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SPACE TIMES

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PRESIDENT'S MESSAGE

Inside *The Journal of the Astronautical Sciences*

Have you ever taken time to read the inside cover of our Journal of the Astronautical Sciences? It's pretty dry stuff compared to the articles that follow. Recent articles have covered topics such as the latest results from Mars Rover navigation, or timely data like that for periodic orbits near Europa, or state-of-the-art solutions like one for trajectory optimization in the presence of uncertainty, and more. All of those findings and insights make the Journal so valuable to the astronautics community. There is, however, a relationship between the cover and what follows.

The Journal's inside cover lists the volunteers whose dedicated and professional service go above and beyond, helping to make the Journal the quality publication that it is. Dr. Kathleen Howell of Purdue University, the Editor-in-Chief, receives all of the papers and works with the Associate Editors to obtain reviews and evaluate revisions. She also manages the issues by assigning papers and developing special issues. Dr. Henry Pernicka of the University of Missouri – Rolla is the Journal's Managing Editor. He works with the authors to prepare accepted papers for publication by ensuring consistency in format and style, as well as technical accuracy. The nine Associate Editors request reviews and evaluate submitted manuscripts based on reviewer opinions and suggestions. And then, of course, our many reviewers do yeoman's work by applying their expertise and experience.

In addition to producing the Journal on a quarterly basis, this team is working with VP Publications Dr. David Spencer and others to lead the Society into the future with an electronic submittal and review system and, ultimately, taking the Journal online.

We owe each one of these volunteers a profound debt of gratitude, as we do our AAS Executive Director Jim Kirkpatrick and Executive Assistant Diane Thompson, who manage and coordinate production.

When you receive the next Journal, please take a moment to read the inside cover and pass along a "thank you" to these colleagues for an important job very well done. And as you are approached to review a paper, please do. It makes a difference.

Mark Craig

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ON THE COVER

FRONT: A series of images taken aboard the amphibious assault ship USS Boxer (LHD 4) shows the moon during a full lunar eclipse. The Boxer Expeditionary Strike Group is operating in the Persian Gulf conducting Maritime Security Operations in support of U.S. 5th Fleet. U.S. (*Source: Mass Communication Specialist Seaman Joshua Valcarcel*)

BACK: The NexSat satellite prepares to re-mate with the ASTRO satellite (not pictured) as part of the DARPA Orbital Express program to demonstrate, for the first time, fully autonomous rendezvous and capture of client spacecraft, satellite-to-satellite refueling, and replacement of battery and flight-computer orbital replacement units. (*Source: DARPA)*

Hydrogen Pressurization of LOX: High Risk/ High Reward (Preprint)

by Andrew E. Turner, Space Systems/Loral and Aaron Leichner, Microcosm Corporation

Hydrogen safety has been an oxymoron in many circles, dating back to the catastrophic loss of the Hindenburg. On May 6, 1937, a sudden fire consumed the eight hundred foot long dirigible, which was filled with hydrogen gas. Airship commercial service, enabled by relatively low-cost hydrogen, died along with the longest vehicle ever to fly - even though thousands of passengers had been transported safely prior to that incident. Since 1937, hydrogen has had a bad reputation, though less prominent applications such as launch vehicles, fuel cells and batteries have been safe and successful. Today, the passing of three generations and the maturation of certain technologies has advanced technologies sufficiently so that a hydrogen fuel transportation infrastructure can be discussed constructively.

One beneficial application of hydrogen is pressurization of launch vehicle propellants. In this usage, hydrogen forces the liquid propellants out of their storage tanks and into the combustion chamber, overcoming combustion back-pressure and other resistance along the way. Hydrogen is the most mass-efficient way to accomplish this task. Helium is considered the safer and more reliable solution. It is more often used, although it weighs twice as much.

While the use of helium is a sensible approach for high-cost, high-reliability systems, hydrogen is attractive for systems that do not require high reliability. An example is Aquarius, a new low-cost, reduced-reliability launch vehicle for low-cost consumables. For this vehicle, an occasional failure will be tolerated.

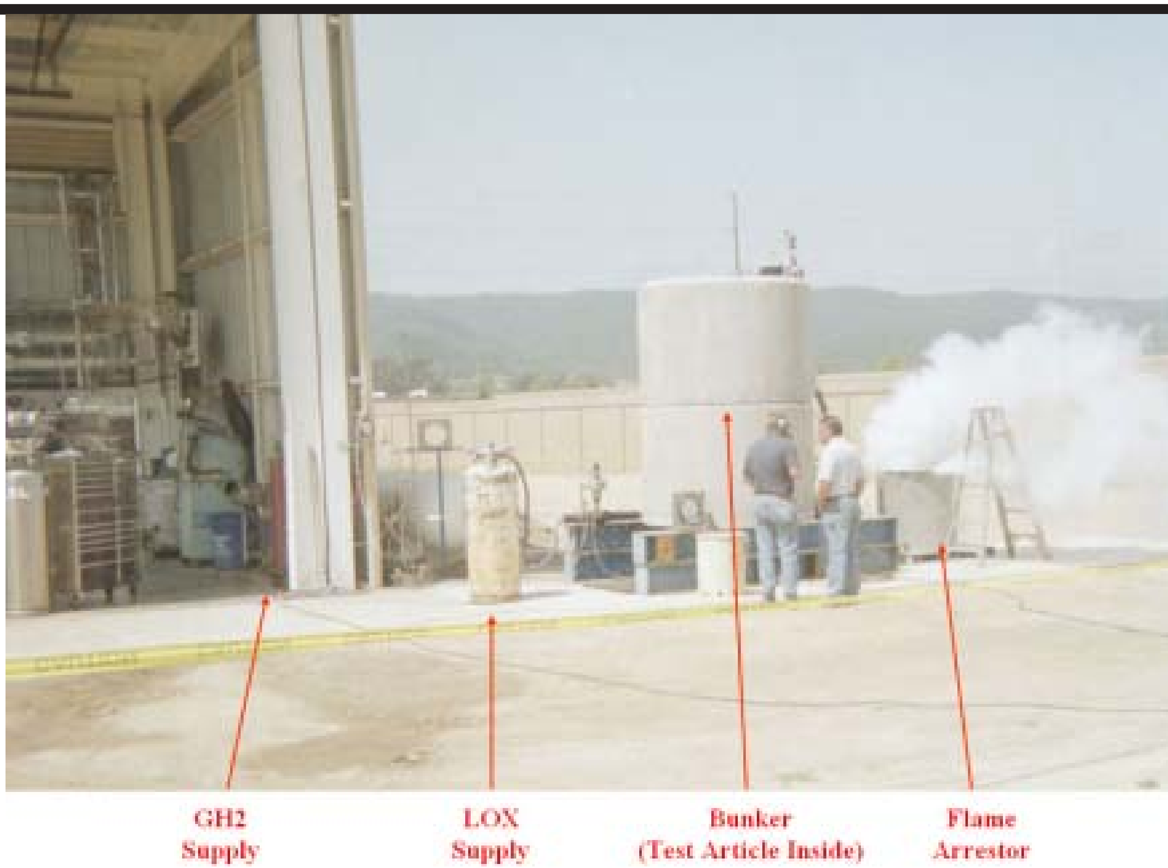
This article discusses pressurization of liquid oxygen (LOX) with gaseous hydrogen. Though most rocket scientists would not attempt this, it has now been shown to be worthy of development.

Aquarius Low-Cost Launch

The Aquarius launch vehicle was discussed in two previous *Space Times* articles (May/June 2001 and March/April 2006). Aquarius achieves low-cost launch by permitting reduced reliability of 0.67-0.80. It will transport low-cost consumables and low-cost spacecraft and other easily replaceable equipment to nominally 200-km orbits, as the mission profile shows. Since high reliability is not required, a cost per pound to orbit of $500 is feasible. This is an order of magnitude below that of any present launcher. Failure of a few vehicles due to hydrogen fires or explosions would be considered acceptable if this helps keep the net cost per successful mission low.

