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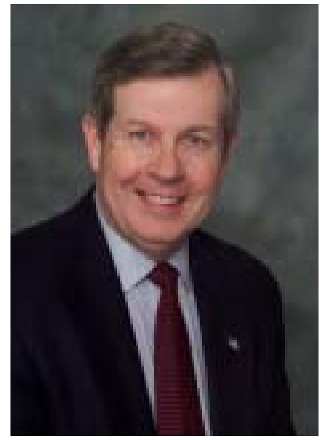
President's Message



I just returned home from the hot and dusty airfield in southeast Texas known as Naval Air Station Kingsville. The occasion was as very special one – one that (almost) made me not notice the 105-degree temperatures. Fresh from his first tailhook landings on a carrier, my son Ben had earned his "wings of gold" as a Navy pilot, and I couldn't have been more proud when his fiancée pinned on those wings. It was, for me, truly a great day to be both a parent and a retired naval officer passing the watch to the next generation.

Other than out of pride, why do I mention this event in these pages? Well, it brings to mind some thoughts which I want to pass along to you, our members. Ben, you see, is an astrospace engineer. He excelled in that major at the Naval Academy and then completed his master's degree in aerospace engineering at the University of Texas in Austin before moving on to basic flight school in Pensacola, Florida, and advanced training at "NAS Kingsville." His training squadron's commanding officer, it turns out, is also an engineer with a space background, having recently served on the U.S. Strategic Command staff in Colorado Springs. Here are two Navy pilots who are also "space guys," one just beginning his career of defending our nation and one who's "been there and done that." Two space professionals, and *neither* is currently a member of the AAS. What's wrong with this picture?

My point is this: the AAS is an organization that individuals such as these can and should belong to as members, even if they're not directly involved in space programs today. As the senior professional society dedicated to astronautics, the AAS has among our members many individuals who are either currently or formerly engaged in the field of space systems research and development, design, manufacturing, or operations. But there are many other folks out there who are trained in the field of astronautics and yet are currently working in other fields. By attracting these professionals to individual membership in the AAS, we can through our *Space Times* and *Journal of the Astronautical Sciences* publications and through our meetings and symposia help to keep them current in the field of astronautics. They, and we as an organization, will be better off for it.

So fellow members, I'm signing up Ben as an AAS member, and I'm reaching out to his commanding officer to invite him to become a member as well. They – and so many other space-trained professionals – have jobs to do outside of our field. *But they'll be back!* The exploration and utilization of space give us challenges too big and too compelling to resist for long. If *you* know of someone like this who should be among our ranks as an AAS member, please invite that individual to join. Invite him or her to come with you to a symposium. Give him or her this copy of *Space Times*. Send him or her to our web site, www.astronautical.org. And then let's all say "Welcome aboard!" to our new members.

And let's not forget to say "Thank you!" to those people out there who are serving our nation in these challenging times, whether they are "space people" or not.

I hope you're having a great summer, and I hope to see many of you at our Annual Meeting and National Conference in Houston in November.

Jon Malay

ON THE COVER

This image of Comet Tempel 1 was taken by the high-resolution camera aboard the Deep Impact fly-by spacecraft sixty-seven seconds after it was struck by Deep Impact's impactor spacecraft on Independence Day weekend. Scattered light from the collision saturated the camera's detector, creating the bright splash seen here. Linear spokes of light radiate away from the impact site, while reflected sunlight illuminates most of the comet surface. The image reveals topographic features, including ridges, scalloped edges, and possibly ancient impact craters. (Source: NASA/JPL-Caltech/University of Maryland)

Sustaining an Interplanetary Supply Chain

The development of NASA's Project Constellation spacecraft and launch systems undoubtedly will be fraught with operational and logistical challenges.

by Frank Sietzen, Jr.

The United States is proposing to sustain a fleet of operational interplanetary spacecraft, payloads, launch vehicles and upper stages out in the dark spaces between worlds – a feat unique in the history of manned space flight. These varied and complex vehicles and their individual requirements will challenge both the National Aeronautics and Space Administration (NASA) and the aerospace industry to first reach and then sustain a mature level of space flight operations. If the goals of President George W. Bush's vision for space exploration are considered in the context of space logistics, it is possible to assess the ramifications to the production and maintenance of space exploration-capable systems. Creating such an interplanetary supply chain will be a sustained logistical challenge new in humanity's exploration of space.

Some three decades ago, the operations of the commercial airlines and the B-52/X-15 fleet were used as analogs for the operational objectives of the space shuttle, then under design. While airline-like operations in terms of vehicle flow and flight preparations were considered the ultimate goal, the shuttle fleet never reached anything approximating such a capability. Shuttle flight rates never reached, much less exceeded, one per month throughout the history of the program to date; nine flights in a single year remains and is likely to remain the maximum capability that the four-orbiter – now three-orbiter – fleet could yield. What was learned instead was how to integrate in a limited way a complex array of payload types into the shuttle's cargo bay as well as how to prepare astronaut equipment and stock supplies to sustain individual mission objectives and, later on in shuttle history, the expedition crews to the International Space Station.

But this experience, as invaluable as it has become, will not be a sufficient one upon which to base the operational philosophies of all of Project Constellation's vehicle elements. Doing that will require a whole new logistical and space support supply chain. This time, a pursuit of high flight rates will not be the main challenge to planners; instead, the test will be how to maintain a series of new launching units, payloads, and instruments that mix robotic elements with manned interplanetary vehicles developed in "spirals." The task of designing this "interplanetary supply chain" will be as challenging as reaching out into deep space itself. Fortunately, there is time for such an effort to come together and an experience base, that being the shuttle, to serve as a point of departure.

At one time, NASA officials envisioned the space shuttle launching missions several dozen times per year. In practice, however, the shuttle program has averaged less than one flight per month. NASA's X-15 program conducted out of Dryden Flight Research Center experienced far greater flight rates. An X-15 is shown here soon after being dropped by its mother ship, the B-52. (Source: NASA/Dryden Flight Research Center)

Drawing from Experience

Consider the production and logistics requirements that existed the last and previously the only time humans attempted to build a transportation system between Earth and cislunar space. From 1961 to 1972, a span of only eleven years, the United States's main human space program was Project Apollo. Following President Kennedy's announcement on May 25, 1961, that a manned lunar landing was his central space goal, a subsequent decision was made as to how to conduct the space missions that would achieve it. A method calling for rendezvous of spacecraft components in lunar orbit was selected. Under the chosen Apollo plan, a single large, heavy-lift launcher (then defined as exceeding one hundred metric tons to low Earth orbit) carried all of the space flight vehicles needed for the landings in a single ascent from a launching site on the Florida coast later named for the president that proposed the goal. Following checkout of spacecraft systems in orbit, a third stage of the rocket ignited to send the stack of spacecraft components out of orbit toward the Moon. En route, the manned Apollo reentry vehicle with its astronaut crew on board and its propulsion unit attached separated from the stack, turned around in midflight, and docked with a lander carried in a cargo hold at the top of the rocket's stage. The combined reentry vehicle and lander maneuvered away from the rocket, which would be either redirected to impact on the Moon or sent into a permanent orbit of the Sun.

No part of either the Apollo reentry vehicle or its propulsion module was reusable. The lower part of the lunar lander remained on the Moon's surface, serving as a launching platform for the upper stage, which was discarded in lunar orbit to eventually crash back onto the surface. A single Saturn 5 launch accomplished each landing mission. No other launch vehicles were needed.

