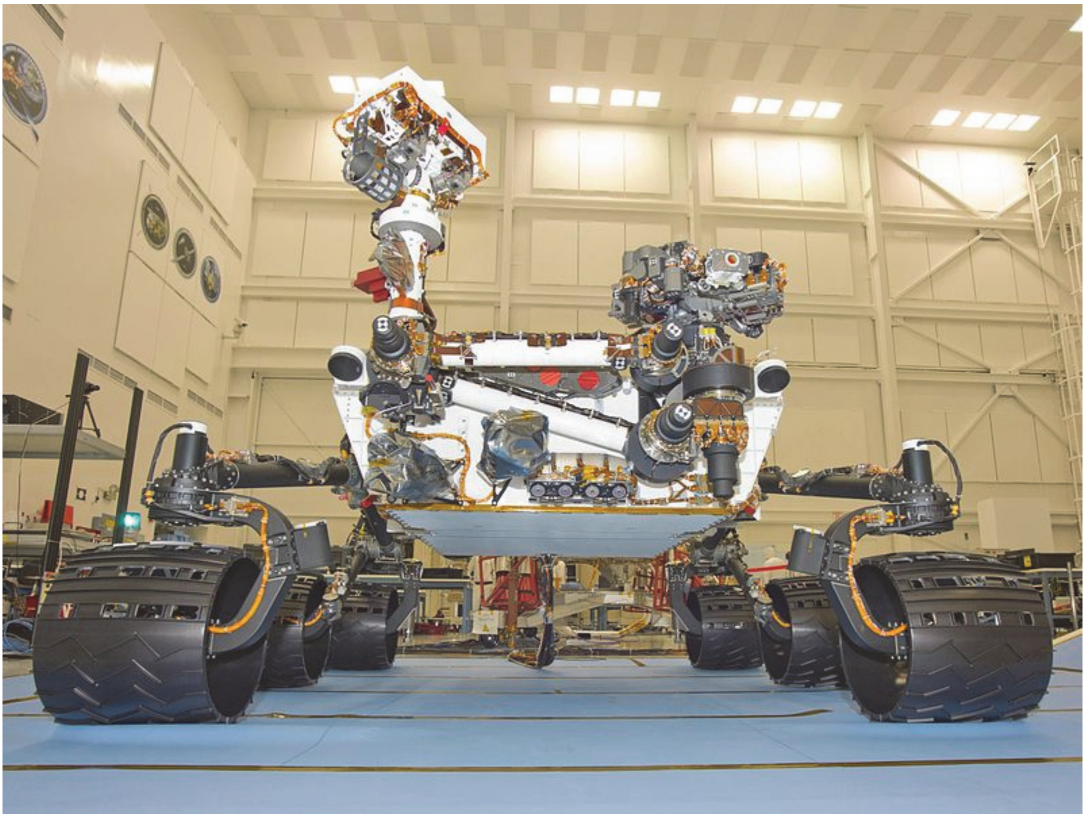
Heat rejection system: The temperatures in the potential areas at which Curiosity may land can vary from +30 °C to −127 °C (+86 °F to −197 °F). Therefore, the Heat rejection system (HRS) uses fluid pumped through 60 m (200 ft) of tubing in the MSL body so that sensitive components are kept at optimal temperatures.

Computers: The two identical on-board rover computers, called "Rover Compute Element" (RCE), contain radiation hardened memory to tolerate the extreme radiation environment from space and to safeguard against power-off cycles. The RCE computers use the IBM RAD750 CPU which is a successor to the CPU used on MER and capable of more than 10 times as many instructions per second.

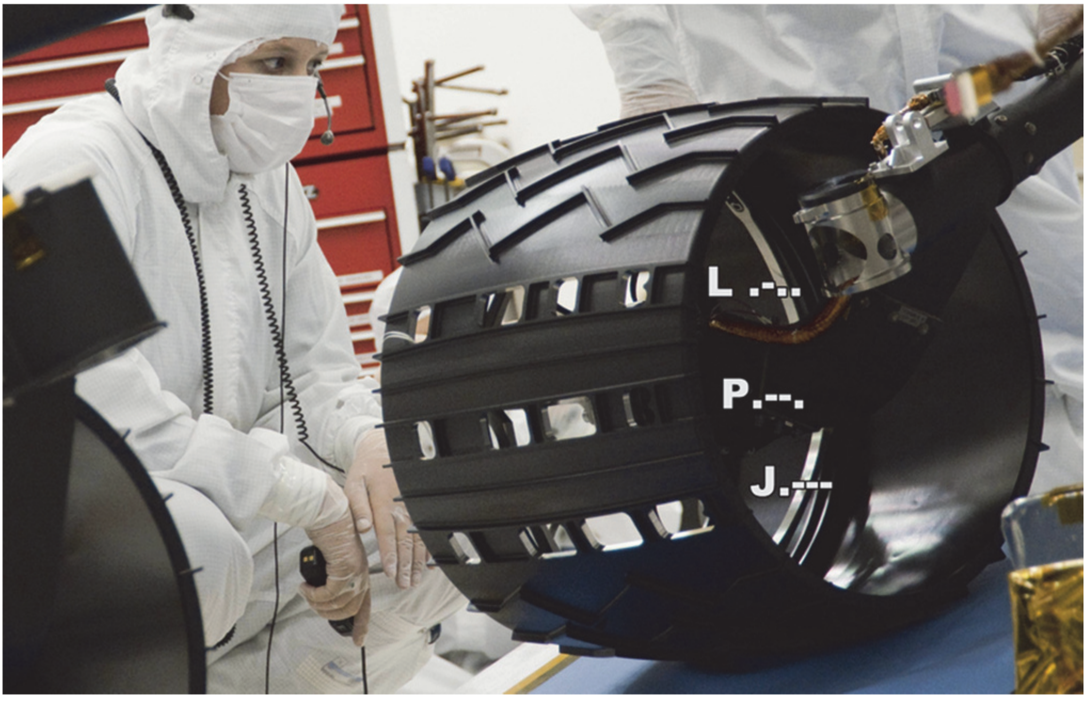
The rover has an Inertial Measurement Unit (IMU) that provides 3-axis information on its position which is used in rover navigation. The rover's computers are constantly self-monitoring to keep the rover operational, such as by regulating the rover's temperature. Activities such as taking pictures, driving, and operating the instruments are performed in a command sequence that is sent from the flight team to the rover. In the event of problems with the main computer, the backup computer will take over.

Communications: Curiosity has two means of communication – an X-band transmitter and receiver that can communicate directly with Earth, and a UHF Electra (radio)-lite for communicating with Mars orbiters. Communication with orbiters is expected to be the main contributor to data return to Earth, since the orbiters have both more power and larger antennas than the lander. At landing time, 13 minutes, 46 seconds will be required for signals to travel between Earth and Mars.

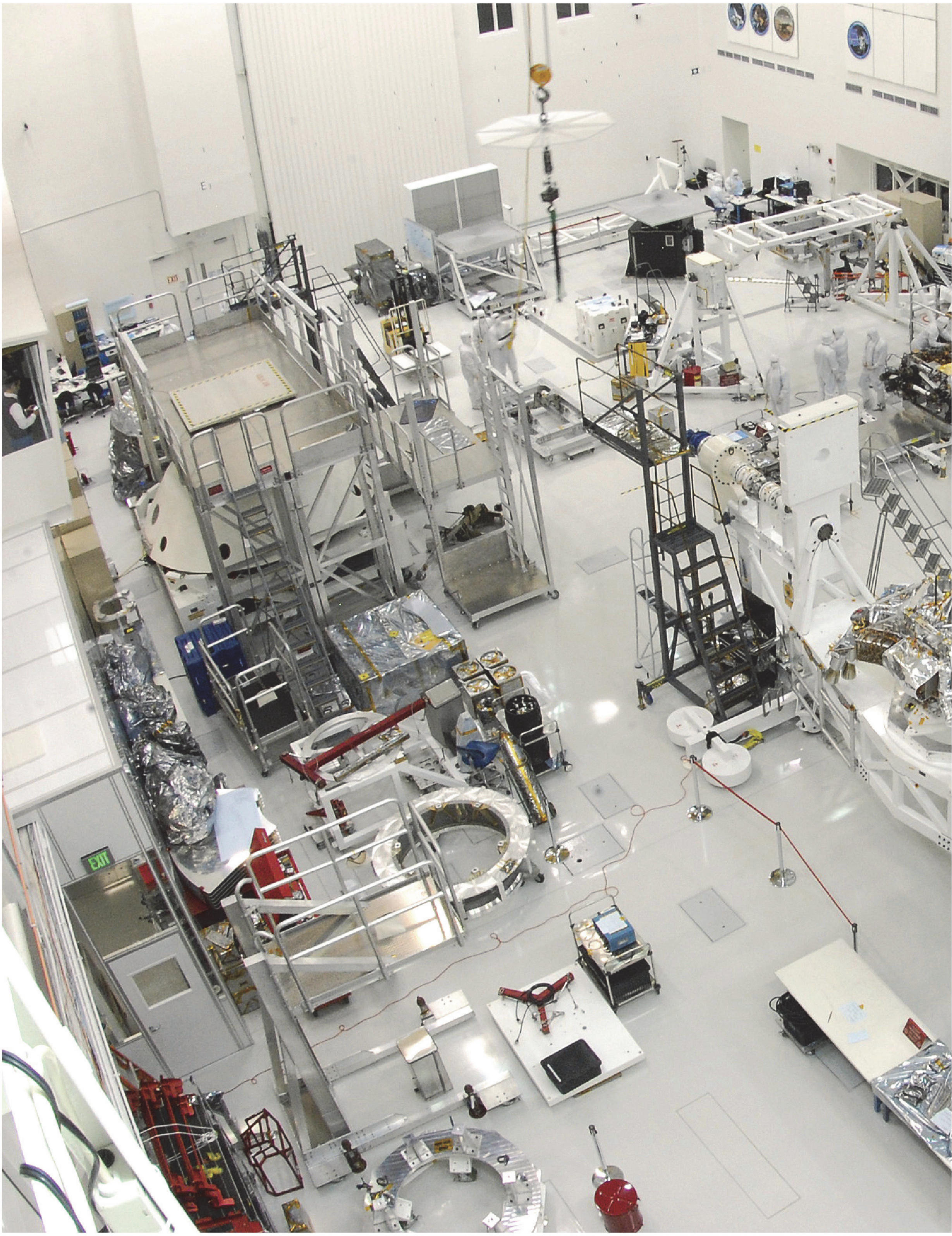
Mobility systems: Like the MER rovers and Mars Pathfinder, Curiosity is equipped with 6 wheels in a rocker-bogie suspension system. Curiosity's wheels are significantly larger than those used on the previous rovers and will also serve as landing gear. Each wheel has a pattern, which is used by on-board cameras to judge the distance traveled and as an added bonus the pattern itself is Morse code for "JPL" (·--- ·--· ·-··).