The most risky aspect of using gaseous hydrogen (GH2) is pressurization of the LOX tank, since hydrogen and oxygen are easily ignited. A literature search by Microcosm indicates that the sudden insertion of only 0.02 milli-joules of energy, equivalent to dropping a one-ounce weight a distance of 0.003 inches, could be sufficient to ignite a pressurized mixture of hydrogen and oxygen. No sparks allowed here! A typical spark contains ten joules, 500 times the energy required for

The Aquarius launch vehicle layout and predicted lifespan from liftoff, satellite delivery, to re-entry breakup. (Source: Space Systems/Loral/Microcosm Corporation)



The experimental test configuration as viewed from inside the control room. Gaseous hydrogen and LOX are supplied from tanks, at left, to the tank under test located within the bunker at center. Gasses are vented at right through the flame arrestor. (Source: Space Systems/Loral/Microcosm Corporation)

ignition. Merely allowing light to shine into the dark, cold, high-pressure interior of the LOX tank might be enough to ignite its contents. The sudden release of tiny quantities of heat are not the only risks the LOX tank faces if pressurized by hydrogen gas; the tiniest metallic particles can also catalyze ignition, with disastrous results.

The use of lightweight, low-cost, metal-free, and linerless graphite composite tanks has already been planned for Aquarius. Tanks of this type produced by Microcosm were demonstrated to contain LOX without incident aboard a sounding rocket by Garvey Spacecraft on June 3, 2000. Prior to this test, and to earlier testing performed by Wilson Composite Technologies, there was concern that such tanks would ignite due to contact between the powerful oxidizer LOX and the carbon fiber material composing the tank walls. But, following Microcosm's and Wilson's successful demos, these metal-free vessels became strong contenders for the demonstration of combustion-less GH2 LOX pressurization. Such a demonstration would pave the way for the development of hydrogen gas as an ultra-lightweight pressurant, obtainable at low cost from the liquid hydrogen already planned for use on Aquarius.

> "There was concern that such tanks would ignite due to contact between the powerful oxidizer LOX and the carbon fiber material composing the tank walls."

An initial tank pressurization demonstration was supported as a part of a fifteen month, one million dollar study contract awarded in June 2005. The study team included Aerojet, ORBITEC, Space Systems/Loral, and Microcosm. The California Space Authority helped obtain support for this study through the office of Rep. Anna Eshoo (D-CA), and funding was channeled through existing Air Force Research Laboratory (AFRL) activities supporting development of advanced launch vehicles.

Microcosm, which produces linerless composite tanks in a wide variety of sizes, fabricated several ten inch

Sean Kenny (AFRL) holds a duplicate of the LOX tank subjected to testing while Aaron Leichner (Microcosm, on left) and Tom Fanciullo (Aerojet) look on. (Source: Space Systems/Loral/Microcosm Corporation)

diameter, eighteen inch long tanks of an already proven design. Testing of hydrogen pressurization of LOX was conducted on May 9, 2006 at the Innovative Engineering Solutions (IES) facility in Murrieta, California, where modest quantities of explosive mixes can be safely tested. To the authors' knowledge, this was the first time a test of this sort had ever been tried.

The tank was loaded with forty pounds of LOX and pressurized to thirty atmospheres (440 psi) with GH2. This pressurization condition was maintained for about six minutes, simulating the time between pressurization of an Aquarius launch vehicle's main propulsion subsystem and liftoff.

To simulate the tank environment during regulated pressure operation for the first two minutes of flight, an expulsion test was conducted. An attempt was made to maintain constant pressure within the tank by adding GH2 as the LOX was drained. However, the pressure fell from 440 to 250 psi because fresh GH2 could not be added quickly enough to maintain constant pressure.

Following the expulsion test a blow-down test was performed during which the tank was not re-pressurized with gaseous hydrogen as it was drained. This simulated the second and last two-minute span of Aquarius powered flight. During this portion of the test, pressure decreased more rapidly. Prior to the test conclusion, the flow of LOX ceased. Gaseous hydrogen and gaseous oxygen were observed to be draining from the tank. No ignition or other harmful effects were observed.

> "For the new Aquarius launch vehicle, the fatal event that brought the greatest of all airships down in flames is not a showstopper."

Bigger and Better

The successful completion of this test validates the general concept of hydrogen pressurization of the LOX tank for the low-cost/reduced-reliability Aquarius launch vehicle. Furthermore, it sets the stage for more ambitious testing involving larger tanks and more stringent environments which are more representative of conditions expected during launch. It is expected that the next series of tests will involve re-use of the same tanks used in the test described here, but the tanks will be mounted on a shaker table to simulate the launch vibration environment. The concept involves Microcosm manufacturing a larger tank of an already proven all-composite design. With a volume of fourteen cubic feet, tests with a much larger volume of LOX and GH2 will be possible.

Shedding the Hindenburg Stigma

Sensible use of hydrogen for air and space transportation is progressing as new technologies involving non-metallic, non-flammable tank materials help to overcome the stigma of the *Hindenburg* disaster.

For the new Aquarius launch vehicle, the fatal event that brought the greatest of all airships down in flames is not a showstopper. It is merely a cautionary tale, and perhaps a challenge. Aquarius can tolerate the risk, as it will carry no people. It will carry only easily replaceable supplies and low-cost, research-class spacecraft. High reliability is not required for Aquarius' economic success; in fact, the costs required for high reliability could doom true low-cost access to space for low-cost payloads. Accepting the risk of using hydrogen as a pressurizing gas for liquid propellants, including LOX, helps realize the reward of low-cost access to space. ■

Andrew Turner has been an engineer with Space Systems/Loral in Palo Alto, California for more than 23 years.

Aaron Leichner was working as a Structural Engineer and member of the Scorpius launch vehicle team at Microcosm, Inc. when this paper was produced.

The Mars Landing Approach: Getting Large Payloads to the Surface of the Red Planet

Some proponents of human missions to Mars say we have the technology today to send people to the Red Planet. But do we? Rob Manning of the Jet Propulsion Laboratory discusses the intricacies of entry, descent and landing and what needs to be done in order to make human presence on Mars a reality.

By Nancy Atkinson

There's no comfort in the statistics for missions to Mars. To date, over 60% of the missions have failed. The scientists and engineers of these undertakings invented phrases like "Six Minutes of Terror," and "The Great Galactic Ghoul" to illustrate their experiences, evidence of the anxiety that's evoked by sending a robotic spacecraft to Mars - even among those who have devoted their careers to the task. Mention sending a human mission to land on the Red Planet, with payloads several factors larger than an unmanned spacecraft, and the trepidation among that group grows even larger. Why?

The answer is that nobody knows how to do it.

Surprised? Most people are, says Rob Manning, the Chief Engineer for the Mars Exploration Directorate. Manning is presently the only person who has led teams to land three robotic spacecraft successfully on the surface of Mars.

"It turns out that most people aren't aware of this problem, and very few have worried about the details of how you get something very heavy safely to the surface of Mars," explains Manning.

Manning believes many people immediately come to the conclusion that landing humans on Mars should be easy. After all, humans have landed successfully on the Moon, and we can safely return human-carrying vehicles from space to Earth for landing. Since Mars falls between the Earth and the Moon in size and also amount of atmosphere, it seems that the middle ground of Mars should be easy. "There's the mindset that we should just be able to connect the dots in between," says Manning.

As of now, the dots must connect across a large abyss.

"We know what the problems are. I like to blame the god of war," quips Manning. "This planet is not friendly or conducive for landing."

The real problem is the combination of the Martian atmosphere and the size of spacecraft needed for human missions. So far, our robotic spacecraft have been small enough to enable at least some success in reaching the surface safely. But while the Apollo lunar lander weighed approximately ten metric tons, a human

Space is Scary

Six Minutes of Terror; Engineers for the Mars Exploration Rovers described the entry, descent, and landing (EDL) phase of the mission as *six minutes of terror*. The rovers entered Mars' atmosphere at 19,300 kilometers per hour (12,000 mph). Within six minutes, airbags slowed to the landers to a speed of twenty-four meters per second (fifty-four miles per hour) before impacting the surface. The landers encountered extreme heat, deceleration pulses, and high winds. They relied on precise performances of the heat shield, parachute, retro rockets, and airbags. Says Rob Manning, "In reality, the stress lasts much longer than six minutes." JPL produced a Hollywood-style trailer detailing EDL, entitled "Six Minutes of Terror." View it at http://marsrovers.nasa.gov/gallery/video/challenges.html.