During the Apollo era, one mighty Saturn 5 launched each Apollo mission that landed humans on the Moon. The Saturn series vehicle achieved its maximum mission launch frequency in 1969, when Apollos 9, 10, 11, and 12 were accomplished successfully in the span of nine months. (Source: NASA)

The first Saturn 5 launch took place in 1967. The following year saw two: the unmanned Apollo 6 and the circumlunar manned Apollo 8. In 1969 there were four Saturn 5 launches, the most ever conducted in a single year during Apollo: Apollo 9 in March, Apollo 10 in May, Apollo 11 in July, and Apollo 12 in November. In 1970, there was only one launch: that of Apollo 13. In 1971 Saturn 5s took Apollos 14 and 15 to the Moon. At the close of the program in 1972, two remaining Saturn 5 launches deployed Apollo 16 in May and Apollo 17 in December. One remaining Saturn 5 was launched in unmanned cargo mode to lift the Skylab space station in May 1973.

For Apollo, a combination of Saturn 5 heavy-lift and smaller Saturn 1B rockets flew during the same period. The Apollo-Soyuz Test Project used Apollo hardware and flew in July 1975. To save costs, the existing Saturn 1B launch pad was abandoned and a "milk stool" platform was used to launch the Saturn 1B carrying the Skylab crews and the Apollo-Soyuz Test Project flight from the Saturn 5 launch complex, pad 39.

From an operational logistics point of view, the most active Saturn operations were launches of manned lunar missions roughly two months apart for part of 1969, Apollo's greatest year. These flight rates paled in comparison to the capability its launch infrastructure was designed to sustain. Two Saturn 5 pads were constructed, with a third cleared but not constructed nearby. There were sufficient mobile launch platforms and crawlers to conduct near simultaneous Saturn manned flights, and in fact early Apollo mission plans called for dual Saturn 1B launches, one carrying the manned crew and a second carrying a lander prototype. Saturn 5 dual launches were considered for the Apollo Extension System and the Apollo Applications program. Use of the heavy lifting capabilities of the Saturn 5 in an augmented variant carrying a nuclear upper stage replacing the S-4B was un-

A shuttle-derived vehicle may carry the new Crew Exploration Vehicle (CEV) into space after the original shuttle fleet is retired several years from now. One concept for a vehicle to be used for the future of human exploration of the Moon is shown here. (Source: Orbital Sciences Corporation)

der design, as was use of the big booster for heavy interplanetary missions. The rocket was also considered key for space station launches then anticipated, since only the Saturn 5 could lift fully outfitted and assembled station components.

The Vehicle Assembly Building, designed in 1962 and constructed beginning in 1964, was laid out to sustain assembly and checkout of multiple Apollo Saturn vehicles simultaneously. With the pads, towers, transport vehicles, and servicing facilities constructed on the grounds of the Kennedy Space Center, a sustained program of lunar and interplanetary manned missions was possible. That this capability was quickly abandoned was the fault of shifting political winds, not industrial capabilities or the lack of advanced planning.

In the early 1970s, these same facilities were modified and retrofitted for the space shuttle configuration. Once again, infrastructure was put into place to sustain a large flight rate capability. Mission manifests for the shuttle fleet, then sized for as many as five or six orbiters, projected bi-weekly then weekly launches from Kennedy Space Center and additional launches of orbiters on military missions from the Vandenberg launching complex on California's southern coast. Using the capacity of the Vehicle Assembly Building, multiple orbiters could be stacked with their tanks and boosters for these missions. Nearby, facilities for the shuttle solid rocket boosters and a processing facility for the winged orbiters were constructed to flank the existing Apollo infrastructure.

But the much anticipated shuttle era produced only a fraction of these flight rates. During 1985 nine shuttles were launched, the maximum ever achieved in the program. In 1992 and again in 1998 eight launches were conducted, the second highest annual flight rate achieved. Four operational orbiters – Columbia, Challenger, Discovery, and Atlantis – were constructed prior to the 1986 loss of Challenger. Following the accident, a replacement vehicle named Endeavour was constructed. But following the loss of orbiter Columbia on February 1, 2003, a replacement vehicle was never seriously considered due to the shrinking of the shuttle program's manifest. Use of expendable Delta, Atlas, and Titan boosters by the military and a Reagan administration decision to remove commercial satellites from the shuttle's manifest left NASA itself as the only user of the shuttle. Without the assembly of the International Space Station, many believe, the shuttle program would have been terminated following the Columbia accident.

A New Era

Now, with the Constellation systems vehicles, much of this same launch and logistics infrastructure will be retrofitted again. The winning builder of the Crew Exploration Vehicle (CEV) must use modified shuttle facilities at Kennedy Space Center to assembly flight-ready CEV spacecraft. A shuttle-derived vehicle is widely anticipated as the launching solution for the Constellation fleet. Part of the attraction of using shuttle components is a combination of their proven flight history and ability to be adapted to various scaled-up heavy-lift launcher designs. For example, under one set of proposals, a solid rocket booster adapted from the shuttle stack and outfitted with a new liquid upper stage could lift a forty-metric-ton version of the CEV to Earth orbit. A heavy-lift vehicle adapted from the shuttle tank and booster set but replacing the winged orbiter with a payload module or pod could sustain eighty to one hundred metric tons to low Earth orbit. A new upper stage could supplement the system's launching capabilities on missions sending cargoes to the Moon.

Constellation will not have a single launcher that could lift all of its flight units. According to the CEV request for proposals, two additional space vehicles are to accompany CEV flights out of Earth orbit. One, an Earth Departure Stage (EDS), performs the function performed during Apollo by the Saturn 5 third stage, the S-4B. This new rocket stage would dock with the CEV to send the manned spacecraft towards the Moon. The engines aboard the EDS would burn to insert the manned CEV into lunar orbit and then either return to near-Earth space for replenishment or be discarded upon reentry.

A third vehicle is an essential part of the CEV lunar missions. Called in the request for proposals and requirements documents the Lunar Surface Access Module (LSAM), this new vehicle performs the function that the Lunar Excursion Module conducted during Apollo missions: taking the astronauts from the docked CEV in lunar orbit down to the surface, then back up for rendezvous and a return to Earth. Before he resigned from NASA, retired navy Admiral Craig E. Steidle confirmed to the author that the LSAM, unlike Apollo's landing craft, would be configured in an all-cargo version capable of launching from Earth to precision landings on the Moon with supplies and equipment, such as construction tools for lunar bases or pressurized roving vehicles resembling Earth-bound roving vehicles. Steidle also said consideration was being made to make the cargo version of the LSAM unloadable by robots.

The LSAM may wind up being large enough to require its own EDS to inject it on a trans-lunar trajectory path. If this design evolves for the Constellation missions, two EDS upper stages must be launched separately into Earth orbit, and their prime cargoes – the CEV on one and the LSAM aboard the other – rendezvous together at some point to conduct the landing. The request for proposals for the CEV requires the rocket engine and propulsion package of the CEV to be powerful enough both to perform a deep space abort from any point during the lunar coast and to inject the CEV on a trans-Earth return trajectory at the end of mission.

The initial CEV request for proposals calls for at least one and no more than four manned lunar landings per year. According to Steidle, each manned flight will require a separate unmanned cargo flight to fly supplies to the surface ahead of the landing of the astronaut crew. Thus an operational Constellation program, at its maximum, may require only eight annual shuttle-derived vehicle launches. It is also possible that Evolved Expendable Launch Vehicle flights of cargo vehicles will be needed and that smaller, Delta 2 boosters will be needed for such missions as the 2008 Lunar Reconnaissance Orbiter and a possible 2010 precision lunar robotic landing mission. Such flights may also use new launchers, such as the SpaceX Falcon 1 or other entrepreneurial-class small boosters.