Say “hello” to the Mars Science Laboratory rover, Curiosity. This image was taken during mobility testing at JPL’s Spacecraft Assembly Facility in Pasadena, California. (NASA/JPL-Caltech)



Detail of Mars Science Laboratory Curiosity Rover with tread pattern which will leave an impression on the Martian surface spelling "JPL" in Morse code. (NASA/JPL-Caltech)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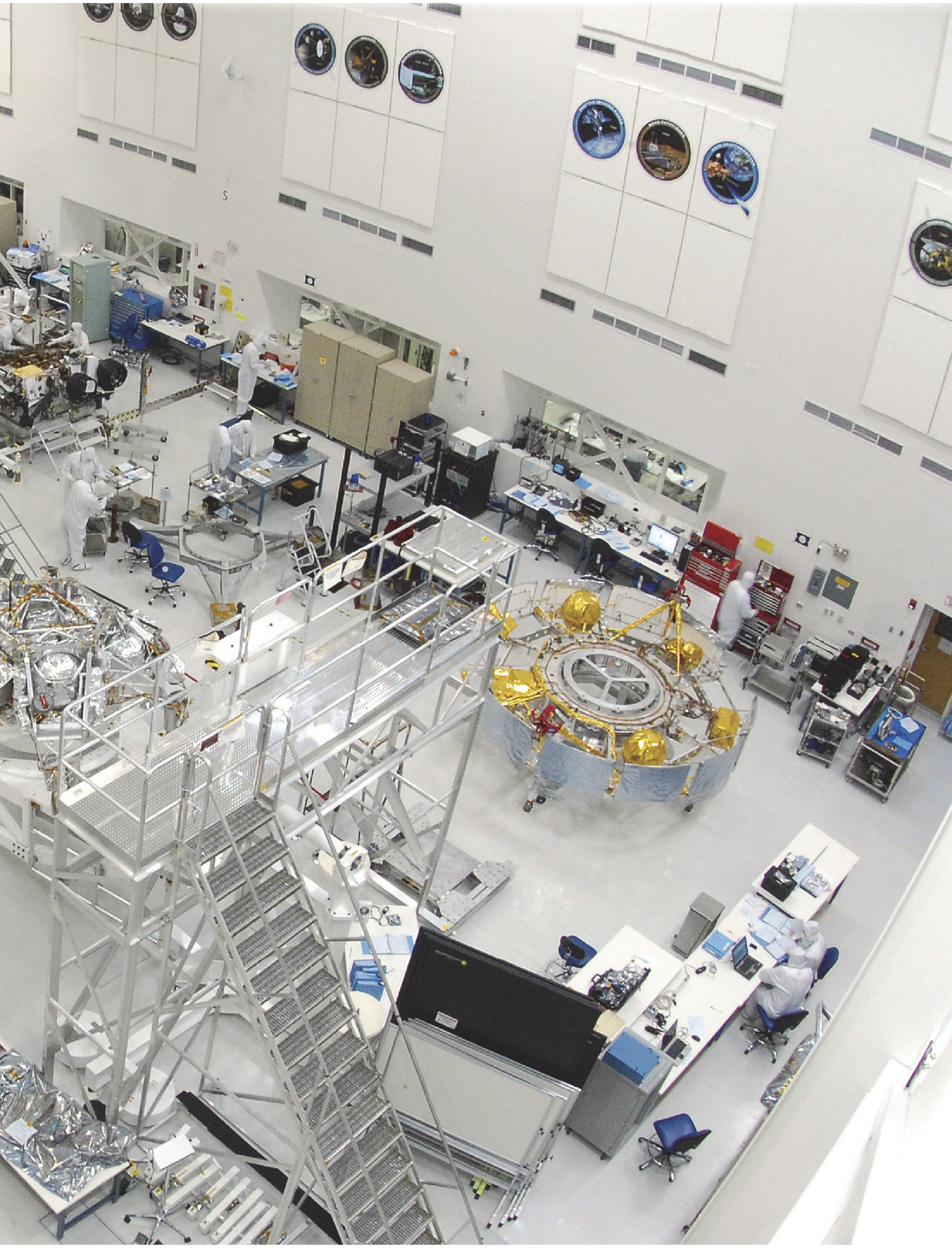
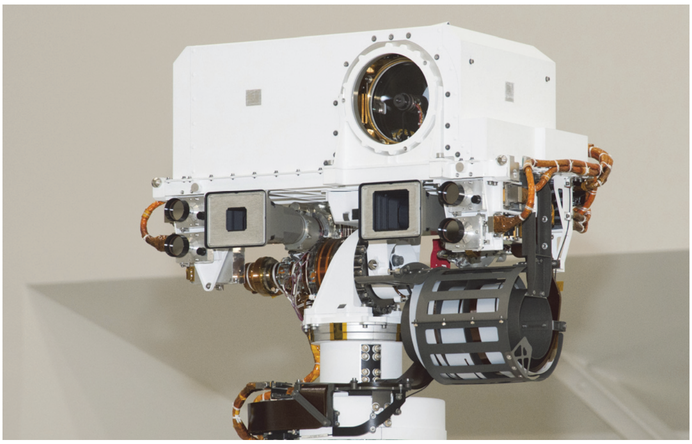


Assembly, Test and Launch Operations (ATLO) in the Jet Propulsion Laboratory. (NASA/JPL-Caltech)

Instrumentation - *The eyes, ears, nose and mouth*

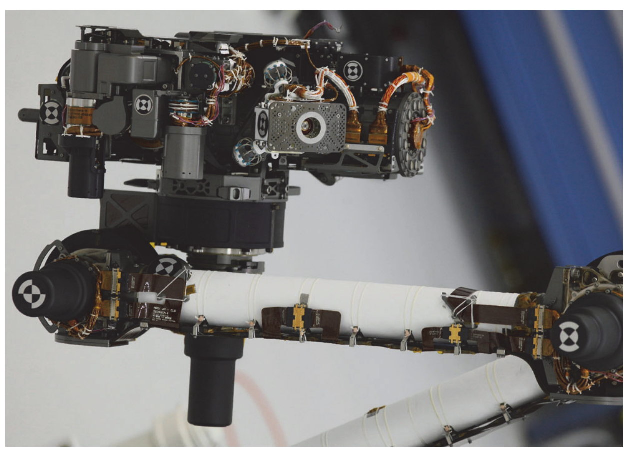
Cameras (MAHLI and Mastcam)

MAHLI and Mastcam will look for signs of habitability by acting as the eyes of the rover. Mastcam can provide the panoramic views of the surrounding area and MAHLI can be used for imaging interesting objects more closely. Both cameras will image geological features that the rover may want to explore or sample. The Mars Exploration Rovers (MER), Mars Reconnaissance Orbiter (MRO) and Pathfinder all used similar cameras. New features include: improved resolution, high definition video, and improved data handling and storage capabilities. These features will build upon the discoveries made by previous cameras. (Malin et al., 2005; Edgett et al., 2009)



Mastcam and ChemCam looking across the bay during ATLO. (NASA/JPL-Caltech)

Several examples of cameras making important habitability discoveries include the Opportunity Rover's images of the "Tisdale 2" rock formation, the "Homestake" gypsum vein (Phillips, 2011), and the hematite "blueberry" geological features (Squyres et al., 2004), which indicate the presence of ancient water. Another is the characterization of the water cycle from imaging the crusty surface and salty sand under the trapped Spirit rover (Coulter, 2009). In the past, cameras have made valuable contributions to the search for habitability, and it is expected that Mastcam and MAHLI will contribute in a similar manner.



MAHLI and APXS on the robotic arm. This super-limb lifts 34 kilograms (almost 75 pounds) of instruments to reach out and test martian rocks and soil. (NASA/JPL-Caltech)

Alpha Particle X-Ray Spectrometer (APXS)

The APXS instrument images samples by bombarding them with radioactive alpha particles from a Curium 244 source. The instrument then images the backscattering of X-rays resulting from collisions with atomic nuclei within the sample (King, et al., 2010). APXS will be instrumental in detecting abundances of heavier elements such as sodium, magnesium, aluminum, silicon, calcium, iron, and sulfur – elements associated with life as we know it.

MSL's APXS improves upon MER's version of the instrument; the sensitivity for elements with lower atomic numbers has increased threefold and detection capabilities for the heavier elements have increased by a factor of six. The speed at which measurements can be taken has also increased dramatically, with quick analyses taking around ten minutes and a full analysis in three hours.