The Great Galactic Ghoul; Early missions to Mars were plagued with difficulties and failures, both for the US and USSR. Engineers from JPL jokingly determined that there must be a space creature, a *Great Galactic Ghoul*, gobbling up the spacecraft heading to Mars. The phrase is usually attributed to the engineering team from Mariner 4. This spacecraft was the first to perform a successful flyby of Mars on July 14, 1965.

This artist's conception depicts the Mars Exploration Rover's landing sequence during the last few seconds of the spacecraft's journey. Approximately thirty to fifty feet above the Martian surface, retro-rockets are fired to slow the parachuting, airbag-padded rovers. (Source: NASA/JPL-Caltech) mission to Mars will require three to six times that mass, given the restraints of staying on the planet for a year. Landing such a heavy payload on Mars is currently impossible, using existing capabilities. "There's too much atmosphere on Mars to land heavy vehicles like we do on the moon, using propulsive technology completely," says Manning, "and there's too little atmosphere to land like we do on Earth. So, it's in this ugly, grey zone."

But what about airbags, parachutes, or thrusters? These have been used on the successful robotic Mars missions. What about a lifting body vehicle similar to the space shuttle?

None of these will work, either alone or in combination, to land payloads upwards of one metric ton on the Martian surface. This problem affects not only human missions to the Red Planet, but also larger robotic missions for purposes such as sample return. "Unfortunately, that's where we are," says Manning. "Until we come up with a whole new trick, a whole new system, landing humans on Mars will be an ugly and scary proposition."

Road Mapping

In 2004, NASA organized a Road Mapping session to discuss the current capabilities and future problems of landing humans on Mars. Manning co-chaired this event along with Apollo 17 astronaut Harrison Schmitt and the late Claude Graves from the Johnson Space Center. Approximately fifty other people from NASA, academia, and industry attended the session. "At that time, the ability to explain these problems in a coherent way was not as good," explains Manning. "The entry, descent and landing process is actually made up of people from many different disciplines. Very few people really understood, especially for large scale systems, what all of the issues were. At the Road Mapping session, we were able to put them all down and talk about them."

The major conclusion that came from the session was that no one has yet figured

Rob Manning is the Chief Engineer for the JPL Mars Exploration Directorate and is the only person who has led teams to land three robotic spacecraft successfully on the surface of Mars. (Source: Rob Manning/JPL)

out how to safely get large masses from speeds of entry and orbit down to the surface of Mars. "We call it the Supersonic Transition Problem," says Manning. "Unique to Mars, there is a velocity-altitude gap below Mach 5 [See figure, page 10]. The gap is between the delivery capability of large entry systems at Mars, and the capability of supersonic and subsonic decelerator technologies to get below the speed of sound."

Plainly put, with current capabilities, a large, heavy vehicle, streaking through Mars' thin, volatile atmosphere only has

"The real problem is the combination of the Martian atmosphere and the size of spacecraft needed for human missions."

about ninety seconds to slow from Mach 5 to under Mach one. During this time, a vehicle must change and re-orient itself from a being a spacecraft to a lander. It must deploy parachutes to slow down further. Thrusters must then be used in order to translate to the landing site, and finally, gently touch down.

No Airbags

When this problem is first presented to people, the most offered solution, Manning says, is to use airbags, since they have been so successful for the missions that he has been involved with. These missions include the Pathfinder rover, Sojourner, and the two Mars Exploration Rovers (MER), Spirit and Opportunity.

But engineers feel they have reached the capacity of airbags with MER. "It's not just the mass or the volume of the airbags, or the size of the airbags themselves, but it's the mass of the beast inside the airbags," Manning says. "This is about as big as we can take that particular design."

In addition, an airbag landing subjects the payload to forces between ten to twenty G's. Robots can withstand such force, but humans can't. This doesn't mean airbags will never be used again. It only illustrates that airbag landings cannot be used for something human or heavy.

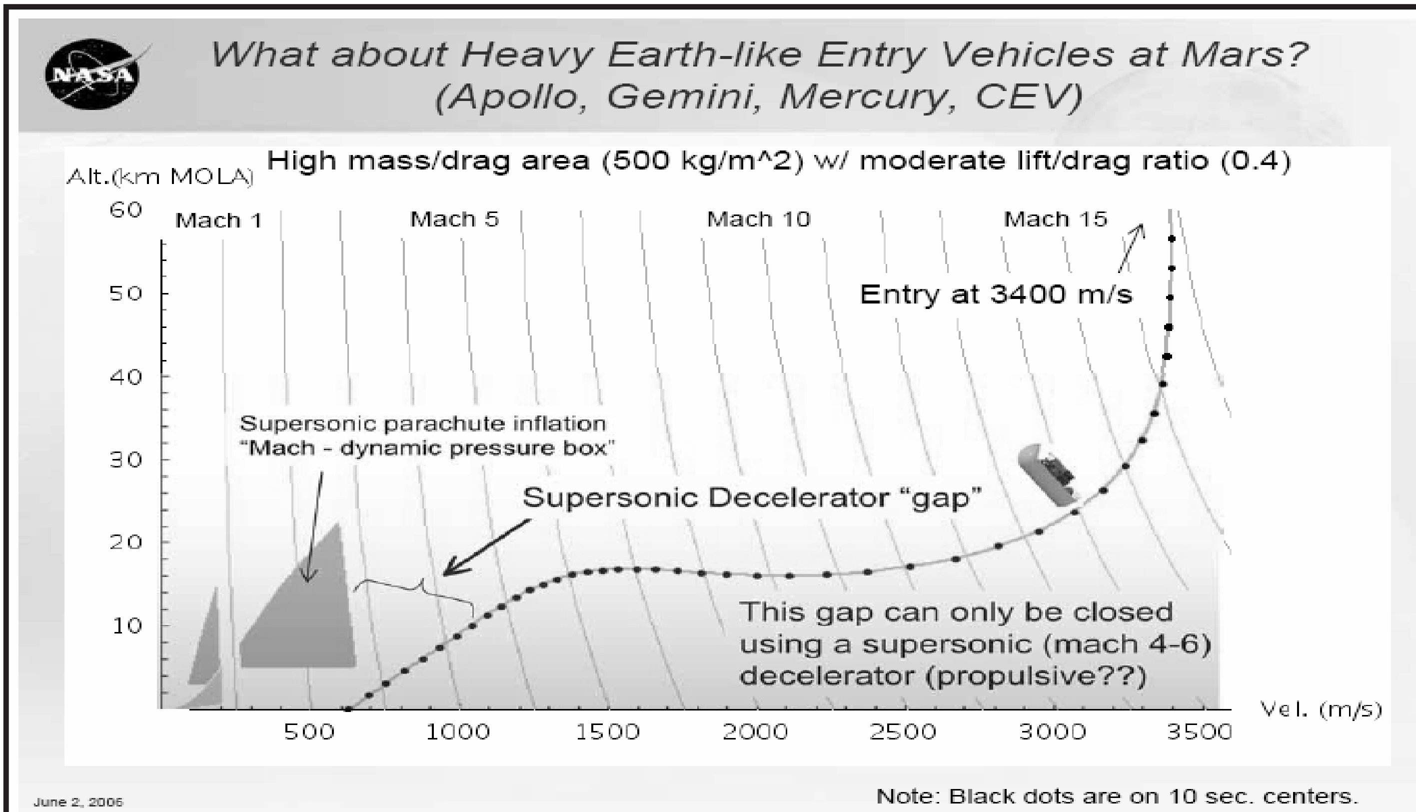
Even the 2009 Mars Science Laboratory (MSL) rover, which weighed 775 kilograms (compared to MER, weighing 175.4 kilograms each) requires an entirely new landing architecture. Too massive for airbags, the small-car sized rover will use a landing system dubbed the Sky Crane. "Even though some people laugh when they first see it, my personal view is that the Sky Crane is actually the most elegant system we've come up with yet, and the simplest," says Manning. MSL will use a combination of a rocket-guided entry with a heat shield and parachute, followed by thrusters to slow the vehicle even more, which will then be followed by a crane-like system that lowers the rover on a cable for a soft landing directly onto its wheels. Depending on the success of the Sky Crane with MSL, it's likely that this system can be scaled for larger payloads - but probably not to the size needed to land humans on Mars.