Until March, it was not clear whether or not the CEV would fly to the International Space Station. New NASA Administrator Michael D. Griffin removed this ambiguity by stating that the CEV should be able to service the space station. To close the gap from shuttle retirement in 2010 to the first initial manned capability of the CEV in 2014, Griffin has ordered an acceleration of this initial limited, Earth-orbit version of the CEV. Such a stripped down CEV would not require subsystems that it will need later for manned lunar flights. In this sense, the CEV might be seen as being procured in a two-block series, much like was done for the Apollo command and service modules. Such Earth-orbit CEVs would not require the heavier heat shields, advanced guidance, navigation, and larger propulsion systems that would be needed for the lunar flights.

For operators of the shuttle-derived vehicle and CEV, these mixed mission requirements will pose the challenge of the interplanetary supply chain. Different types of flight units will need to be maintained at Kennedy Space Center for different types of missions. Either United Space Alliance or a similar industrial capability will need to stockpile supplies

Launches of low-mass payloads to support President Bush's vision for space exploration are likely to employ small-class Evolved Expendable Launch Vehicles, while large payloads, such as the new Crew Exploration Vehicle, may require heavy-lift capability similar to the Saturn 5. Newly developed rockets, like the Falcon 1, shown here, may also offer launch services for small payloads. (Source: SpaceX) ranging from spacesuits to tools and equipment. The mix of supplies that will need to be maintained will be much different than the supplies needed for International Space Station and shuttle missions. And while none of the Constellation documents thus far list reduced cost of access to space as a logistics requirements, some form of manned launch capability will be needed in stand-by mode once lunar surface missions and early base camps extend human presence on the Moon beyond a few weeks to three months, and eventually to permanence. In this way, many of the planned capabilities needed for the unflown Apollo Extension Systems and Apollo Applications missions may once again be needed in an operational interplanetary manned space program.

Beyond the Moon flights, the logistics trail becomes even more complex. Once base camps are established on Mars, Administrator Griffin has indicated, nuclear-electric propulsion systems will be needed for cargo flights to the Mars base camps. How will the operators of the Mars-bound CEVs, shuttle-derived vehicles, or related upper stages and cargo launch vehicles assemble their equipment supply chains? Will stockpiling of supplies at Mars destinations be needed? And how will these supplies be packaged, stored, and assembled for robotic and human crews to unload? How much will redundancy drive the cost of Constellation logistics?

These are the challenges that lie ahead for those whose task it will be to develop the operational capabilities for the vision for space exploration. ■

***Frank Sietzen, Jr.*, is a writer and lecturer on space affairs and communications strategy. The views expressed in this article are his own.**

ABOVE: *Preparing rocket for launch. (Source: Andy Carmain)* ***RIGHT:*** *Blast off! (Source: Andy Carmain)*

CanSat Competition a Success

College students from around the country gathered June 2-4 in Plaster City, California, to compete in a new design-build-launch competition. In order to experience a hands-on space program at an affordable cost, they had to launch a payload the size of a twelve-ounce soda can to an altitude of 1.6 kilometers (one mile). The basic mission required that the payload determine its altitude, range distance from deployment to landing, direction of travel, and temperature. Each team was also required to write a mission proposal, generate design documentation, and prepare a post-mission debrief.

A total of $6,500 in prize money went to the winning teams, with the University of Nevada taking first place (advanced) and the University of Michigan taking first place (standard). The University of Kansas took second place.

This year's competition was supported by AAS, the American Institute of Aeronautics and Astronautics, Jet Propulsion Laboratory, Naval Research Laboratory, NASA Goddard Space Flight Center, Swales Aerospace, and Computer Sciences Corporation. Planning for next year's competition on the East Coast, which will be expanded to include high school teams, is already underway; dates and location will be announced shortly. To view additional photographs of the Plaster City competition, see www.cansatcompetition.com. For sponsorship opportunities for the 2006 competition, contact the AAS business office. ■

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Space Tourism: Economics and the Ultimate Space Dream

It's been slow in the making, but the space tourism industry is on the rise. And there is every reason to believe the public demand for the space experience is strong.

by Laura S. Woodmansee

People have always dreamed of flying to the stars, but the true beginnings of the space tourism market began with the technical fantasies of visionaries like Jules Verne. Technology has fueled the dream of space flight. Over time, books, radio, movies, television, and the internet have created a demand of sorts for the real thing. Now, with the award of the X Prize in October 2004, there has been an explosion of interest among the general public, and a surge of hope among space buffs, that there may soon be true space tourism for the masses.

What's Available in Space?

The suppliers of space tourism experiences fall into three categories: orbital, suborbital, and Earth-side. "Tourism" implies traveling to experience a place, so "space tourism" means going on vacation to experience space. The suppliers of space tourism are selling the *space experience*. The word "experience" is key here because it is the selling point of the whole enterprise. The suppliers of space tourism make their money by bringing the joy of the space adventure to the public.

Orbital space tourism is the most adventurous space experience you can purchase today. There are very few flights available, and only the wealthiest Earthlings need apply. If you can get the approval of the National Aeronautics and Space Administration (NASA) and the Russian Space Agency, have about $20 million to spend, and are willing to spend six months in flight preparation in Star City, Russia, then you can spend a few days on the International Space Station (ISS). Two space tourists, Dennis Tito and Mark Shuttleworth, have funded their own adventures to the ISS via Soyuz launches from Star City, Russia. Each hired Space Adventures, a Virginia-based firm that specializes in selling space experiences to the public, to help arrange their space flights.

Currently there are no other suppliers of orbital space flights, but the future looks bright. New companies, and even some established ones, are now considering orbital space tourism to be a good market, if the technology can make it affordable.

In the near future, if you happen to have an extra $102,000 floating

The world's first space tourist, Dennis Tito, captured media attention worldwide when he flew to the International Space Station aboard a Russian Soyuz rocket in the spring of 2001. Tito is believed to have paid about $20 million for his space flight. The company that brokered the flight, Space Adventures, continues to offer a variety of space flight experiences to the public. (Source: Space Adventures)

The Cosmopolis 21 may become one of the first commercial suborbital space flight vehicles capable of taking tourists on a quick and exciting adventure to space. The vehicle will be carried to an altitude of seventeen kilometers by the M-55 "Geophysika" aircraft and will light a rocket to complete its trip to space once detached from the mother ship. (Source: Space Adventures)

around, a *suborbital* flight to the edge of space just may light your fire. Suborbital flight involves an extremely expensive, extremely short trip to the edge of space where one can see the blue glow of Earth's atmosphere.

Building on their success of winning the X Prize with SpaceShipOne, Scaled Composites of Mojave, California, has agreed to build a commercial vehicle called Enterprise for Virgin Galactic, a company formed under the Virgin Group which will offer suborbital flights into space within two to three years.

A subset of suborbital flight is high-altitude flight. A Russian Mig-25 "Foxbat" is at your service now for a forty-minute flight to the edge of space, forty kilometers high. Included in the $23,000 fee is a four-night stay at a luxury hotel in Moscow, a tour of Star City, a leather flight jacket, photos, and a DVD with footage of your near-space adventure, as well as several other very nice goodies. The only people who reach higher altitudes are astronauts.

Earth-side space tourism includes *simulated* space adventures. To get the best "feel" of what it is like to be in space you can, for brief periods, experience weightlessness while still inside Earth's atmosphere by taking a ride on an airplane that flies in ballistic arcs. Following the same idea as NASA's famed KC-135 "Vomit Comet" aircraft for training and research, the Zero-G Corporation provides this service recreationally on the G-Force One airplane out of Florida. For $3700 per person per flight, customers riding aboard the Zero-G aircraft can experience weightlessness as well as the simulated gravities of the Moon and Mars – one-sixth and one-third of Earth's gravity, respectively. "Float, flip, and fly the same way orbiting astronauts do," says the company's web site. The package also includes instruction from real astronauts as to what it's like to float in microgravity. After the flight, clients are treated to a party, award ceremony, dinner, and Zero-G promotional goodies.