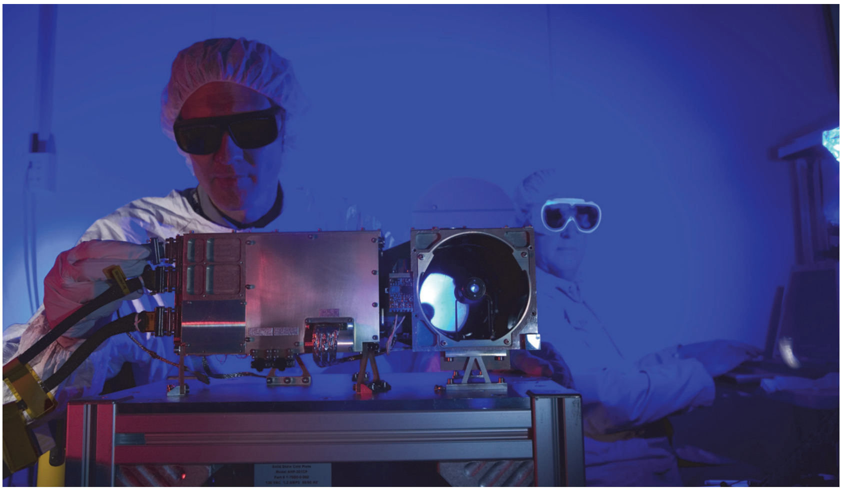
MER's APXS was instrumental in analyzing key samples such as the Homestake gypsum veins and the zinc-rich Tisdale rock, which gave strong evidence of past Martian habitability (Phillips, 2011). The vast improvement in MSL's sensors will be essential to developing these discoveries and furthering the exploration of Mars's past habitable environment.

Chemistry and Camera (ChemCam)

ChemCam is a remote sensing suite consisting of a laser---induced breakdown spectroscopy (LIBS) instrument and remote micro---imager (RMI). Using techniques described below, ChemCam will further the search for habitability on Mars by rapid remote rock elemental composition identification as well as remote identification of surface ices, conducting surveys of soil and pebbles, detecting and studying hydrated minerals and organic materials, analyzing the weathering coating on rocks and studying rock morphologies, indentifying abundances of toxic elements such as beryllium, lead, cadmium, and arsenic, and generally assisting MSL by investigating out-of-reach areas of interest.

ChemCam will fire a 14 mJ laser at a wavelength of 1067 nm at a target in the Martian environment, vaporizing a spot a few hundred microns in diameter, and then image the subsequent flash of plasma produced as the material vaporizes. This plasma is analyzed spectroscopically to determine the makeup of the vaporized material. ChemCam's laser pulse is very short (5 ns), and the instrument is capable of firing multiple pulses at frequencies between 1 and 10 Hz, meaning that the possibilities for rapidly gathering data are numerous. ChemCam is set apart from X-ray spectrometry instruments like APXS in that its spectral range is 240-850 nm, and as such ChemCam is sensitive to light elements such as hydrogen, carbon, oxygen, and nitrogen: all of which are essential to life as it is currently understood. As such, ChemCam is an essential tool for developing out understanding the chemical makeup of the Martian environment, and is designed to complement APXS in the search for habitability on Mars.

ChemCam will work at distances up to seven meters, meaning that it can reach high rocks or take samples in terrain that would be otherwise unreachable for MSL. This feature adds orders of magnitude of versatility compared to previous rovers, ensuring that even if Curiosity becomes stuck the way Spirit did, its data gathering capabilities will not be as severely compromised. (Wiens et al., 2011)



ChemCam uses a pulsed laser beam to vaporize a pinhead-size target, producing a flash of light from the ionized material - that can be analyzed to identify chemical elements in the target. (NASA/JPL-Caltech/LLNL)

Chemistry and Mineralogy (CheMin)
CheMin is a definitive mineralogy instrument that is designed to identify and quantify the minerals in complex natural samples, including Martian rocks, basalts, soils and multicomponent evaporate system. By determining the mineralogy in rocks and soils, the MSL mission will be able to identify and characterize past or present Martian habitable environments.

Minerals preserve information of environmental conditions when they formed. The CheMin data is useful to assess the involvement of water in the minerals' formation, deposition or alternation. CheMin will also give clues to potential mineral bio-signatures, energy sources for life or other indicators of habitability.

To prepare samples for CheMin analysis, the rover will drill into rocks, collect the fine powder, sieve it, and deliver it to a sample holder. Also, the rover scoop will be able to collect soil and deliver it to a sample holder. Then CheMin will direct a collimated X-ray beam from the X-ray tube through a transmission sample cell, which contains the prepared powdered sample. On the opposite side of the sample, an X-ray sensitive charged coupled device (CCD) imager can detect the diffracted and fluoresced X-rays by the sample. Some of the X-rays interacting with the sample will be absorbed by atoms in the material and re-emitted or fluoresced at certain energies, which are unique to particular atoms. Some X-rays are reflected by the sample's crystal structure and produce a unique two-dimensional diffracted pattern on the CCD. Diffraction patterns are characteristic to all minerals and can serve as fingerprints to identify the minerals in the sample. The CCD is able to measure the energy of each photon which strikes it as well as the number of diffracted photons at the characteristic frequency of the X-ray source. Therefore, X-ray energy-dispersive histograms can be obtained by summing all the fluoresced X-ray photons detected by CCD; while diffracted photons are summed circumferentially about the center of the undiffracted beam, thus producing a plot of photon number versus the diffracted angle. The information derived from these two measurements can then be used to identify both crystalline and amorphous materials on Mars. (Blake, 2010)

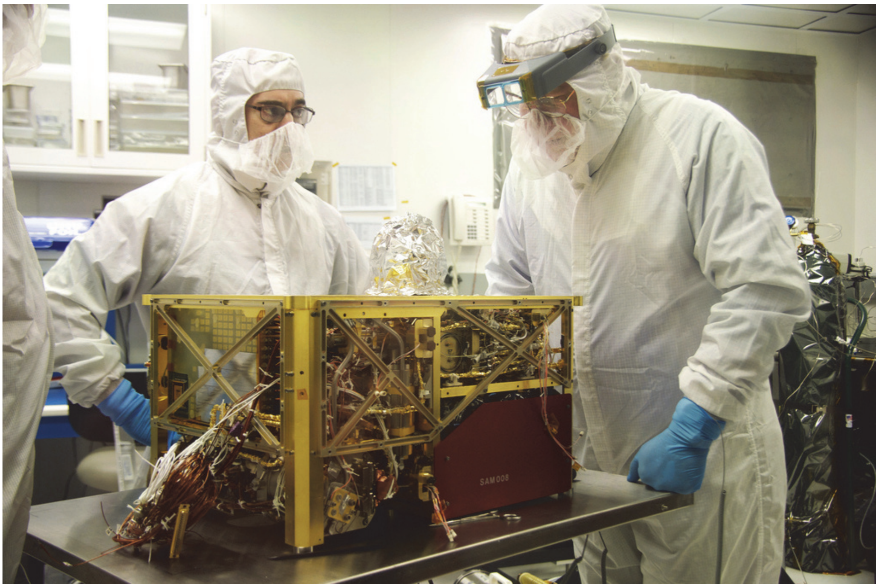
Sample Analysis at Mars (SAM)
The Sample Analysis at Mars (SAM) instrument suit, which weighs about 83 pounds, takes up more than half the science payload on board the MSL rover. SAM is the key instrument to address the present and past habitability of Mars. It is designed to search for carbon compounds of biotic and prebiotic importance and their possible mechanisms of formation and destruction, including methane. In addition, SAM will measure the chemical and isotopic state of other light elements from atmosphere, soil and rocks, such as hydrogen, oxygen and nitrogen, which are associated with life. SAM consists of a Quadrupole Mass Spectrometer (QMS), a Gas Chromatograph (GC) and a Tunable Laser Spectrometer (TLS). A brief introduction to each instrument and its operation principles is given below.

The GC separates individual gases from complex mixtures into molecular components for QMS and GC analysis (Webster and Mahaffy, 2011). In GC, an inert-unreactive gas is used as a carrier or "mobile phase." For MSL, the mobile phase is helium. The "stationary phase" is a microscopic layer of liquid or polymer inside a piece of glass or metal tubing, which is called a column. The gaseous compounds carried by the helium interact with different stationary phases, which coat on the walls of the column. Different compounds take different times to elute. In this way, GC prepares pure compounds for further analysis.

The QMS will detect gases sampled from the atmosphere and those released from solid samples by heating to sub ppb sensitivity. It also serves as the primary detector of the GC. The detection range of QMS is 2-550 m/z. In a QMS, ions are filtered based on their mass-to-charge ratio (m/z) by the quadrupole, which consists of four parallel metal rods. An RF voltage and a DC voltage are applied between each pair of opposing rods. Given a ratio of RF to DC voltage, only ions of a specific mass-to-charge ration are able to reach the detector. Other ions will collide with the rods. This allows QMS to measure the amount of ions with a specific mass-to- charge ratio.

TLS on MSL is a two-channel Herriott cell design spectrometer, which provides highly sensitive detection of target species (CH_4, H_2O and CO_2) and selected isotope ratios. The sensitivity of its direct measurement of methane is 2 ppb and that of water is 2 ppm. These sensitivities can be improved by a factor of 100 if SAM's Chemical Separation and Processing Laboratory enrichment is applied. Isotope ratios associated with habitability will also be measured with a typical precision smaller than one percent.