Atmospheric Anxiety and Parachute Problems

"The great thing about Earth," says Manning, "is the atmosphere." Returning to Earth and entering the atmosphere at speeds between seven and ten kilometers per second, the space shuttle, Apollo and Soyuz capsules and the proposed Crew Exploration Vehicle (CEV) will all decelerate to less than Mach one at about twenty kilometers above the ground. This will be accomplished simply by skimming through Earth's luxuriously thick atmosphere and using a heat shield. To reach slower speeds needed for landing, a parachute may be deployed. In the case of the space shuttle, drag and lift allow the remainder of the speed to bleed away.

But Mars' atmosphere is only one per cent as dense as Earth's. For comparison, Mars atmosphere at its thickest is equivalent to Earth's atmosphere at about 35 kilometers above the surface The air is so thin that a heavy vehicle like a CEV will basically plummet to the surface. There's not enough air resistance to slow it sufficiently. Parachutes can only be opened at speeds less than Mach two, and a heavy spacecraft on Mars would never go that slow by using only a heat shield. "There are no parachutes that you could use to slow this vehicle down," says Manning. "That's it. You can't land a CEV on Mars unless you don't mind it being a crater on the surface."

That's not good news for the Vision for Space Exploration. Would a higher lift vehicle like the space shuttle save the day? "Well, on Mars, when you use a very high lift to weight to drag ratio like the shuttle," explains Manning, "in order to get good deceleration and use the lift properly, you'd need to cut low into the atmosphere. You'd still be traveling at Mach two or three fairly close to the ground. If you had a good control system, you could spread out your deceleration to lengthen the time you are in the air. You'd eventually slow down to under Mach two to open a parachute, but you'd be too close to the



(Source: Rob Manning/JPL)

ground. Even an ultra large supersonic parachute would not save you."

Supersonic parachute experts have concluded that to sufficiently slow a large shuttle-type vehicle on Mars and reach the ground at reasonable speeds would require a parachute one hundred meters in diameter.

"That's a good fraction of the Rose Bowl. That's huge," says Manning. "We believe there's no way to make a 100-meter parachute that can be opened safely supersonically, not to mention the time it takes to inflate something that large. You'd be on the ground before it was fully inflated. It would not be a good outcome."

Heat Shields and Thrusters

It's not that Mars' atmosphere is useless. Manning explains that with robotic spacecraft, 99% of the kinetic energy of an incoming vehicle is taken away using a heat shield in the atmosphere. "It's not inconceivable that we can design larger, lighter heat shields," he says, "but the problem is that right now, the heat shield diameter for a human-capable spacecraft overwhelms any possibility of launching that vehicle from Earth." Manning adds that it would almost be better if Mars were like the moon, with no atmosphere at all.

If that were the case, an Apollo-type lunar lander with thrusters could be used. "But that would cause another problem," says Manning, "in that for every kilogram of stuff in orbit, it takes twice as much fuel to get to the surface of Mars as the moon. Everything is twice as bad since Mars is about twice as big as the moon." That would entail a large amount of fuel, perhaps over 6 times the payload mass in fuel, to get human-sized payloads to the surface, all of which would have to be brought along from Earth. Even on a fictitious air-less Mars, that is not an option.

Showing heritage, the relative sizes of Pathfinder (center), Mars Exploration Rover (left), and Mars Science Laboratory (right) wheels keep growing. (Source: NASA/JPL)

Using current thruster technology in Mars' real, existing atmosphere poses aerodynamic problems. "Rocket plumes are notoriously unstable, dynamic, and chaotic systems," says Manning. "Basically flying into the plume at supersonics speeds, the rocket plume is acting like a nose cone; a nose cone that's moving around in front of you against very high dynamic pressure. Even though the atmospheric density is very low, because the velocity is so high, the forces are really huge."

Manning likens theses forces to a Category Five hurricane. This would cause extreme stress, with shaking and twisting that would likely destroy the vehicle. Therefore, using propulsive technology alone is not an option.

Using thrusters in combination with a heat shield and parachute also poses challenges. Assuming the vehicle has used some technique to slow to under Mach one, using propulsion just in the final stages of descent to gradually adjust the lander's trajectory would enable the vehicle to arrive very precisely at the desired landing site. "We're looking at firing thrusters less than one kilometer above the ground. Your parachute has been discarded, and you see that you are perhaps five kilometers south of where

"Supersonic parachute experts have concluded that to sufficiently slow a large shuttle-type vehicle on Mars and reach the ground at reasonable speeds would require a parachute one hundred meters in diameter."

“Mars is really begging for a space elevator,” says Manning.

you want to land,” says Manning. “So now, you need the ability to turn the vehicle over sideways to try to get to your landing spot. But this may be an expensive option, adding a large tax in fuel to get to the desired landing rendezvous point.”

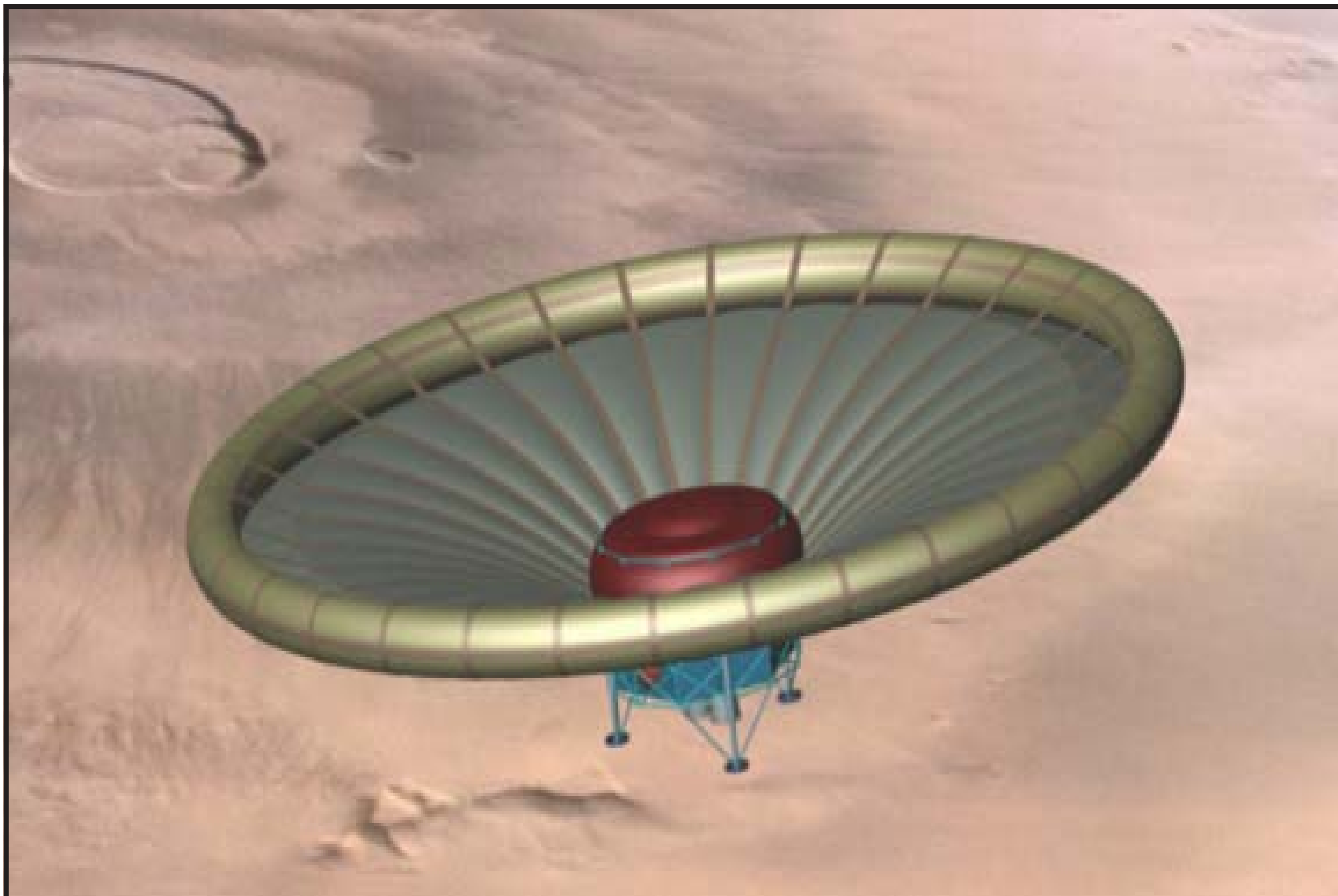
Additionally, on the moon, with no atmosphere or weather, there is nothing pushing against the vehicle and taking it off target. Like Neil Armstrong proved during Apollo 11, the pilot can “fly out the uncertainties,” as Manning calls it, to reach a suitable or more desired landing site. On Mars, however, large variations in the density of the atmosphere coupled with high and unpredictable winds conspire to push vehicles off course. “We need to have ways to fight those forces, or ways to make up for any mis-targeting using the propulsion system,” says Manning. “Right now, we don’t have that ability, and we’re a long way from making it happen.”