With advances in simulators today, space can be experienced without a rocket or airplane, and for much less money. The Earth-side market includes several space-themed immersive experiences such as Disney World's Mission:SPACE ride and Japan's Space World. Disney advertises its Mission:SPACE ride as, "As close as you can get to blasting off into space without leaving Earth."

We Demand Our Space!

Current buyers of space tourism run the gamut from the "average" person to the extremely wealthy international entrepreneur. People all over the world want to experience space flight. We can think of space tourism like any other type of tourism. A family might decide to venture to the Grand Canyon one summer and to Space World the next. For the very few, very rich, hardcore enthusiasts, cost might not matter much. But, for everyone else, space tourism must be affordable.

To a certain degree, buyers are willing to purchase "substitutes" for space tourism. This raises the question: *are* there substitutes for space tourism? It depends on the particular customer. If you consider watching a space movie or reading a space book as a close substitute for space travel, then the answer is yes. If you're a thrill-seeker and are just as happy skydiving as taking a suborbital flight, then there are clearly many substitutes. But, if only seeing the blackness of space and the Earth below and feeling weightless will satisfy you, then only the real thing will do.

Tourism is one of the biggest businesses in the world, coming in as the second largest business in the United States at $400 billion per year in this country alone. It is not unreasonable to assume that if more people could afford to fly in space, they would, and market studies verify this.

In 2002, the Futron Corporation published a market study on the potential of orbital and suborbital space tourism. Futron hired Zogby International to survey 450 wealthy Americans (making at least $250,000 per year) about orbital and suborbital vacations. According to the survey, the average customer interested in, and willing to pay for an orbital or suborbital flight, is a man in his mid-fifties. Forty-eight percent of these men spend a month or more of their salary each year on vacations. The survey showed that there is high demand for space tourism among those who can actually afford the experience. Nineteen percent of those polled said they would be willing to pay $100,000 or more for a fifteen-minute suborbital flight at an altitude of eighty kilometers.

A 1993 survey in Japan found that 70 percent of those polled are interested in traveling into space, and half of the people surveyed were willing to pay three months' salary to do it! Given an average three-month wage, that's potentially a good demand for space tourism, if advances in technology can reduce the recurring costs sufficiently to make the business profitable.

A similar U.S. survey taken in 1997 by Yesiawich/Pepperdine/Brown of Florida and Yankelovich Partners of Connecticut polled fifteen hundred families about their interest in taking a trip to space. The poll concluded that 42 percent of Americans were interested in going into space. The average price they would be willing to pay is $10,800. This is more in the range of a future suborbital flight, rather than a full, orbital vacation. But 7.5 percent of those polled admitted that they would be willing to pay over $100,000.

While this is not as enthusiastic a response as the Japanese poll encountered, it does demonstrate vast market potential, if the price is low enough. For the vast majority of customers, an immersive theme park or exhibit will serve well as an affordable substitute for actual space travel.

The fact that more than one thousand people have flown on ballistic flights sold by the Zero-G Corporation since September 2004 proves that the demand and market potential for the space experience is real. Zero-G seems to have hit upon a cost-effective, accurate enough simulation of space that people will pay $3700 to participate.

The popularity of space tourism conferences such as the International Space Development Conference sponsored by the National Space Society indicates the strong interest in future space tourism. The 2001 Space Tourism Conference as well as future events such as the proposed Space Tourism Summit indicate that businesses are serious about investing in this budding market.

The first aircraft to provide microgravity flight experiences to paying customers was the Il-76 MDK airborne laboratory, stationed at the Yuri Gagarin Cosmonaut Training Center in Star City, Russia. Parabolic flight training began in 1971 and has been used to train crewmembers for space flight missions. (Source: Space Adventures)

Making Space Affordable

Because a sizable portion of the world is interested in experiencing space, cost is the only serious drawback. It is obvious that if space tourism becomes more cost effective, the demand will increase.

So how do we get the cost down? There are two hurdles keeping the cost of orbital and suborbital flight high: technology and regulations.

Technology is a major factor in the high cost of space travel. In the 1990s a number of ambitious companies determined to make inexpensive launch vehicles for many purposes, including space tourism, rose up and then went bankrupt. Some like SpaceX and its Falcon launch vehicle may achieve their goals and reduce costs a bit, but the per-launch cost will still be high.

One idea that lingers is Japan's reusable launch vehicle project called the Kankoh-Maru. At first glance, the plan seems profitable, but upon further inspection it becomes clear that the Kankoh-Maru technical requirements, such as flight time before refits, are unrealistic and far exceed proven capabilities.

The Enterprise being designed by Scaled Composites for Virgin Galactic might be able to achieve its more modest goals for a cost effective commercial suborbital vehicle, but flights of the vehicle still won't be cheap. Typically, development of a launch vehicle costs hundreds of millions of dollars. Scaled Composites was able to develop SpaceShipOne for much less, about $27 million, because it was an experimental vehicle. SpaceShipOne was only able to fly because of "experimental aircraft" rules. One *Aviation Week and Space Technology* article quoted Burt Rutan estimating that the cost to obtain a Federal Aviation Administration flight certificate for SpaceShipOne would have run between $100 million and $300 million, or five to ten times the hardware development cost.

It turns out that the launch costs for an orbital vehicle are probably going to remain high for some time to come. Even the most optimistic estimate, shared by Dr. David Livingston and colleagues in the "Challenge of Cheap Orbital Access," a recent seminar at the University

In the United States, commercial reduced-gravity flights have been available since the end of 2004. Zero-G Corporation, based in Florida, provides customers with weightless flight activity in its modified Boeing 727 cargo aircraft, G-Force 1. (Source: Zero-G Corporation)

of North Dakota, suggested that a near-future expendable launch vehicle will cost about $4400 per kilogram to operate. Current range costs and insurance costs are a significant factor in this estimate, as it assumes companies can significantly reduce the amortized development cost.

To get into orbit, a person needs to pay not only for his or her own mass but also for the mass of the seat, life-support equipment, consumables, and surrounding spacecraft structure. All of this will run over 1,560 kilograms per person even in the best case. Soyuz and Apollo-like capsule masses per person are even higher.

Multiplying the best case launch cost by the minimum payload mass per person yields a cost of just under $7 million per person to orbit. Unless things change significantly in technology, insurance costs, and range costs, then $7 million per person to orbit is as low as the price will get, at least for the foreseeable future. At $7 million, demand is much lower than even the Futron/Zogby study or the 1993 Japanese study investigated. While much better than the $20 million you might pay today, it's still out of the price range of most Earthlings.

The Future Is in the Stars

Both fiction and reality have inspired people to follow their dreams of experiencing space flight. When considering future trends in space tourism we must remember that what suppliers are selling is the space tourism *experience*. The evolution of the idea of space as a tourist attraction began long ago with the science fiction of visionaries like Jules Verne. The "vision" of space tourism is key to selling the experience. Suppliers must sell the vision of zero-gravity resorts, the magnificent vistas, and the other unique experiences that space offers to get the market off the ground – literally.

One near-term Earth-side space adventure, planned to open in June 2007, is the "Mars OASIS," a red-planet-themed luxury adventure vacation spot located on the main highway between Los Angeles and Las Vegas, near Barstow, California. Led by space tourism visionary John Spencer, Red Planet Ventures is already taking $100 deposits for the $2000 per person, three-day Martian "expedition" experiences. What makes this particular Mars simulation intriguing is that most of the facility will be located inside a faux Mars crater three hundred meters in diameter. The company plans to host 121 of these vacations per year for groups of twelve "Mars explorers." "We only need 1,400 people per year to be 100 percent booked," exclaims the company's web site.