One channel of TLS produces lights at wavelengths of 3.27 µm for CH_4 and 2.78 µm for CO_2 and H_2O. The light causes the target molecule to vibrate and absorb energy. Then the laser is shifted minutely to wavelengths that have similar temperature dependence. The light energy absorbed at the original absorption frequency and that at the shifted frequency are compared. Thus it can give a sensitive and accurate measurement of CH_4 and H_2O. (Webster and Mahaffy, 2011)



Sample Analysis at Mars will be one of the most complicated instruments ever to land on the surface of another planet. Equipped with a gas chromatograph, a quadruple mass spectrometer, and a tunable laser spectrometer, SAM will carry out the initial search for organic compounds when MSL lands in 2012. (NASA/GFSC)

Radiation Assessment Detector (RAD)

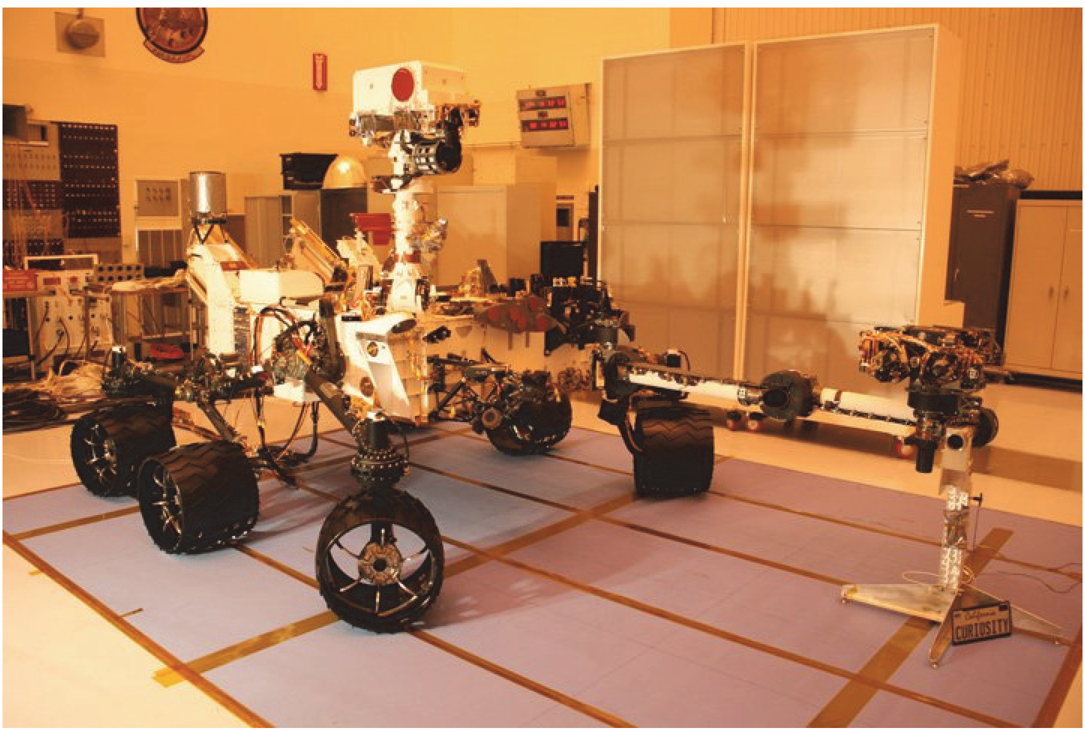
RAD will measure and identify all high-energy radiation on the Martian surface, including protons, energetic ions, neutrons, and gamma rays. While Mars Odyssey carried an instrument to study the radiation environment above the atmosphere, the radiation environment on the surface of Mars has never been characterized (Zeitlin et al., 2004). This in-situ measurement is critical to understanding the past and present habitability of the planet because models suggest radiation levels on modern Mars would make the surface inhospitable to microbial life and break down any organic compounds present. This measurement is also critical to understanding how radiation has affected the chemical and isotopic composition of Martian rocks and soils. It is foreseen that RAD measurements will help to determine the depth that future missions, such as ExoMars, will need to drill to reach a "microbial-safe zone." (Dartnell et al., 2007)

Dynamic Albedo of Neutrons (DAN)

DAN is a pulsing neutron generator (PNG) coupled with a passive neutron detector and electronics (DE) assembly capable of detecting hydrogen nuclei indicative of ice and hydrated minerals in the shallow subsurface (to a depth of 0.5 m). DAN-DE measures the interaction of energetic neutrons with hydrogen nuclei. When a fast neutron collides with a light nucleus, it loses a large fraction of its energy and slows down. Therefore, the presence of hydrogen in the subsurface results in a deficiency of fast (1 eV to 0.1 MeV) neutrons and an increased flux of thermal (~0.025 eV) neutrons. In active mode, DAN-PNG produces 1-2 μs pulses of emission with 3.5 MeV α particles and 14.1 MeV neutrons, which enables faster measurements with DAN-DE. When DAN-PNG is used with DAN-DE, the instrument is sensitive enough to derive the vertical distribution of water-equivalent hydrogen with an accuracy of 0.1-0.3% by weight. This measurement will be taken every meter along the rover's path, significantly improving on the 600km spatial resolution of the High Energy Neutron Detector (HEND) on Mars Odyssey. (Litvak et al., 2008; Boynton et al., 2002)

Rover Environmental Monitoring Station (REMS)

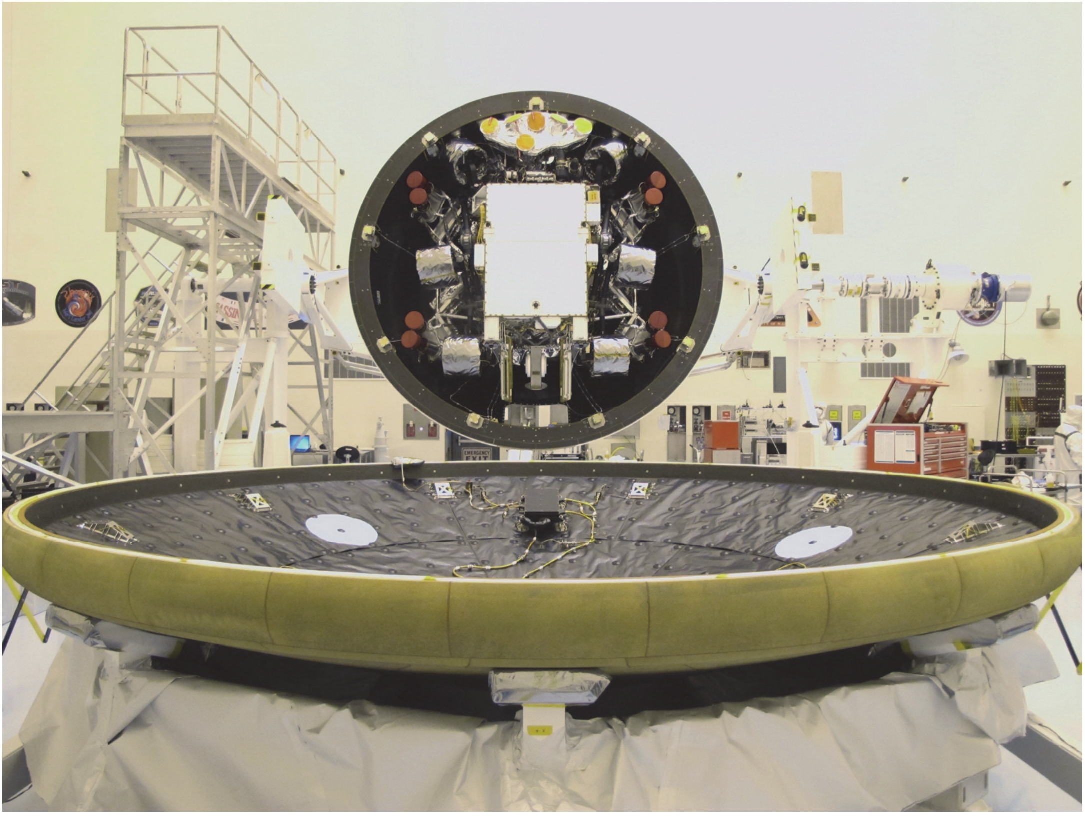
REMS represents a suite of sensors to record the ground temperature, air temperature, pressure, humidity, wind speed, wind direction, and ultraviolet (UV) radiation around the rover. This data will help to assess the current conditions and habitability of the planet. In particular, understanding the diurnal and seasonal variation of the atmospheric water vapor content could shed light on seasonal flows seen on warm Martian slopes (McEwen et al., 2011). As with RAD, characterizing the solar UV flux with REMS could help to elucidate the effect of energetic radiation on biomolecules such as amino acids and DNA (Kate et al., 2005; Cockell et al., 2000). Furthermore, the high UV flux is believed to have created an oxidizing layer in the Martian topsoil, thought to cause the apparent lack of organic materials during the Viking missions (Yen et al., 2000).



All done and ready to roll! (NASA/JPL-Caltech)

Mission Architecture

One of the most important aspects of the Mars Science Laboratory (MSL) mission is the transit from Earth to Mars. The spacecraft will be lifted up to space by a launch vehicle, the Atlas V- 541, and then be placed in a specific orbit to Mars. Finally, Curiosity will be deployed from the payload when it reaches the surface of Mars; the landing sequence is discussed in greater detail later in the report.



Integration of the rover, skycrane, aeroshell, and heatshield for transport to Kennedy Space Center. (NASA/JPL-Caltech)

Applying the finishing touches to the launch vehicle after integration. (NASA/KSC)

The Atlas V-541 launch vehicle is a two stage rocket provided by United Launch Alliance. It is composed of the first stage common core booster with RD-180 engine made by Pratt & Whitney which can provide thrust up to about 3.8 million Newtons, Centaur upper stage with single RL 10 engine which can provide thrust up to about 100,000 Newtons, four solid rocket boosters which can provide thrust up to about 1.36 million Newtowns each, 5-meter payload fairing which protects the MSL spacecraft, Centaur Interstage Adopter which connects the common core booster and Centaur upper stage, and finally the rover payload on top of the Centaur. The launch vehicle is 58 meters tall at takeoff.