Supersonic Decelerators

The best hope on the horizon for making the human enterprise on Mars possible is a new type of supersonic decelerator that’s only on the drawing board. A few companies are developing a new inflatable supersonic decelerator called a Hypercone.

Imagine a huge donut with a skin across its surface which girdles the vehicle, and inflates very quickly with gas rockets (like air bags) to create a conical shape. This would inflate about ten kilometers above the ground while the vehicle is traveling at Mach four or five, following peak heating. The Hypercone would act as an aerodynamic anchor to slow the vehicle to Mach one.

Glen Brown, Chief Engineer at Vertigo, Inc. in Lake Elsinore, California was also



The Hypercone, an inflatable supersonic decelerator design, is a technology being developed to allow for eventual human landings on the surface of Mars. (Source: Vertigo, Inc.)

a participant in the Mars Road Mapping session. Brown says Vertigo has been doing extensive analysis of the Hypercone, including sizing and mass estimates for landers from four to sixty metric tons. “A high pressure inflatable structure in the form of a torus is a logical way to support a membrane in a conical shape, which is stable and has high drag at high Mach numbers,” Brown says. Brown adds that the structure would likely be made of a coated fabric such as silicon-Vectran matrix materials. Vertigo is currently competing for funding from NASA in order to support further research. The project’s next step, deployment in a supersonic wind tunnel, is quite expensive.

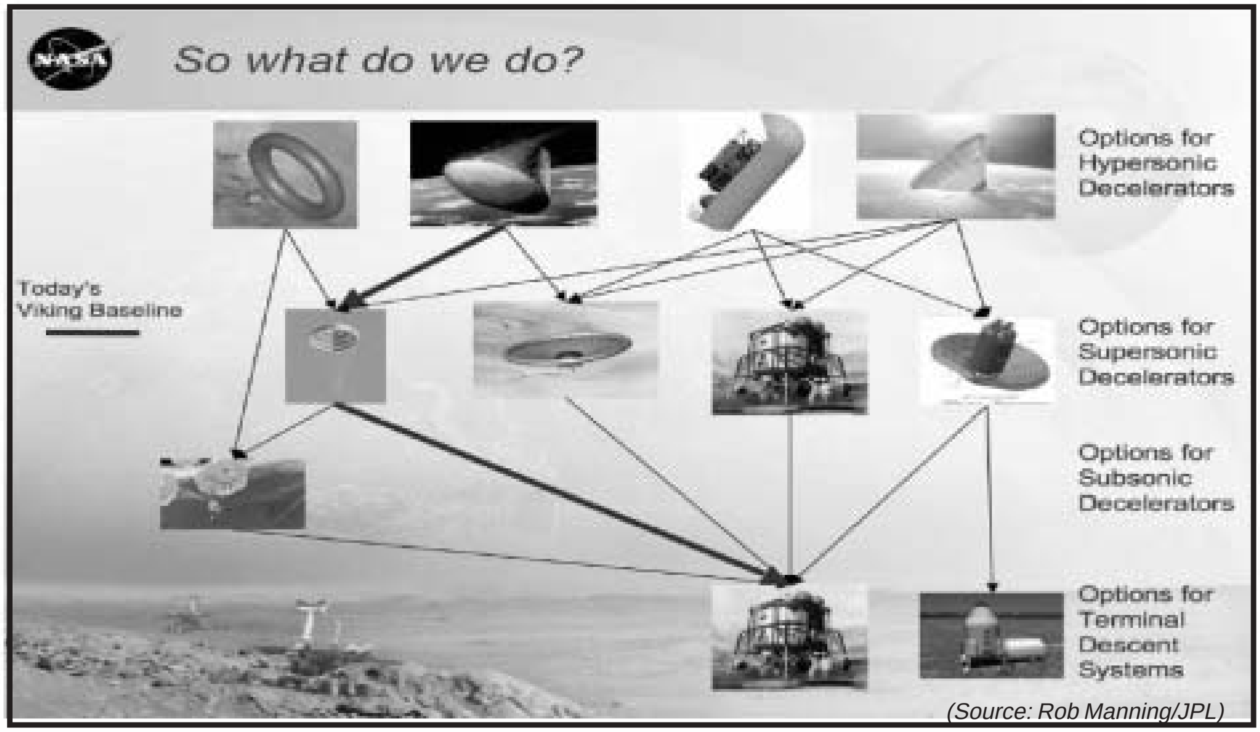
The structure would need to be about thirty to forty meters in diameter. The problem is that large, flexible structures are notoriously difficult to control. At present, there are also several other unknowns involved with the development and use of a Hypercone.

One train of thought is that if the Hypercone is able to slow the vehicle below Mach one, then subsonic parachutes could be used, much like the ones employed by Apollo, or similar to those which the CEV is projected to use for landing on Earth. However, it takes time for the parachutes to inflate. Subsequently, there would only be a matter of seconds of use, allowing little time to shed the parachutes before converting to a propulsive system.

“You’d also need to use thrusters,” says Manning. “You’re falling ten times faster, because the density of Mars’ atmosphere is one hundred times less than Earth’s. That means that you can’t just land with parachutes and touch the ground. You’d break people’s bones, if not the hardware. So, you need to transition from a parachute system to an Apollo-like lunar legged lander sometime before you get to the ground.”

Manning believes that those who are immersed in these matters, like himself, see the various problems fighting each

Data from successful Martian exploration missions are used together. This image taken by the Mars Reconnaissance Orbiter HiRISE instrument is being used to point out potentially interesting geological samples for analysis by Opportunity, the nearby Mars Exploration Rover. (Source: NASA/JPL/University of Arizona)



(Source: Rob Manning/JPL)

other. "It's hard to get your brain around all these problems, because all the pieces connect in complex ways," he says. "It's very hard to see the right answer in your mind's eye."

The additional issues of creating new lightweight but strong shapes and structures, with the ability to come apart and transform from one stage to another at just the right time means developing a rapid-fire Rube Goldberg-like contraption.

"The honest truth of the matter," says Manning, "is that we don't have a standard canonical form, a standard configuration of systems that allows us to get to the ground with the right size that balances the forces, loads, and the people, allowing us to do all the transformation that need to be done in the very small amount of time that we have to land."