Even the once anti-capitalist Russians are now getting into the act. Anatoly Perminov, the head of the Russian Space Agency, believes that space tourism will take off very quickly. "In five to seven years there will be a large number of private spaceships flying in the Earth's orbit, offering tourists a chance," Perminov recently said. He wants to see more private work as private space tourism technology brings money into the economy faster and speeds up the pace of space research.

Technological and regulatory limitations may inhibit cost effective space flight, but Scaled Composites and other space ventures are looking to break records for launch vehicle affordability. Once that barrier is broken, look for a breakthrough in space tourism.

Bigelow Aerospace is counting on just such a breakthrough. The company has developed large inflatable space habitats for space hotels and requires cheaper launch vehicles to make it cost effective to sell vacations to orbit. With this in mind Robert Bigelow created America's Space Prize, similar to the X Prize. It is a $50-million prize for the first company or person to launch a reusable orbital vehicle capable of docking with an inflatable space station.

From Dreams to Reality

As the giggle factor declines, the demand for off-world space tourism will increase. As the lovely visions of space tourism are marketed to the people of the world, the demand for space tourism vacation packages and honeymoons in orbit will increase astronomically. Perhaps someday in the not too distant future, the Moon will be the hot vacation spot. Beyond that, who knows what may be. The universe is our playground, and thus the

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Space Age Benefits: Technology Derived from the Apollo Program

People may think of the flag and footsteps the astronauts left on the Moon as Apollo's legacy, but the program was responsible for much, much more.

by Kevin M. Brady

On October 1, 1958, the U.S. government, with the approval of President Dwight D. Eisenhower, established the National Aeronautics and Space Administration (NASA) to explore space for the benefit of humankind. Government officials asserted that the newly created space agency would contribute to the expansion of human knowledge, improve aircrafts, develop vehicles designed to carry humans into space, and preserve the nation's role as a leader in science and technology. By 1961, President John F. Kennedy committed the United States to a human Moon landing within ten years. On May 25, 1961, the president announced to the American public his goal of landing an astronaut on the surface of the Moon and returning him safely to Earth by the decade's end. During the 1960s, the American space agency spent nearly $65 billion (in current-year dollars) to land a human on the Moon.

Although the United States accomplished its human lunar landing by 1969, many within the American public doubted the importance of the American space program. NASA officials responded to these arguments by noting that the Apollo program led to a phenomenal burst of technology and science within the United States. They also maintained that the technological advances derived from the space program would result in improved industrial processes and ultimately raise Americans' standard of living. This article examines the various benefits derived from the space program during the Apollo era. It also demonstrates that while one of the main goals of the American space agency is to explore the universe, a more important benefit of NASA is its technological activities, which impact every section of society.

Many people understand that the American space program had a dramatic impact upon education and the economy during the 1960s but do not appreciate the technological benefits derived from the space agency. In a June 18, 1962, NASA news release, NASA Administrator James E. Webb noted that he regarded "the creation of a truly national effort for mobilizing large scale resources of scientific knowledge and advanced technology to achieve clearly defined national goals" as a vital outcome of the American space agency. By the late twentieth century, research in aeronautics, space sciences, and space flight brought forth an array of sophisticated technologies that were transferred to the private and public sectors of American society.

Medicine and Health

Perhaps, medicine benefited more from space science and technology than any other field. For example, in 1966, medical researchers developing new vaccines adapted a sensor originally designed to measure micrometeorite impacts to

NASA's Jet Propulsion Laboratory pioneered the use of digital signal processing technology in computers to enhance and analyze images of the surface of the Moon while investigating possible Apollo landing sites. Today, digital signal processing technology is used in critically important medical imaging tools such as Computerized Tomography (CT) scanners and Magnetic Resonance Imaging (MRI) machines. (Source: Westhauser Photography)

NASA contracted with the Black and Decker Corporation to develop the first battery powered drill in the 1960s for Apollo astronauts to use to gather samples of the lunar surface. Since then, many kinds of convenient cordless tools have been developed and are available worldwide, and even today, cordless tools help keep space-walking astronauts and the common handyman free from extension cord tangles. (Source: Stephanie Thomasson)

spacecraft to monitor bird embryos without damaging the egg. The scientists noted that the sensor could detect life within the egg after only four days of incubation and could determine any changes within an embryo's heart rate if they introduced experimental chemicals into the egg.

The medical-monitoring requirements of space flight spawned the development of miniaturized electronic devices used in heart peacemakers. San Francisco's Children's Hospital used equipment developed by NASA to trigger an alarm when patients had trouble breathing. Ambulance operators employed electronic telemetry systems designed by NASA engineers to transmit data on heart patients to doctors waiting at nearby hospitals. Medical equipment designers adapted a space helmet to serve as a respirometer to measure a patient's oxygen consumption with exercise. Surgeons utilized duplicates of the liquid-cooled Apollo Moon-landing suits to lower the temperatures of critically feverish patients.

Space-related technology also offered new ways to serve the needs of individuals confined to beds or wheelchairs. Often times, bed-ridden individuals develop abrasions on the skin referred to as bedsores. These skin abrasions cause patients great pain and discomfort. Medical equipment designers utilized a plastic foam, which aerospace engineers had developed for the contour seats of the Apollo spacecraft, to provide relief for individuals who suffer from bedsores. The designers molded the lightweight foam into bed pads that would fit the contours of individual patients. These new bed pads cushioned an individual's body while providing relief from the pressure and tension that cause bedsores. Physicians also used the material to upholster wheelchairs, and medical researchers noted that the foam could serve as a lining for splints and medical coverings.

In 1972, NASA in conjunction with the Southwest Research Institute in San Antonio, Texas, which had designed and built scientific instruments for various Apollo missions, developed a way for individuals who lost the use of their arms and legs to control their immediate environments. The system utilized an intricate network of paddles and switches activated by an individual's eye movements and puffs of breath to control room lights, radios, televisions, and other electronic devices. Breath-controlled paddles hung suspended in front of an individual's face. If an individual wanted to change positions in bed, he or she would merely blow a specific number of times on the sensitive paddle. An eye switch included a pair of special glasses that aimed a beam of light on the white portion of an individual's eye. To turn the switch on, the individual merely turned his or her head, causing the light to strike the dark portion of the eye. The logic unit in the eye switch perceived the color change and activated a specific appliance in the room.

Remote handling and manipulation techniques of the space program also led to advances in prosthetics devices. During the 1960s, the space agency received various proposals from contractors for an unmanned vehicle that would carry scientific instruments over the surface of the Moon. Although the space agency used the lunar rover to transport astronauts and equipment across the Moon's surface, NASA technicians and engineers did not disregard these other proposals. Instead, they decided to improve upon these initial designs and build a walking chair for individuals who had lost the use of their legs. The redesigned walking chair had six controllable short legs extending from a box-like carriage. NASA officials noted that the vehicle would surmount obstacles that would stop ordinary wheelchairs. After various tests, engineers noted that the walking chair maneuvered over curbs and steps and even through sand.