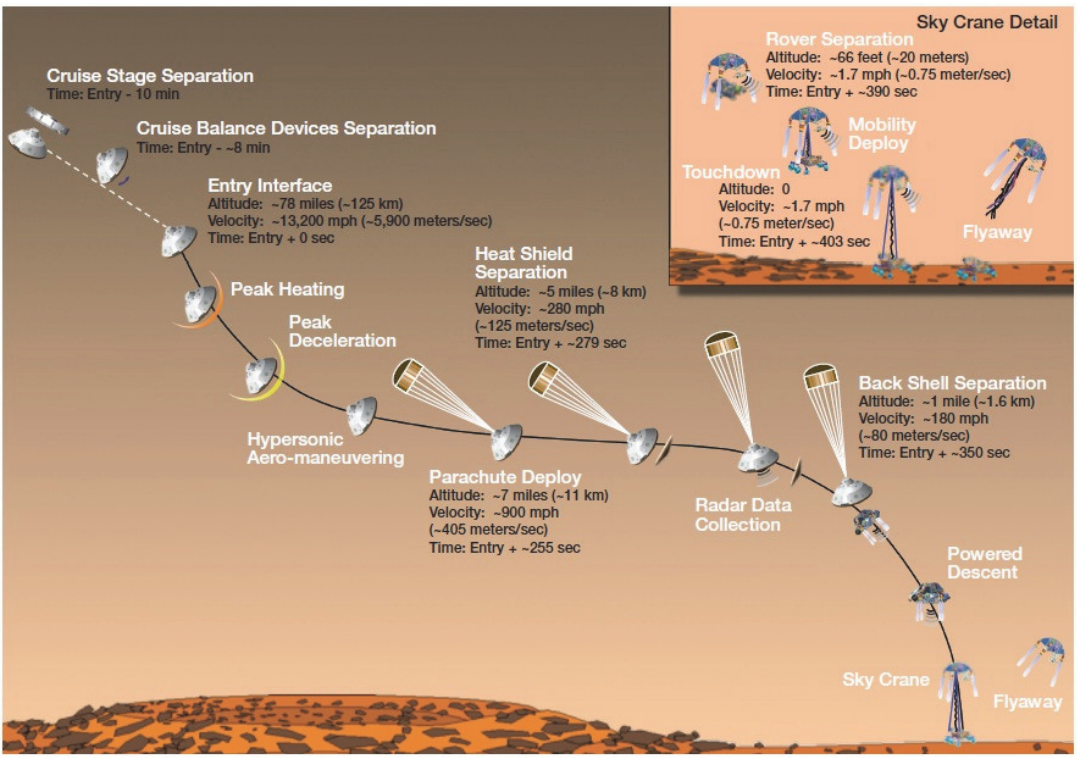
The Atlas V-541 was launched successfully on November 26, 2011, at Cape Canaveral Air Force Station, FL. The common core booster and four solid rockets were ignited first to lift off the vehicle; the solid rocket boosters were jettisoned after about 2 minutes from liftoff. The payload fairing was discarded next, with the Centaur upper stage separating from the first stage a few minutes later. The Centaur main engine was then ignited for about 7 minutes for placement in a parking orbit around Earth. After several minutes of orbiting around the Earth, the main engine was ignited again for approximately 8 minutes for insertion into the transfer orbit towards Mars. After a few minutes, the spacecraft separated from the Centaur second stage, thus ending the launch portion of the mission. The speed of the spacecraft at this point was about 10 kilometer per second. Once the spacecraft achieved separation, the x-band transmitter antenna expanded and began its telecommunication system link with the ground station. (Webster et al., 2011)

Liftoff at 10:02EST on November 26, 2011 from Florida's Cape Canaveral Air Force Station starting the MSL on the first leg of its 8 month journey to Mars. (NASA/KSC)

The transfer orbit period will last approximately 36 weeks, with most of that time occurring in the cruise phase. During the voyage to Mars, there will be 6 trajectory correction maneuvers (TCMs). The first two TCMs, 15 days and 120 days after the launch, are for the spacecraft to be in right path to Mars; these course corrections were intentionally designed in order for the Centaur upper stage to not collide with Mars. The third TCM is for the spacecraft to reach the desired Mars atmospheric entry point. The final three TCMs will be performed when the spacecraft is in the vicinity of the Martian atmosphere to accurately touch down at the right location. These operations will be performed based on the spacecraft's trajectory, which is tracked from an Earth based ground station using three types of methods: ranging, Doppler, and delta differential one-way range measurement. The spacecraft is scheduled to arrive at Mars on August 6, 2012.

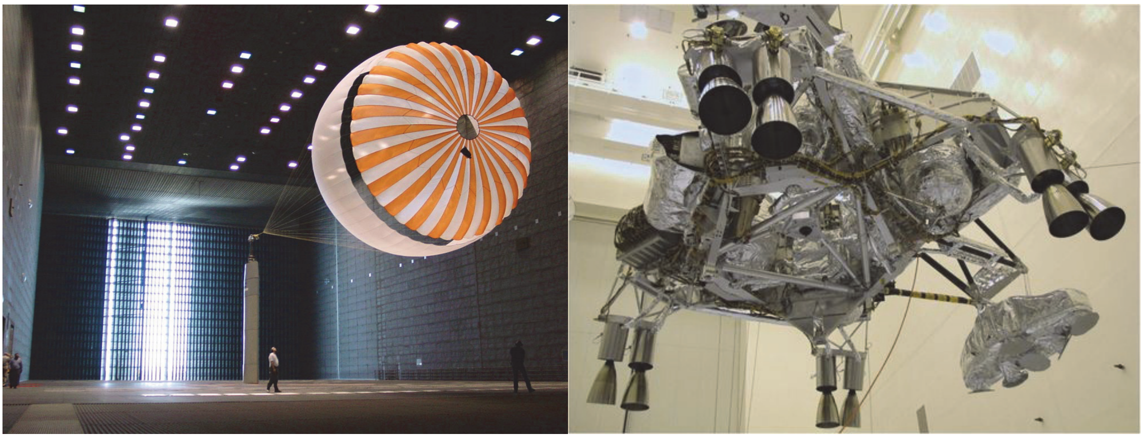
Entry, Descent, and Landing System

Safely landing Mars Science Laboratory at a specified location in Gale Crater presents several engineering and technical challenges. Because of its weight and size (approximately one metric ton and volumetric footprint of a small automobile), previous landing techniques used on past Martian rover missions are unfeasible, i.e. the airbag/tumble approach (Prakash et al., 2008). The unique composition and density of the Martian atmosphere also prevents air-braking devices, such as ballutes and parachutes, from being solely responsible for complete deceleration; likewise, reverse thrusting cannot be relied upon as the singular source for braking because of its significant fuel consumption. Further complications arise with the autonomous nature of the landing procedure; because there is no human contact that can actively guide the payload to a soft landing, the rover must rely on sensed and timed events from atmospheric entry to touchdown on the surface of Mars (Webster et al., 2011). The solution for safe landing is a combination of heritage technology with a novel approach to gentle touchdown – a skycrane. This systematic approach to landing is known as the Entry, Descent and Landing (EDL) system.



Entry, Descent and Landing System of Mars Science Laboratory. (NASA/JPL-Caltech)

The entry phase of the landing sequence begins when the spacecraft reaches the Martian atmosphere. Because the atmosphere of Mars has no clear boundary between it and space, the atmospheric entry interface point is artificially set at 3,522.2 kilometers. This altitude measurement is done via the Mars Science Laboratory Entry Descent and Landing Instrument (MEDLI) which begins to take measurements ten minutes before atmospheric entry. Entering at approximately 5.9 kilometers per second, the main source of braking during this initial phase is the heat shield (Webster et al., 2011). Small thrusters on the back of the aeroshell provide minor corrections if necessary to the entry angle and direction of tilt. Overall, this frictional force of atmospheric entry provides nine-tenths of the overall deceleration. Small weights are jettisoned to realign the center of mass before the next stage of entry begins – the parachute descent.



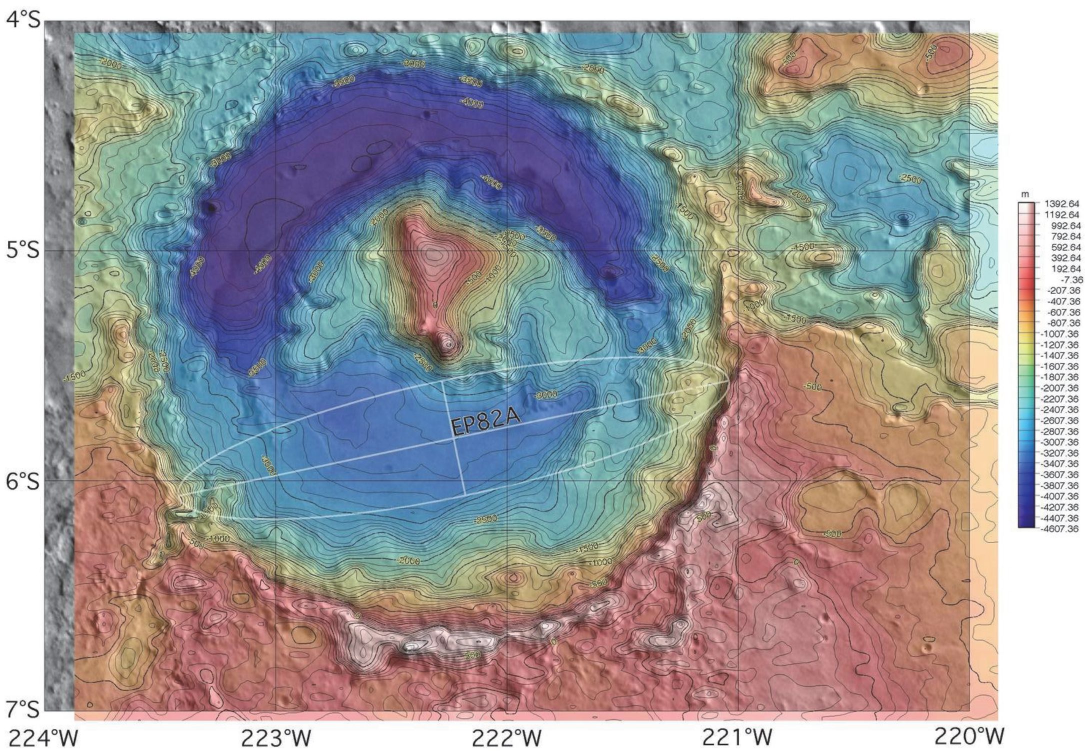
(Left) The MSL parachute being flight qualified inside the world's largest wind tunnel, at NASA Ames Research Center, Moffett Field, California. (Right) The descent stage being lifted during assembly of the spacecraft in this photograph taken inside the Payload Hazardous Servicing Facility at NASA Kennedy Space Center. (NASA/ARC/KSC)