Other Options and Issues

Another alternative discussed at the 2004 Mars Road Mapping session was the space elevator.

"Mars is really begging for a space elevator," says Manning. "I think it has great potential. That would solve a lot of problems, and Mars would be an excellent platform to try it." But Manning admits that the technology needed to suspend a space elevator has not yet been invented. The issues with space elevator technology may be vast, even compared with the challenges of landing.

Despite these known obstacles, there are few at NASA currently spending quality time working on any of the issues of landing humans on Mars.

Manning explains, "NASA does not yet have the resources to solve this problem and also develop the CEV, complete the International Space Station, and do the lunar landing systems development simultaneously. But NASA knows that this is on its plate of things to do in the future, and is just beginning to get a handle on the needed technology developments. I try to go out of my way to tell this story, because I'm encouraging young aeronautical engineering students, particularly graduate students, to start working on this problem on their own. There is no doubt in my mind that with their help, we can figure out how to make reliable human-scale landing systems work on Mars."

"I'm encouraging young aeronautical engineering students, particularly graduate students, to start working on this problem on their own."

While there is much interest throughout NASA and the space sector to try to tackle these issues in the ensuing years, technology also needs a few more years to catch up to the dream of landing humans on Mars. This story, like all good engineering stories, will inevitably read like a good detective novel with technical twist and turns, scientific intrigue, and high adventure on another world. ■

***Nancy Atkinson* is a freelance journalist and a NASA/JPL Solar System Ambassador.**

SYMPOSIUM EXPLORES PAST, PRESENT, FUTURE SPACE EXPLORATION

By Michael Calabrese, SGT, Inc.

The 45th Robert H. Goddard Memorial Symposium was held March 20-21, 2007 at the University of Maryland University College Inn and Conference Center. This annual symposium is sponsored by the American Astronautical Society (AAS) and supported by the NASA Goddard Space Flight Center.

This year's theme, "Sputnik to Orion: Perspectives, Opportunities, and Future Directions," provided a forum to reflect and wonder about humankind's fascination with space exploration.

Goddard's Center Director Ed Weiler began the symposium by welcoming attendees and introducing keynote speaker NASA Administrator Michael Griffin. Dr. Griffin reflected on the last 50 years of space exploration and John F. Kennedy's challenge which propelled our nation into a leadership role on the space frontier. "I do believe the most significant and lasting outcome of our national reaction to Sputnik was the creation of NASA in 1958 as the agency responsible for our nation's civil space program," Griffin said.

Looking into the future, Griffin cited his recent article in the online edition of *Aviation Week and Space Technology*, in which he concluded that "If we continue to receive today's budget in inflation-adjusted dollars – no more and no less – we will have enough money to do an Apollo-scale program, three times over, and more, by the 100th anniversary of Sputnik."

Center Director Edward Weiler offers a warm welcome to attendees on the first day of the Symposium (Source: Christopher Gunn/NASA GSFC)

In conclusion, Griffin spoke about program planning and insisted that "We must bring forward realistic programs, executable within the budget portfolios." He also emphasized that these programs should not be relying on the achievement of "miracles in series." He described the "three mission areas of space exploration, scientific discovery, and aeronautics research as strategic capabilities for our nation. And further, that they can operate in balance and synergistically with each other."

A "Sputnik to Orion: 50 Years in Space" video was presented as an introduction for the first session of the symposium. The video included a few memorable images that captured some of the amazing accomplishments of the first 50 years of the space age.

The first day of the symposium also included technical sessions covering *The Space Age at 50: What Can History Tell Us?* moderated by Roger Launius; *Engineering Space Exploration* moderated by Doug Cooke; *Engineering Space Commercialization* moderated by Doug Comstock; and *Engineering the Systems – Lessons Learned* moderated by Joe Rothenberg.

Congressman Nick Lampson speaks to attendees at the Tuesday luncheon (Source: Christopher Gunn/NASA GSFC)

During lunch, Congressman Nick Lampson (D-TX) addressed attendees and reflected on the importance of keeping the public informed as to the results and importance of our space exploration, scientific discovery and aeronautics research efforts.

Kathie Olsen, Deputy Director of the National Science Foundation (NSF), provided the keynote address on the second day. She discussed the role of the NSF working together with NASA and making contributions to Astronomy, Space Weather, and Astrobiology. Technical sessions on the second day included *The Science Enabled by the Moon* moderated by Jim Garvin and *Space and Earth Science 2020* moderated by Laurie Leshin and Rick Obenschain.

The first panel session discusses The Space Age at 50: What Can History Tell Us? (Source: Christopher Gunn/NASA GSFC)

Wednesday's lunch speaker was Lon Rains, Editor of Space News. During lunch, AAS President Mark Craig presented Wesley T. Huntress, Jr. with the Randolph Lovelace II Award, Marcia Smith with the John F. Kennedy Astronautics Award, Richard Williams with the Melbourne W. Boynton Award, and Dr. James Hansen with the Eugene M. Emme Astronautical Literature Award.

The 2006 co-recipient of the Nobel Prize for Physics Dr. John Mather concluded the second day of presentations.

Dr. John Mather, Nobel Prize winner, concludes the symposium with his presentation on COBE (Source: Christopher Gunn/NASA GSFC)

He spoke about his work with Cosmic Background Explorer (COBE) and winning the Nobel Prize, and provided a future glance into space science with the James Webb Space Telescope (JWST). Dr. Mather concluded that JWST will continue our pursuit of improved understanding directed at the major questions facing us in astrophysics.

Student and Goddard Research and Development Posters were presented in the lobby throughout the symposium.

The presentations and videos from the symposium are available on the AAS website, www.astronautical.org. ■

A student explains his poster (Source: Christopher Gunn/NASA GSFC)

2007 AAS/AIAA Astrodynamics Specialist Conference

Mission Point Resort ■ Mackinac Island, Michigan

August 19-23, 2007

Come to beautiful Mackinac Island, Michigan and join with leaders in the field of Astrodynamics at the 2007 AAS/AIAA Astrodynamics Specialist Conference. This annual event is hosted this year by AAS and cosponsored by the American Institute of Aeronautics and Astronautics (AIAA). The conference will be held August 19-23 at the Mission Point Resort and is organized by the AAS Space Flight Mechanics Committee. The technical program, special presentations and social events are not to be missed – check www.space-flight.org for details and online registration. Registration is also available on-site.

Attention All AAS Members

CALL FOR 2007 NOMINATIONS

Fellows: To qualify as an AAS Fellow, a candidate must be a current active member with significant scientific, engineering, academic, and/or management contributions to astronautics and space. In addition, contributions to AAS are considered. Selection procedures and a complete list of Fellows elected since 1954 can be viewed on the AAS web site. Nominations may be submitted by any AAS member, and must be received by the AAS Business Office by June 15. The Fellows Committee will review all submissions, and their recommended candidates will be approved by the Officers, Directors, and Active Fellows.

Awards: Each year AAS presents awards to recognize the excellence and professional service of our own membership and members of the space community. All AAS members are invited and strongly encouraged to nominate worthwhile candidates for this year's awards. Award descriptions, previous recipients, and nomination procedures can be viewed on the AAS web site. Nominations will be accepted by the AAS Business Office through July 20, at which time the Awards Committee will review all submissions and forward names of recommended candidates to the Officers and Directors for vote. Recipients and newly elected Fellows will be invited to accept their award at the annual AAS Banquet on November 13, 2007 at the South Shore Harbour Resort in Houston.

Officers and Directors: Each year the Society must elect (or re-elect) a slate of eleven officers and one third of the Board of Directors. A Nominations Committee will select qualified candidates, who will then be placed on the ballot and voted on by the AAS membership. Are you interested in serving in an elected position, or would you like to nominate a qualified individual? If so, please contact the AAS Office.