During the 1960s, NASA engineers and scientists developed wireless digital telecommunication devices to improve communications between flight controllers and astronauts during the Apollo missions. These technological innovations also benefited health services in rural regions of the United States. During the 1960s, government officials in New

Mexico noted that individuals residing in isolated areas of the state had to travel hundreds of miles to seek medical attention; they asserted that certain regions thus witnessed high incidence of chronic illnesses and deaths. By August 1969, the New Mexico Health and Social Service Department in cooperation with officials from the NASA Manned Spacecraft Center (now Johnson Space Center) in Houston, Texas, utilized space technology to improve the medical services in Las Cruces, New Mexico. Upon learning of the problems associated with New Mexico's health services, NASA officials recommended the establishment of remote physician-monitored operating facilities throughout the state. The remote facilities contained biomedical instruments, communication equipment, and emergency room supplies. The health centers also had paramedical personnel, who were supervised by nearby hospital physicians. Furthermore, each station was equipped with color television cameras designed for medical examinations. This technology enabled hospital physicians to monitor patients at the remote facilities and allowed them to instruct paramedical technicians to administer first aid. New Mexican officials maintained that the establishment of the remote physician-monitored operation facilities saved the lives and improved the health of numerous individuals residing within the isolated regions of the state.

Environmental Monitoring and Protection

The launching of satellites during the Apollo era also helped improve scientists' understanding of Earth and their ability to predict weather and natural disasters. While some Americans argued over the cost of launching satellites into space, NASA justified these expenditures by maintaining that satellites helped analyze and predict weather patterns. On April 1, 1960, the space agency launched the Television and Infrared Observation Satellite (TIROS), the world's first meteorological satellite. Upon its successful launch, TIROS returned thousands of cloud coverage images of Earth. Subsequent TIROS launches allowed scientists to make observations of cloud coverage at night. Additionally, these meteorological satellites enabled scientists to observe hurricanes, tropical storms, and other adverse conditions that existing ground networks could not detect in a timely fashion. Government officials credited early warnings from these weather satellites with saving thousands of lives and crops. For example, the Environmental Science Services Administration predicted that without these satellites nearly 50,000 people would have died because they would not have been evacuated in time when Hurricane Camille hit the Gulf Coast in 1969. By the early 1970s, NASA officials noted that the data collected by the various satellites assisted individuals in meeting the demands of a burgeoning global population.

Although the American space agency had been studying Earth and its environment through observations from space, NASA officials affirmed their commitment to examining the planet's resources with the 1972 launch of the Earth Resources Technology Satellite (ERTS). The satellite had three television cameras, which used different shades of the color spectrum. The various color images would allow scientists to analyze the data collected by the ERTS in different manners. Following the successful launch of the ERTS, the satellite remained in polar orbit, which enabled it to monitor any point on Earth. Aside from monitoring the coastlines, wetlands, and wildlife habitats, the various experiments on board the satellite represented a first in space history because they examined issues on local levels. For instance, Thomas Heller, a Colorado scientist, used the ERTS to examine the quality of the state's ranges during grazing season. Scientists from the University of California at Berkeley used the satellite to monitor haze

With the aid of the National Bureau of Standards's Fire Technology Division, NASA revolutionized the self-contained breathing apparatus (SCBA) that makes fresh air available to firefighters while in the midst of heavy smoke and fire. Based on the spacesuits worn by Moon-walking Apollo astronauts, new SCBAs feature less bulk, less weight, inverted tanks for valve protection, an integrated low-pressure warning system, and a composite casing to allow double the air pressure previously available. (Source: Aaron Crouse) in Northern California. They believed that the data collected from ERTS would enable them to improve the state's air quality. Technicians and scientists in Indiana applied information gathered by the satellite to locate fractures in the Earth, which might contribute to cave-ins within coal mines in Indiana.

In the summer 1970, a team of three hundred engineers, technicians, and scientists from the various NASA centers applied the knowledge and technology they had acquired from the space program to oceanography. Prior to the 1970s, some oceanographers believed a strange material existed on the ocean floor that was so dense it deflected the pull of gravity. They believed that this peculiar mass would cause navigators to miscalculate their courses. By July 1970, the NASA team decided to solve this undersea mystery by conducting a ten-day experiment, which involved a NASA tracking ship monitoring the contour of an eight-kilometer-deep trench off the coast of Puerto Rico. During the experiment, the tracking ship took six readings of the trench. The scientists' findings enabled oceanographers to accurately map the ocean floor. Additionally, the information they gathered about the effects of underwater masses on gravity allowed oceanographers to perfect other tracking methods and instruments. The NASA scientists also planned on utilizing the data from the experiment to develop an altimeter, which measured ocean depths without the use of a ship. Otto Thiele, who supervised the experiment, remarked, "It would take years by plane and boat to get the information we can now get in months and much less accurately." The Apollo program reached its conclusion during the early 1970s, but NASA continued to use space technology and research in an effort to improve the mapping of the ocean floor.

In the early stages of the Apollo era, NASA launched its first Earth-observing experimental satellite, the Television Infrared Observation Satellite (TIROS). TIROS allowed scientists to make the world's first accurate weather forecasts based on information on the Earth system gathered from space. Such a capability has proven to be invaluable since then, with weather monitoring satellites having led to many early-warning evacuations in anticipation of natural disasters. (Source: NASA)

The technology derived from the NASA Apollo program also contributed to the reduction of air pollution. During the 1970s, the Environmental Protection Agency (EPA) sought to develop a low-pollution gas turbine engine for automobiles. EPA officials enlisted the help of NASA engineers and scientists because of the space agency's experience in related propulsion and power technologies. By 1973, technicians and engineers at the NASA Lewis Research Center developed an automobile turbine engine that performed well and offered a more efficient fuel economy compared to internal combustion engines, which consumed between 20 and 30 percent more fuel than a gas turbine engine. They maintained that consumers would benefit from this new engine because the early 1970s had witnessed an increase in the cost of gasoline. The scientists also remarked that the newly developed turbine engine met federal emission standards. Upon learning of NASA's research regarding an automobile gas turbine engine, some in the automotive industry decided to utilize this new technology in future car models because it served national interests and emitted fewer pollutants into the atmosphere. By the early 1970s, the Chrysler Corporation produced turbine cars for consumers.

From Silicate Paint to Space Science

During the early 1960s, the American space agency established the Technology Utilization Program to inform public and private industries about the by-products of space research. The program was composed of two divisions: the Technology Utilization Division, which published technology briefs, reports, surveys, and handbooks; and the Scientific and Technical Information Division, which offered industries and government agencies access to a computer-indexed library to conduct their own research about space-related technology. NASA Administrator James E. Webb maintained that the program was designed to "strengthen the bridge between technical research and marketable end use." Webb also remarked that the space agency planned to spend nearly $5 million a year to enlighten the non-aerospace industries about NASA's vast number of technological innovations.

Many industries benefited from NASA's Technology Utilization Program. For example, after reading a NASA technology report that discussed how Apollo spacecraft used a special protective coating designed to resist thermal temperatures and ultraviolet rays, a company in Michigan used NASA's research to create a new alkali silicate paint, which could serve as a protective coating for automobile tailpipes and mufflers.

Space engineers also developed various luminous materials to aid astronauts in docking the Apollo spacecraft on the dark side of the Moon during the lunar missions. By the late 1960s, airline companies adapted these materials for aircraft exit signs. The military also utilized the space agency's luminous material for map-reading devices and on gun sights for combat soldiers in the Vietnam War.

Another technology stemming from the space program was fire resistant material. Following the Apollo 1 fire, the space agency sought new measures to prevent another similar tragedy. The Monsanto Company in conjunction with NASA developed a fireproof material called beta yarn to protect astronauts and their spacecraft against fire hazards. By the early 1970s, a number of commercial manufactures adapted the space agency's fireproof material for consumer goods. For instance, the beta yarn was woven into such items as bedspreads, draperies, curtains, tablecloths, and pillowcases.