The parachute is expected to deploy roughly 255 seconds after initial atmospheric entry, corresponding to an altitude of approximately 11 kilometers and a speed of 405 meters per second. Once the parachute has been deployed, the Mars Decent Imager begins to record video of the surface directly beneath the payload while a radar system mounted on the decent portion of the payload begins to take measurements of altitude and velocity. At 1.4 kilometers above the surface (80 meters per second), the aeroshell assembly will be discarded including the parachute. The powered descent stage then takes over, with eight mono-propellant hydrazine retrorockets firing for further deceleration. When the speed of the payload has reached a steady 0.75 meters per second, half of the rockets will cease to fire; at this point, the rover will be lowered via a system of nylon cords at 20 meters above the surface of Mars. Wheels and suspension system which act as landing gear lock into place, and the suspended rover continues its decent at a constant speed until landing. This final part of the landing sequence is referred to as the skycrane; once the rover senses touchdown, surface mode is activated and tethers cut which allows the upper structure of the skycrane to fly and crash away from the landing site. (Webster et al., 2011)

Gale Crater / Curiosity's new home

by Harvey Elliott

Gale Crater is an impact crater on Mars located at 5.3°S, 137.7°E, placing it at the "North-South Dichotomy Boundary" between Mars' southern highlands and northern lowlands. It is 155 kilometers in diameter with a floor-to-rim depth of 2-4 kilometers (Anderson and Bell, 2010). In its center there is a mound rising about 5 kilometers above the crater floor, comprised of layers of stratified rock (Edgett, 2010). Gale crater exhibits many fluvial features and other evidence of liquid water (Anderson and Bell, 2010), has one of the thickest exposed stratigraphic sequences in the Solar System (Edgett, 2010) and has features common to many other Martian locales (Le Deit et al., 2011), all of which contributed to its selection as the Curiosity landing site.



Topographical image of Gale Crater, courtesy of MOLA-the Mars Orbiter Laser Altimeter onboard Mars Global Surveyor (MGS). (NASA/JPL-Caltech)

Water-related features

Gale Crater holds ample evidence for the presence of liquid waters on Mars in the past, a key requirement for the existence of life as we know it. Valleys and inverted channels imply water flow into and inside the crater, while hydrous minerals can tell us about the abundance of water. Valleys. The crater walls are full of valleys, leading into the crater with no apparent outlet. Several of them form branching networks, and many lead to fan-shaped features. These observations suggest that flowing water was at least one of the mechanisms eroding the crater (Anderson and Bell, 2010).

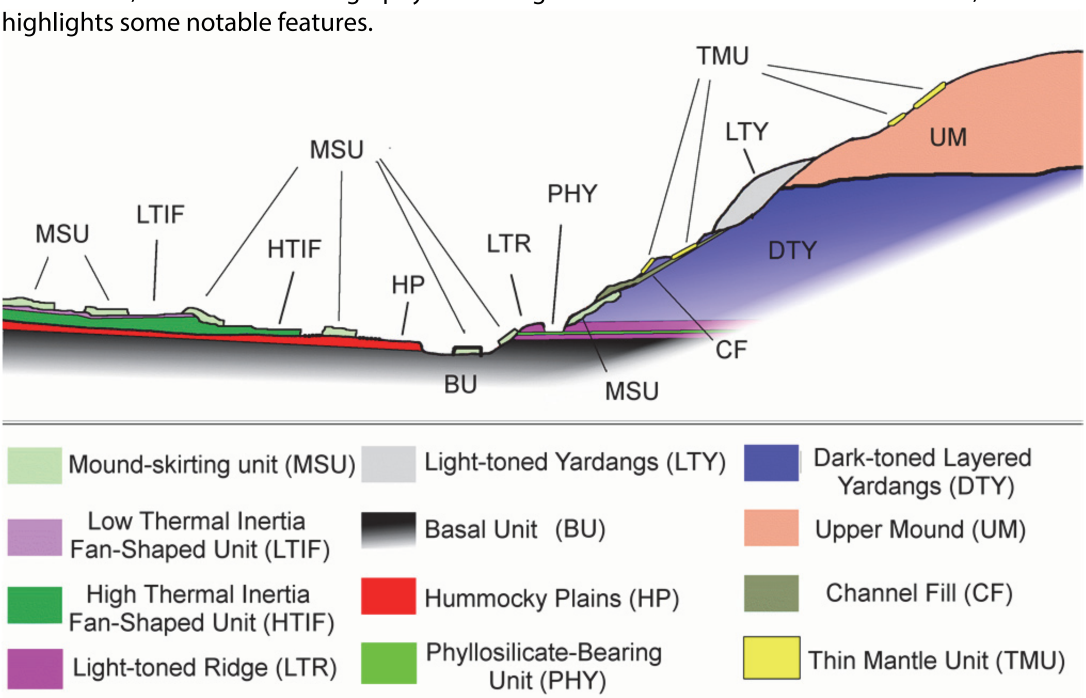
Inverted channels: Many ridges interpreted as inverted channels appear on the crater floor, with width <100 meter and length reaching upward of 10 kilometers. Some of the ridges are highly sinuous, others are branching, and some are a continuation of regular, "non-inverted" channels, all supporting the interpretation of these ridges as inverted channels, formed by the flow of water (Anderson and Bell, 2010).

Sediments: many of the minerals detected in the crater and on the mound's sides can form only in the presence of water. Among them are clay-bearing minerals, and sulfates and other salts forming under water-limited conditions. Whether these minerals where formed in-situ or carried into the crater, they not only show the existence of water, but the internal ordering of their layers, along with layers of anhydrous minerals, can help us learn about the processes of changing climate at Mars (Milliken et al., 2010).

A former lake: Carbol (1997) argues that the streamlined morphology of the Gale Crater mound and its terraces show that the crater had been a lake in the past. Anderson and Bell (2010) agree that the crater's features are consistent with the presence of a lake but argue that there is no conclusive evidence. An investigation by the MSL rover could help solve this question.

Stratigraphy of the crater

Anderson and Bell (2010) identify the various geological units of the northwestern crater floor and mound, and infer the stratigraphy of that region. This section is based on their work, and highlights some notable features.



Geological units and stratigraphy of the landing site and the mound (not to scale). (Anderson and Bell, 2010)

The Hummocky Plains (HP) unit of the crater floor contains several sinuous ridges – inverted channels – that imply it was once buried and then eroded by at least the ridges' current height. The inverted channels' shape is consistent with slow-flowing water. A fan-shaped feature is located at the northwest of the crater within the landing ellipse, overlying the Hummocky Plains. This feature contains two units: High- and Low- Thermal Inertia Fan (HTIF and LTIF, respectively), and is interpreted as a lithified alluvial fan. Near the base of the mound, hydrous minerals are exposed in the Phyllosilicate-Bearing unit (PHY), interpreted as a thin plane of clay-bearing bedding.

The Upper Mound unit (UM) is comprised of large terraced packages of fine layers, with a pattern suggestive of a lithified dune-field. If it was indeed a dune field, this implies the unit was formed at a time when the mound was buried (after already forming), since dune fields do not generally form on top of mounds. The uppermost layer, and possibly the youngest, is the Thin Mantle Unit (TMU), suggested by Anderson and Bell (2010) as an air fall deposit such as pyroclastic or impact-generated dust and ash.

Gale Crater contains diverse geological units representing a record of many different events: sedimentation, erosion, transport and more. Together with the thick and relatively continuous stratigraphic sequence, this makes it a fascinating site for exploration with the potential to tell us much about the history of Mars.

Mars Habitability Record

The diversity of the geological units in Gale Crater implies they were deposited during times of changing conditions (Anderson and Bell, 2010). The crater region was variously a water-reach environment conducive to the formation and sedimentation of clay, a water-limited, high-pH environment in which sulfate-bearing layers were formed (Edgett, 2010), and a dry place shaped by winds and sand (Anderson and Bell, 2010). These conditions are important factors in determining habitably. The record of changing conditions is potentially global in scope, as there are many other locations on Mars where features similar to those of Gale Crater are found (Anderson and Bell, 2010). In particular, the geology of Gale Crater has been shown by Le Deit et al. (2011) to have many similarities with other Equatorial Layered Deposits (ELDs). The ELDs are located within ±30° of the equator in a variety of geological settings including cratered and chaotic terrains, chasmata in Valles Marineris, and impact craters such as Gale. Any inference about the history and habitability of Gale Crater may be applicable to these places as well (Anderson and Bell, 2010).

One important aspect of investigating the habitability question is the ability of the examined site to preserve bio signatures. On Earth, organic material is most likely to be found in sediments deposited in low-energy, aqueous environments such as lakes and slow-flowing rivers. In particular, phyllosilicates and sulfates, both present in Gale Crater, are known to effectively preserve organics. If the past existence of a lake there is confirmed, that would increase the probability of any organics being preserved. Regardless, the fact that Gale Crater shows relatively few impact craters means its exposed surfaces are relatively fresh, implying that any bio signatures that might have been preserved are not likely to have degraded much through radiation or chemical reactions with water or atmosphere (Anderson and Bell, 2010).

Alternate Landing Sites

The landing site for the MSL mission will deeply influence both the quality and type of scientific data obtained during the mission and the pace and strategy of surface operations for the Curiosity rover. NASA engineers and Mars specialists researched, discussed, and voted on over 60 potential landing sites. The final four candidates were Gale crater, Eberswalde crater, Holden crater, and Mawrth Vallis. The following sections will discuss a few key requirements that went into choosing the final landing site and a description of each of the final four candidates.