AAS ANNUAL AWARDS

- *Space Flight Award* (our highest honor – individual whose outstanding efforts and achievements have contributed most significantly to the advancement of spaceflight and space exploration)
- *Flight Achievement Award* (outstanding achievement as flight crew or flight crew member)
- *Victor A. Prather Award* (honors researchers, engineers, and flight crew members in the field of extravehicular protection or activity in space)
- *Lloyd V. Berkner Award* (person who has made significant contributions to the commercial utilization of space technology)
- *Randolph Lovelace II Award* (recognizes significant contributions to space science and technology)
- *Melbourne W. Boynton Award* (conferred upon a physician who has made a significant contribution to the biomedical aspects of spaceflight)
- *Dirk Brouwer Award* (recognizes significant technical contributions to spaceflight mechanics and astrodynamics – nominated by Space Flight Mechanics Committee)
- *John F. Kennedy Award* (individual who has made an outstanding contribution to public service through leadership in promoting our space programs for the exploration and utilization of outer space)
- *Eugene M. Emme Astronautical Literature Award* (selected by a subcommittee of the AAS History Committee)
- *Military Astronautics Award* (for outstanding leadership in the application of astronautics to the development of space systems for national defense)
- *Industrial Leadership Award* (individual in the space industry who has made an outstanding contribution through leadership in development and acquisition of space systems)
- *Advancement of International Cooperation Award* (for outstanding contributions in advancing international astronautics activities)
- *Carl Sagan Memorial Award* (an individual who has demonstrated leadership in research or policies advancing exploration of the Cosmos – recipient is expected to give the Sagan Lecture at the National Conference – chosen by a joint committee of AAS and The Planetary Society)
- *Lifetime Achievement Award* (recognizes individuals who have made sustained, personal contributions to the field of Astronautics – last awarded in 2004 – awarded at every tenth anniversary of the Society)

Complete descriptions and past recipients available at www.astronautical.org

MARK YOUR CALENDARS

for the 2007 AAS National Conference and 54th Annual Meeting in Houston, November 13-14!

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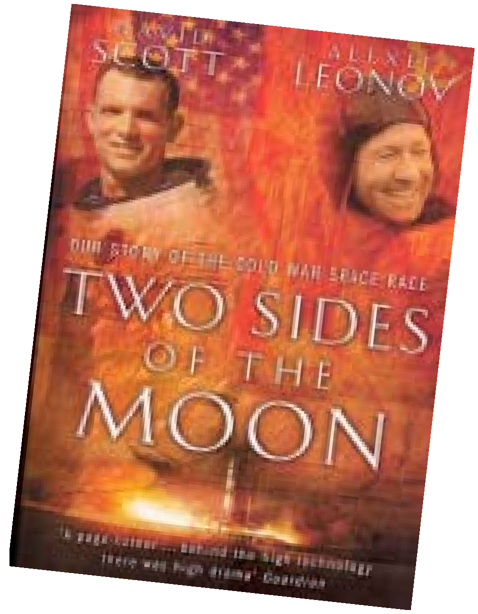
TWO SIDES OF THE MOON: OUR STORY OF THE COLD WAR SPACE RACE

Reviewed by Mark Williamson



Two Sides of the Moon, by David Scott and Alexei Leonov, Simon & Schuster UK, 2005, 415 pages, £8.99, ISBN 0-7434-5067-1 [softcover]

Of the many people writing space history books these days, some have the distinct advantage of having actually been to space. Written by Apollo astronaut Dave Scott and Vostok cosmonaut Alexei Leonov, *Two Sides of the Moon* is a good example. The book also benefits from the intrigue of celebrity, with a foreword by Neil Armstrong and an introduction from space buff Tom Hanks.

Though the book's subtitle, *Our Story of the Cold War Space Race*, places the book neatly within its historical context, that race's role in determining the course of history will probably always remain open to argument. Armstrong quotes the common belief that the Space Age began because of the Cold War between the US and USSR, but suggests this view is "not quite right," citing the additional influence of the International Geophysical Year (IGY) and its pursuit of scientific understanding. In a jacket quote, Arthur C. Clarke states his opinion that the book "provides a very valuable account of the way the Cold War was *ended* in space [reviewer's italics]."

Although the book is a largely chronological story – from the early 1930s to the early 2000s – it is, by necessity, two tales woven into one. This is done by alternating relatively short sections from each author, which illustrate what each was doing and thinking througout his career. This assimilation nonetheless manages to be a seamless and engaging story. Much of the credit for this must go to writer Christine Toomey, whose name does not appear on the cover. Obviously, the raw material comes from the book's principal subjects, but somehow Toomey manages to ensure that respective sections are unified while still maintaining the individual characters of the two space veterans.

Although the majority of the book relates to a bygone age, an epilogue provides interesting opinions on recent events. Leonov addresses criticism of space tourism pragmatically. "[Dennis] Tito had worked hard for his money," states Leonov. "Why should he not be allowed to spend it as he wished?" Later, he adds, "Three space tourists like Dennis Tito each year would have been enough to secure Mir's financial future."

Leonov also recalls Arthur C. Clarke's book *2010: Odyssey Two*, which centers on the voyage of a spaceship named after Leonov, and to whom the book was also dedicated. Halfway through the serialisation of the story in a Soviet youth magazine, Leonov remembers that he was "hauled before a meeting" of the Communist Party's Central Committee. How could he allow this to happen, they asked; the crew of the *Alexei Leonov* consisted of Soviet dissidents! Leonov's response was blunt. "You're not worth the nail on Arthur C. Clarke's little finger," he told them.

Elsewhere, Scott explains his "left seat, right seat hypothesis" regarding how the six Apollo landing missions affected their crews. While the lunar module commanders, by convention occupying the left-hand seat, went on to pursue "more straightforward" business and academic careers, he says, the right-seat pilots "tended to follow more unusual, and sometime difficult, paths." He cites Buzz Aldrin's decent into alcoholism, Al Bean's career as a professional artist, Ed Mitchell's research into "the nature of consciousness," Jim Irwin's career as an evangelist, and Jack Schmitt's six-year term as a Senator in the U.S. Congress.

Scott suggests that reasons for these unconventional choices might include frustration in not commanding their own lunar missions, or "not being burdened with the same level of responsibility" and therefore having more time to think. Whatever your view, this book offers plenty to consider. It should be read not only by those with an interest in space exploration, but also those who enjoy biographies. It will surely open eyes to a world beyond typical celebrity, and may even encourage some to gaze at the Moon with a new-found wonder.

Mark Williamson is an independent space technology consultant and author.

WHERE'S MY JETPACK? A GUIDE TO THE AMAZING SCIENCE FICTION FUTURE THAT NEVER ARRIVED

Reviewed by Gideon Marcus

Where's My Jetpack, by Dr. Daniel H. Wilson, Bloomsbury USA, 2007, 192 pages, $14.95, ISBN 1-5969-1-136-0 [softcover]

Fortune-telling is a tricky business. Sometimes, the future seems so obvious, one can't help making accurate predictions. In the early 1950s, everyone knew that space travel was just around the corner. In the late 1960s, it was a safe bet that electronics would get faster and faster. But who would have guessed that space travel would stagnate once we reached the moon? Who would have foreseen that we'd have personal computers and iPods instead a giant MULTIVAC running the world? Sometimes, reality exceeds our wildest dreams - look at what we can do with biotechnology these days. Most advances we expected as children still haven't come to pass, however. These frustrated visions of the future are the subject of Where's My Jetpack? A Guide to the Amazing Science Fiction Future That Never Arrived, a new book by Dr. Daniel H. Wilson.

As an historian, I've always enjoyed scientific what-if scenarios. I'll often page through my collection of ancient Galaxy magazines and see what the far future looked like to writers of the 1950s. If I'm in a more serious mood, I'll pore through my fourteen volume set of predictions commissioned during the late 1960s by TRW. Wilson's book is a collection of short essays grouped by subject, each detailing the fate of a predicted technology that "failed to launch."

In addition to the personal jetpacks featured on the cover, there are essays on flying cars, zeppelins, and sentient robotic pets: all the staples of mid-century science fiction. To be fair, a good many of the essays feature technologies which are now on the cusp of being realized. These are the most fun. For instance, slidewalks can be found in malls and airports. Self-guiding cars navigated by GPS are here to a degree. While humanity has not moved *en masse* into the oceans, there is one five-star hotel currently under construction off the coast of Dubai.