In addition, NASA engineers applied the technology derived from the Apollo program to aviation safety. In August 1968, engineers and technicians conducted various experiments to determine the effectiveness of grooved runways at NASA's Wallops Station in Virginia. The engineers believed that grooves less than a centimeter wide that ran across the width of a runway would drain away excess water that might cause an aircraft to skid during landings. The various tests conducted by NASA engineers revealed that the grooves improved the traction of airplanes during icy and rainy conditions. Upon learning of the experiment's success, agents from the Federal Aviation Administration and the U.S. Air Force expressed interest in the project because they thought that the grooved runway concept could be utilized at future airports and military airfields. By the early 1990s, grooved runways had been constructed at nearly eight hundred U.S. commercial airports and military bases.

NASA's safety grooving research program analyzed the effects of cutting grooves across stretches of runway and highway sections. The research showed that grooves effectively channel rainwater off of a contact surface, allowing spacecraft, aircraft, or automobile tires to better maintain traction during poor weather conditions. (Source: NASA)

NASA officials also asserted that satellites and spacecraft of the Apollo era expanded scientists' knowledge of the universe. During the early 1960s, NASA's Mariner program provided scientists with a better understanding of the various planets in the solar system. For example, Mariner 2 collected data on Venus's atmosphere and surface temperature. In 1965, the Mariner program continued its success when Mariner 4 returned images of Mars to Earth. These pictures represented the first close-up views of another planet. NASA established the Ranger program to collect pictures of the Moon's lunar surface. The success of the Ranger 7 mission in 1964 enabled scientists and engineers to determine landing sites for future Apollo missions. In December 1968, the Orbiting Astronomical Observatory (OAO) began to assess the properties of interstellar dust and stars in the Milky Way and gathered basic information on comets. The spacecraft also offered scientists conclusive evidence that black holes

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Entertaining Proposals

A human mission to Mars won't be all fun and games...but part of it just might be!

by Tom Hill

Crewed space activities to date have lasted no longer than 181 days with a single team, and during these activity-packed missions, crew leisure time has been more of an afterthought in mission planning. Human missions to Mars, however, will have to include a leisure component in order to keep crew morale and performance at acceptable levels.

After all, current Mars mission profiles call for flights lasting nearly one thousand Earth days. Missions to the red planet today are limited to flying every twenty-six months or so, whenever Earth and Mars align properly. Barring any fantastical change in propulsion technology, this interval between flights shall remain for the future. Using such modern-day propulsion, once a crew leaves Earth orbit, it will be locked in for a trip of approximately two hundred days to the vicinity of Mars. After receiving a "go" for landing, the crew will touch down on the surface for a stay of approximately 550 days. These days will be spent alternating between exploring the surface and analyzing discoveries made in the process. Once Earth and Mars have aligned again for the return flight, the crew will take off for the two-hundred-day flight back home.

Historical Lessons

Just how much free time have previous space travelers enjoyed? The answer: not much. The Mercury and Gemini capsules contained notoriously cramped quarters, and many missions were either so short or so crammed with mission activities that crew "off time" was not even a consideration. One mission in these series, Gemini 7, deviated from that model slightly, staying aloft for fourteen days with relatively little scheduled activity. Astronauts Frank Borman and Jim Lovell have described the long periods of time they spent on orbit with little to do except look out the window.

The Apollo program brought about some major changes that allowed for more crew leisure time. The profile for flights to the Moon involved a relatively busy first few hours, followed by a quiet, multi-day drift to the Moon. The travel time was used to let the crew unwind a bit from training in preparation for its busy lunar exploration period. The relative roominess that the capsule provided allowed more freedom of movement for the astronauts and gave them a much greater appreciation for the effects of microgravity. The additional mass of the Apollo system also allowed more personal effects to be brought along as well as equipment such as television cameras. These innovations combined to let the crews become documentary filmmakers, and their antics impressed Earth-bound audiences. Personal crew leisure-time activities, however, were still limited to reading books or listening to music brought along for the voyage.

While space shuttle mission planning did not show any concerted effort to plan crew leisure activities, perhaps the best historical lessons concerning leisure time availability aboard space missions can be drawn from America's two space station experiences: Skylab and the International Space Station. The Skylab space station was launched in one piece and, after some initial work, did not require much on-orbit maintenance. There are indications that leisure activities were thought about in preparation for Skylab, such as the magnetic Scrabble™ on display in the new Smithsonian National Air

Since the beginning of human space exploration, taking time to gaze at the Earth has been many astronauts' favorite leisure activity on missions. Andre Kuipers of the European Space Agency took time to observe the Earth beneath him during his stay aboard the International Space Station in 2004. (Source: NASA) and Space Museum Steven F. Udvar-Hazy Center in Chantilly, Virginia (although that particular board game did not fly with the crews). Favorite stories of astronauts having fun on Skylab recount races around the inside diameter of the station and include one anecdote in which resident Pete Conrad deliberately extended his time on the exercise bicycle to ninety minutes so he could claim to have biked around the world.

The International Space Station is approaching the record for being the longest continuously inhabited spacecraft. Crews spend much of their time in repair tasks, especially in the post-Columbia phase of having few spare parts delivered, but inhabitants have also found some interesting ways of spending their time. Video beamed from the station shows crewmembers playing personal musical instruments. Another favorite pastime is using the onboard ham radio to talk to people on the ground in both planned and unplanned chat sessions.

The Leisure Environment of the Future

How human exploration missions to Mars are carried out will drive the amount of leisure time available and the activities possible. The long duration missions under consideration today will differ in several key ways from missions of the past. Certain schedule requirements of human missions to Mars will constrain the leisure environment for travelers, while new technological capabilities will help to augment it.

Travelers to Mars will be busy. A mission to Mars will by necessity have greater scientific autonomy than previous human excursions to the lunar surface. Apollo missions were mainly quick reconnaissance trips, with hastily trained field observers in the form of astronauts scurrying around to pick up a few interesting samples before having to return to their spacecraft and, in a matter of tens of hours, return to Earth. With 550 days scheduled on Mars's surface in a spacecraft equipped with a miniaturized laboratory, Mars crews will participate much more in documenting findings and performing analyses in support of their exploration agenda, leaving less time for leisure activities. (Of course, some crew members may consider conducting research and writing scientific papers quite enjoyable!)

Human travelers will also spend a good bit of time practicing landing and ascent maneuvers required for various phases of their journeys. Space shuttle pilots rehearse launches, orbital maneuvers, and landings over and over using simulators before starting their missions because despite the repeated nature of space shuttle flights, they cannot be considered routine. In the case of a Mars-bound mission, the crew will experience two ascents and two atmospheric entries and landings in what will be a groundbreaking effort. In addition to participating in pre-flight exercises, crews to Mars will engage in simulations of landing and ascent activities on board several times a week during the trip. These simulations will have to test the crew in the same nefarious ways that space simulations on the ground do today.

But just as crew members will face considerable schedule demands, advances in technology will present them with new leisure opportunities. It is probable, for instance, that astronauts traveling in space for long periods of time will be placed in an artificial gravitational field in order to prevent human bone and muscle decay. Creating such a field by rotating a spacecraft and counterweight around their combined center of mass was demonstrated in the Gemini program, though further research is necessary to finalize the practice. Having gravity aboard the craft reduces the need for the requisite two hours of exercise per day aimed at preventing muscle atrophy and bone-mass loss that would occur in the absence of gravity and also makes common tasks such as cooking and waste processing much simpler than in their current microgravity forms, freeing time for other purposes.