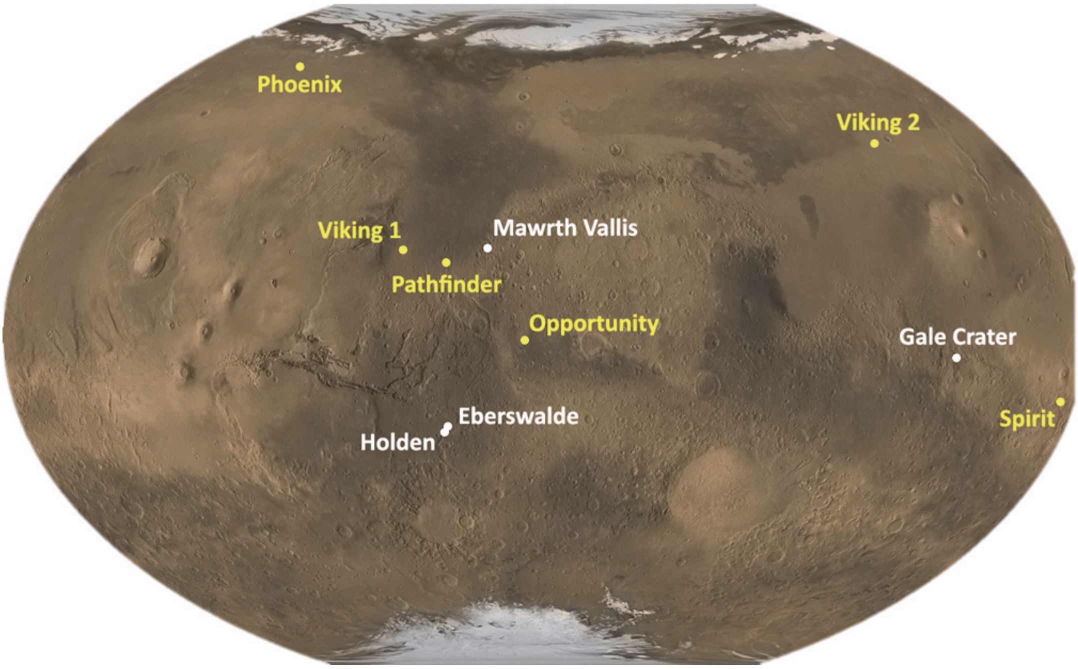
How do we choose?

The requirements for choosing a landing site were based on the objective that MSL is to assess whether Mars is or was ever a habitable environment. A few of NASA's key requirements that drove the selection of the final site are:

1. The landing site shall have evidence that water was involved in the formation of the landscape and in the rock deposited there

2. The landing site shall have evidence suggestive of a past or present habitable environment, whether geological, chemical, or biological

3. The landing site's geography and environment shall be deemed "safe" as it shall not inhibit the rover's mobility or operational performance



The final four MSL landing site candidates (white) along with the landing sites of previous Mars Exploration Program missions (yellow). (NASA/JPL-Caltech)

Past Mars explorations incorporated a "follow-the-water" strategy. However, the Curiosity rover's instruments have the ability to identify organic compounds, a biomarker and essential building block of life. Thus, the MSL landing site will be used to focus more on the second requirement. Under the third requirement, elements that may affect the rover's mobility and operational performance include terrain, climate, and weather. Moreover, NASA chose to research craters, rather than the traditional flat-land locations, for the MSL mission due to the diverse sedimentology found below the surface, in the craters' walls, and in any central mounds that may exist within the craters. This diverse sedimentology represents billions of years of sediment layering, as well as the environmental and geographical changes on Mars, which provides unique information on the climate, hydrology, and geochemistry of Mars. Thus, craters present the opportunity to study the habitability aspects of Mars and how life would have been affected by the changing environment.

Eberswalde Crater

Eberswalde crater was one of the final two landing site candidates for the MSL mission. Eberswalde is centered near 23.90°S, 33.26°W. It is -1435 meters in elevation and 65.3 kilometers in diameter. This makes it the smallest and shallowest of the final four candidates. Eberswalde is unique because it is the most evidential site of an ancient river delta, formed when and where a river flows into another body of water, and is deemed a source-to-sink site. This strongly suggests that the crater may have once been a lake. If this is true, sediments from the surrounding areas would have been transported downstream by the flowing rivers into the stationary lake. These sediments would have eroded into finer-sized pieces, sunk to the bottom, and created sediment layers present at both the floor and in the walls of the crater. Many of these sediments have been found to be clays which are great preservers of organic compounds. Lastly, Eberswalde has the largest surface rock density of the final candidates, which represents the most amount of trouble in regards to the rover's mobility. (Dietrich, 2010)

Holden Crater

Holden crater was one of the final four landing site candidates for the MSL mission. Holden is centered near 26.40°S, 34.84°W. It is -2177 meters in elevation and 155 kilometers in diameter. Holden is nearly identical in size compared to Gale crater. Holden is unique because it contains evidence of prior water in the form of alluvial fans. An alluvial fan is a fan-shaped deposit that forms when fast flowing water flattens, slows, and spreads onto a flatter plain. Additionally, geological studies suggest that a catastrophic flood may have occurred at Holden. As the water from the flood disappeared over time, wind would have eroded the surface and exposed old flood deposits. If this is true, runoff sediments from higher elevations would have been transported to lower elevations and created sediment layering, similar to Eberswalde, at the bottom of the crater along with the flood deposits. Lastly, Holden has the lowest surface rock density of the final four candidates, which represents the least amount of trouble in regards to the rover's mobility. (Irwin, 2010)

Mawrth Vallis

Mawrth Vallis was one of the final four landing site candidates for the MSL mission. Mawrth Vallis is centered near 23.99°N, 18.96°W and has more of a valley than crater geographical structure. It is -2245 meters in elevation and 636 kilometers in diameter. This makes it the largest of the four final landing site candidates. Mawrth Vallis is unique because it contains the largest abundance of phyllosilicates, clay-like mineral that only forms in the presence of water, compared to any other potential landing site. Over 50% of the area is populated with phyllosilicates, and there is also evidence of at least two different clay-like minerals present found from both the Mars Express orbiter and the Mars Reconnaissance Orbiter data. Clay minerals preserve evidence of microscopic life and organic compounds on Earth which may prove to be the same on Mars. Also, due to the large size of Mawrth Vallis and the large amount of diverse phyllosilicates present, this landing site indicates multiple environments in which to search for biomarkers. Additionally, Mawrth Vallis has a relatively low surface rock density when compared to the other final four candidates, which represents a small amount of trouble in regards to the rover's mobility. Lastly Mawrth Vallis is not a go-to-site, which is beneficial because it is the only landing site of the final four that the rover has the ability to land inside the region and to begin taking measurements immediately after landing. (Michalski et al., 2010)

Alumni Spotlight / Chris Lewicki

by Kaizad Viraf Raimalwala

Our SEDS spotlight alumnus member for this publication is Christopher A. Lewicki, former SEDS-USA Chair (1995-96) and SEDS-UA President. Chris has had quite an illustrious career in the space industry so far, having served at NASA's Jet Propulsion Laboratory as the Flight Director of Spirit & Opportunity and the Surface Mission Manager for the Phoenix mission. Currently, he is President & Chief Engineer at Arkyd Astronautics Inc., a space-tech firm that Chris co-founded with Peter Diamandis and Eric Anderson.

While in high school, Chris was greatly inspired by the Voyager program and soon thereafter fixated his eyes on the space program. With a newly unbridled passion for all things space, Chris quickly gained momentum in his undergraduate career by working on several space-related projects. They ranged from the SEDS satellite program to interning at NASA via the Arizona Space Grant Consortium undergraduate research program to working at UA's Lunar & Planetary Lab. All these projects allowed him to acquire several invaluable skills such as grant writing, electronics design, and computer programming. After completing undergraduate studies in 1997, he pursued a Master's degree in Aerospace Engineering as well. His graduate work involved designing, prototyping, and testing of a device that could analyze soil samples on a planetary surface and as such, undoubtedly helped him gear up for his subsequent work and success at JPL. In between having acquired his Master's degree in 2000 and securing that dream job at JPL, Chris worked at an online business called Blast Off, with Peter Diamandis at Starport.com, at Space.com, and at Space Adventures with Eric Anderson. As if being assigned as Flight Director for the MER program at the age of 29 wasn't enough, Chris has also been the recipient of two NASA Exceptional Achievement Medals and yes, even has an asteroid named after him: 13609 Lewicki.

With such a diverse career portfolio in the space industry and glamorous accomplishments to boot, all of us may wonder how he got so far at such a young age. "It's not a two-step process," advised Chris, referring to that mindset of just getting a degree and then simply just getting a job. Aside from that default requirement of getting a college degree, Chris recommends following a path where you get seriously involved in a number of space projects, acquire a treasury of experience while constantly expanding your skill set, and maintain good relationships with other people in the space community. Working hard is imperative. "The message I want to give is that it doesn't happen to you. You make it happen and you have to make it happen in a lot of small steps." A true practitioner of his preaching, Chris is a constant supporter of SEDS and an inspiration to us all. As his SEDS wiki says, "All hail Chris Lewicki!"