And who's to say that there won't be colonies on the moon or city-skyscrapers in the future? This is the point of the book - to touch upon dreams of the past, see which ones failed and why, and consider whether they might yet come true.

Of course, the real point of such a book is to entertain. Well written with tongue lodged firmly in cheek, Wilson's book is a quick read. This is definitely no scholarly work, but the reader will come away with some amusing trivia, and perhaps successfully avoid watching the boring in-flight movie during a transcontinental flight. If you are a technology buff, or someone who wants to know why the local Wal-Mart doesn't sell ray guns, or wonders why Walt Disney's head probably won't be traveling the lecture circuit anytime soon, you'll enjoy this book. ■

***Gideon Marcus* is a space historian and member of the AAS History Committee.**

SPACE TIMES Article Submission Guidelines

Feature articles (1500-3000 words), op-eds (500-1500 words), and book reviews (600 words or less) are accepted. Exceptions to these lengths must be discussed with the editor. The editor and author will agree on a length at the time an assignment is made.

Articles may cover virtually any topic involving space science, technology, exploration, law, or policy. Articles that touch on issues relevant to the civil, commercial, and military and intelligence space sectors alike are also welcomed.

Articles should be written for a well-educated audience that has a great interest in space topics but may not necessarily be familiar with your specific topic.

Space Times is a magazine, as opposed to a technical journal. Articles should therefore be written in active voice, with a clear explanation of technical concepts provided. The tone should lean more toward conversational rather than formal. References will not be included with any articles.

Submission deadlines are typically six to seven weeks prior to the first month of the issue (e.g., July 16 for the September/October issue). Exceptions must be discussed in advance with the editor.

Articles should be submitted in Microsoft Word format, Times New Roman font. Other formatting will be handled by us during the editing process.

Please provide with your article: a title; a subtitle or one to two sentence summary of the subject matter; subheadings to provide separation between major sections of the article; and a one to two sentence author biography which will appear at the end of the article. Complimentary copies of the issue in which your article appears will be mailed to all authors, so please provide a mailing address.

Submission of photos or other visual support is encouraged, but not required, and must be provided in high resolution (at least 300 dpi) and JPG, TIF, or GIF format. Visuals may not be imbedded in an article but must be provided separately. Please provide proof of permission from the owner of any photos or visuals, or contact information of the owner if permission has not already been obtained prior to submission of an article.

A few style suggestions: units of measurement should be conveyed in metric, not English, terms; acronyms should be used sparingly and only when a term is used several times; names of specific spacecraft (e.g., *Columbia*) should be italicized, but general spacecraft names (e.g., space shuttle, Delta) should not be; and numbers one through one hundred should be spelled out.

Contact: Jeffrey Elbel, Editor (elbelj@saic.com)

VOLUNTEERS NEEDED

Your help is requested! Three important committees will meet later this summer, and each is critical to the work of AAS. The Awards Committee reviews nominations for ten major AAS annual awards and selects worthy candidates for election by the Board. The Fellows Committee reviews candidates for the annual Fellows election; over 420 distinguished men and women have been chosen for this honor since 1954. Finally, the Nominations Committee develops a slate of officer and director candidates for election by the membership. Although the AAS President selects the committee chairs, membership of each is open to AAS members. If you are interested in serving as a committee member, please contact the AAS office at aas@astronautical.org.

AAS Events Schedule

June 8–10, 2007
***Student CanSat Competition**
Amarillo, Texas
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August 19–23, 2007
***AAS/AIAA Astrodynamics Specialist Conference**
Mission Point Resort
Mackinac Island, Michigan
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November 13–14, 2007
***AAS National Conference and 54th Annual Meeting**
South Shore Harbour Resort
Houston, Texas
703-866-0020
www.astronautical.org

January 27-31, 2008
***AAS/AIAA Space Flight Mechanics Winter Meeting**
The San Luis Resort
Galveston, Texas
703-866-0020
www.space-flight.org

February 2-6, 2008
31st AAS Guidance and Control Conference
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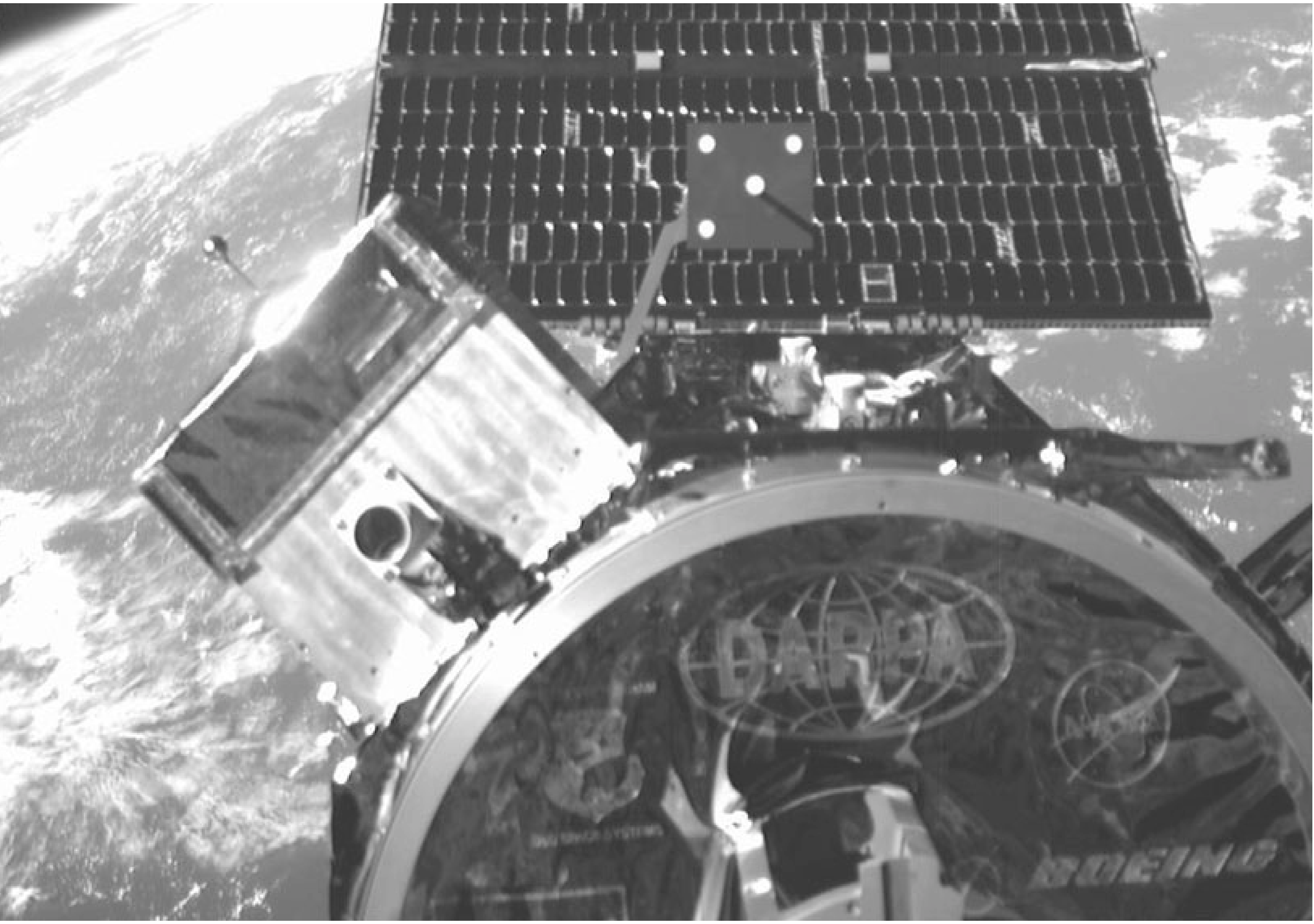

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