SEDS-USA Projects / 2011 Rocketry Competition Highlights

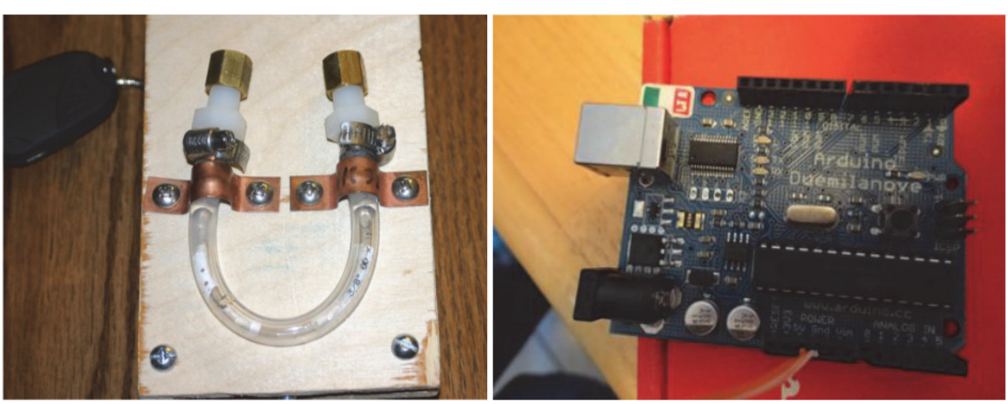
by Sally Haselschwardt

Last year, six SEDS chapters participated in the High-Powered Rocketry Competition, and three teams successfully launched their rockets before the deadline. The teams from the University of Central Florida, Arizona State University, and Purdue University successfully built and launched rockets with a 4+ kg payload. The goal of the competition was to reach 10,000 feet with the least amount of extra mass by October 24, 2011.

(Left) ASU SEDS members assemble their rocket for the first time. Purdue (Center) and UCF (right) SEDS members proudly display their creations

Each team had a different method to approaching a seemingly straightforward problem. ASU and UCF built their rocket from scratch, while Purdue used an existing kit and made modifications.

ASU chose to build a payload designed to measure the roll rate of the rocket. This involved programming a microprocessor to record data from an accelerometer, photo resistors, and a gyro, while another microprocessor parsed GPS data to transmit back to the ground.



(Left) Purdue's capillary tube payload designed to help understand the effects of microgravity. (Right) ASU's payload flight computer designed to log accelerometer, photo resistor, and gyro outputs.

Purdue's payload was a microgravity experiment done to characterize fluid in a capillary tube. A capillary was designed using fluid and volume specifications and a camera and scale were set up to measure the changes during flight.

Both teams also opted to fly a camera to record the rocket's flight as part of their payload for an extra two points is added to their final score.

ASU's data showed that their 31.27-pound rocket reached an altitude of 10,404 feet, meeting the goal of the competition. Unfortunately, their payload data was not recorded and the camera unexpectedly turned off just before launch.

Purdue was able to launch their rocket after the cutoff date, but before a second cutoff date incorporated once it became aware that there was a late harvest and difficulty securing a launch site. Once a site was procured, they launched their rocket twice and weighing in at around 27.34 pounds. They reached altitudes of 6,848 and a whopping 13,137 feet. Unfortunately, their payload was under the 4 kg weight requirement and the outcome of their camera data was unknown at press time.

Purdue's 2011launch for the SEDS-USA Rocketry Competition

UCF's reports show that they also launched twice, reaching altitudes of 6,930 and 7,021 feet. They chose not to incorporate a launch camera into their design. Their rocket weighed only 15.87 pounds, and the info on their payload was unknown at press time.

Despite having a payload malfunction, the winning team was Arizona State. Central Florida was second, and Purdue came in third place. No matter the final score, each team put in a lot of dedication and hard work to successfully launch. We hope to see these teams again next year armed with lessons learned from 2011. SEDS-USA has also tried to encourage more participation from chapters this year by relaxing some of the requirements. If you would like to compete in the 2012 challenge, check out the announcement on SEDS.org or email projects@seds.org for more information.

Chapter Updates

University of Michigan

Update: 2/16/12

SEDS@UM recently held an "AstroBio Week" with talks by Pete Worden, Lynn Rothschild, Ted Bergen, and Mark Moldwin. We're following this up with a week of talks focused on space law and policy featuring Len Fisk, Thomas Zurbuchen, and Matthew Schaefer. This is in addition to our "Challenger Memorial Lecture" by Ken Davidian and two talks earlier this year by astronauts Jim Bagian and John Herrington. To round out the semester, we'll be teaming up with the Michigan Electronic Dance Music Association (MEDMA) once again for our annual Yuri's Night celebration at the NECTO dance club in downtown Ann Arbor. Get pumped for the biggest space rave in the tri-state area!

Carnegie Mellon

Update: 2/4/12

SEDS at Carnegie Mellon (SEDS-CMU) is celebrating the successful end to its first year. The chapter has doubled in membership since our founding by attending two CMU activities fairs. The executive board attended the nation conference, and took a wealth of information back to the chapter. This coming semester, our hard work will be paying off. SEDS-CMU will participate in multiple outreach programs in local Pittsburgh schools and has received a research grant from Carnegie Mellon to build a testbed for a Lunar excavator robot. Additionally, we have a completed high-altitude balloon and are waiting for a sunny launch day. Every other week, the club meets to talk about student internship opportunities in the industry and space-related current events. SEDS-CMU looks forward to continuing research, projects, STEM outreach, and generating enthusiasm for all things space this semester!

University of Arizona

Update: 1/29/12

Since the last update, UASEDS participated in several different events and activities. In October, about 14 students from UASEDS attended SpaceVision 2011 in Boulder, CO. We all enjoyed the conference and are looking forward to next year in Buffalo, NY. Our Arizona Space Grant ASCEND! team launched a balloon payload in November and are currently working on a new design for this next semester.

More recently, we have been working on a few improvements to our 18″ Dobsonian telescope. Once complete, several more members will be trained in using the telescope for outreach events. Our annual spring break trip is also in the planning stages. We expect to visit several different space sites throughout California. We have also been working on recruiting new members by attended club fairs when possible.

Purdue University

Update: 1/16/12

Purdue SEDS has witnessed an expansion in active and diversified membership over the past couple of years and we are looking forward to another prosperous semester. Our current projects include:

- Competing in NASA's USLI (University Student Launch Initiative) High Power Rocketry competition
- Competing in NASA's Lunabotics Competition
- Competing in SEDS-USA High Power Rocketry Competition
- Working on a next-gen hybrid rocket to improve upon previous hybrid rocket projects
- Outreach programs planned throughout the semester
- Spring Space Forum, an event where we invite professionals from space industry and academia to give a talk. Previous speakers include John Gedmark, former Executive Director of Commercial Spaceflight Federation, Dr. Michael Griffin, former NASA administrator, and Rick Tumlinson, leading space activist and co-founder of Space Frontier Foundation. This year we hope to invite representatives from the front-running NewSpace companies.

We also regularly have movie nights and other social events like paintball and informal space debates. Last semester we started a 'SEDS Member of the Week' award which recognizes anyone in our chapter who has put in extra effort for a particular project/activity.

American Society for Gravitational and Space Biology

Update: 1/15/12

This quarter we elected a new board, were joined by several new members, and had a great time getting to know one another in San Jose, CA. Check out our ASGSB-SEDS-newsletter for all the details!

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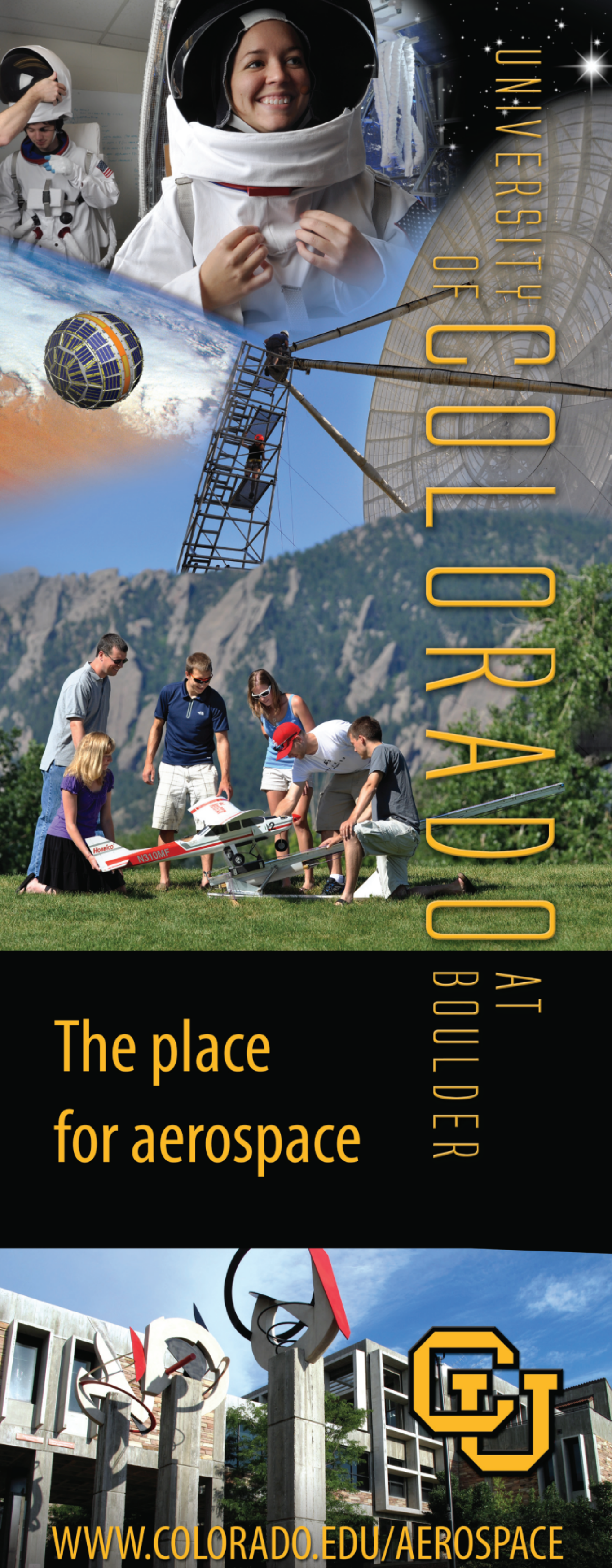

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