Of all the technological changes that have taken place since early space

The huge signal transmission distance will make two-way communication very slow between Mars exploration crews and mission controllers on Earth. For years, astronauts in low Earth orbit have enjoyed the convenience of communicating with their families via laptop computers and radios. Laptops aboard the International Space Station have allowed crewmembers like James S. Voss of Expedition 2 to keep in touch with loved ones and share the excitement of space travel. (Source: NASA) missions, the miniaturization of computers and the accompanying decrease in their electrical power needs is the most striking. Growth in computing power per unit mass will allow crews traveling to Mars to have a much greater insight into the functioning of their spacecraft and can also open a wealth of capabilities for crew leisure time. The rise in computer power has been coupled with an increase in data flow rates in all areas of society, and it is natural to assume that this increase in bandwidth will be carried into supporting the scheduled activities as well as the leisure pursuits of future human space explorers. New technologies such as laser links may help data transfer rates approach those of terrestrial communications, although no technology on the horizon will be able to make up for the time delay in communications between a Mars crew and its Earth-based support team.

The Fun Awaits

Finally, we arrive at the question of what human travelers to Mars will do with the free time they will have. The pastimes enjoyed on prior human space expeditions such as reading books, playing or listening to music, and participating in recreational exercise will undoubtedly be options to long-duration space explorers. Mars crews will have still other leisure activities from which to choose to occupy their time.

In great voyages of the past, food played a major part in keeping a crew's morale up throughout the journey; it is quite likely that Mars travelers too will take enjoyment in the experience of food preparation and consumption. The addition of gravity to Mars-bound missions would allow food to return to prominence in exploration. Such missions would require bulk storage of raw materials for use in creating meals. Missions flying today include ready-made foods that require minimal preparation but sacrifice flexibility as a cost for the convenience.

As he noted in his book *Mars on Earth* (Tarcher/Penguin, 2003), Robert Zubrin was surprised at the role food played in team morale in his experiences at arctic and desert research stations. Each crew member took turns as the cook, and friendly competitions arose to see who could create the most exotic meal using the basic materials brought along for the mission. It is likely that some crew mem-

LEFT: *With modifications to allow long-term survival in the space environment, small commercial electronic devices could be carried and used by astronauts on long-duration missions. Expedition 8 Commander C. Michael Foale tested his Personal Digital Assistant during his 2004 mission to the International Space Station. (Source: NASA)* ***RIGHT:*** *Our short history of space travel has revealed that long-term exposure of humans to a microgravity environment leads to skeletal and muscular weaknesses. Crews have endured stays on the International Space Station for many consecutive months to better understand methods of resisting the biological detriments of space travel, which are sure to be more damaging during missions to Mars and beyond. Special apparatuses, such as the Treadmill Vibration Isolation System used by cosmonaut Salizhan S. Sharipov on Expedition 10, allow crewmembers to exercise aboard the space station to slow muscle atrophy. (Source: NASA)* bers will enjoy preparing food more than others, but mealtime is an experience that all crew members will share. Food has been such a contributor to morale that, in the past, mission commanders on journeys of exploration have been given stores of special foodstuffs for use to mark holidays or milestones in the journey. That tradition should continue as we explore the solar system.

As men sailed over the horizon in centuries past, family members and friends were largely out of contact with their loved ones throughout the trip. This does not have to be the case in a long-duration space mission. International Space Station crew members correspond via email with family and friends, and they are even granted video communications with family members on occasion. The long communications times between Mars and Earth will make real-time communications such as a video conference impractical for most of the mission, but text messages such as emails can easily be beamed back and forth across the void. Perhaps the link could serve as the re-awakening of an old form of literature if letters from the red planet are shared with the public.

The same computing power that will improve crew insights into the functioning of their spacecraft as well as efficiency of operations will allow the crew the capability to play computer games as a pastime. The types of games possible are quite varied and could involve something as simple as cards or as involved as a team-play strategy or first-person-shooter program that would again allow some friendly rivalry within the group. Such rivalries need to be created with care, however. Antarctic researches have found that the game Risk™, essentially a board-based version of a computer strategy game, created more problems in crew morale than it solved. As a result, the game is banned from Antarctic research stations.

Without a doubt, the most entertaining space activity must be trying to catch food in one's mouth. Since the beginning of the space program, the world has watched astronauts gulp free-floating gelatin, chocolate candy, and flavored drink droplets. During STS-99, astronauts Mamoru Mohri (left) and Dominic L. Gorie enjoyed capturing gummy worms. (Source: NASA/JAXA)

Combining computing power with an increase in communications bandwidth will allow a Mars-bound crew to keep up with video versions of news, sports, or any other event occurring on Earth. First-run movies can be beamed to the travelers, although the picture quality may not be up to Earth-bound standards. Television shows are also an option, even though it is unlikely that the first people to go to Mars will be described as "couch potatoes." Libraries of books will also be able to be shipped in electronic form.

Crews that watch first-run movies and television shows or read newly published novels may even be asked to voice their opinions of the new releases, creating a truly out-of-this-world buzz about the latest media successes and bombs. Such an idea is an anathema to U.S. government space efforts today, which eschew over-identification with commercial entities, but could be incorporated into a strategy to keep the public focused on multi-year missions to Mars. Holding that focus will be the topic of a sequel to this article. ■

***Tom Hill* is an aerospace engineer by day and a space activist by night. His book, *Space: What Now?* (Publish America, 2005), explores topics such as leisure time in space. He can be reached at tom@spacewhatnow.com.**

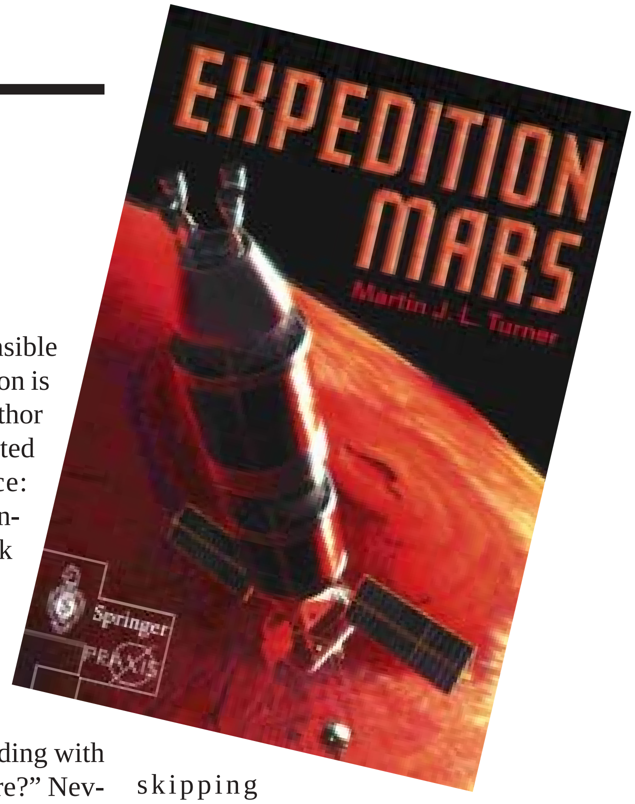
Editor Wanted

Space Times is seeking a new editor, beginning with the March-April 2006 issue. If you have the desire to communicate, the skill to lead a vigorous editorial team, and the time to commit to AAS, please contact the AAS business office at 703-866-0020 or aas@astronautical.org for more information.

NOTES ON A NEW BOOK

Expedition Mars

Reviewed by Mark Williamson



Expedition Mars, Martin J. L. Turner. London: Springer-Praxis, 2004. 321 pages. ISBN: 1-8523-3735-4. $39.95 (paperback).

At a time when many in the space community have "Mars fever," it seems appropriate to find a book called *Expedition Mars*. The cover illustration of this one implies that it is a book about a manned mission to Mars, as does the cover blurb, which asks: "What will be the next 'giant leap' in space exploration? Could it be a manned expedition to the Red Planet – Mars?" But this book by Martin Turner is more than that.

As with most stories, it is necessary to place the main theme in context. *Expedition Mars* does this by reviewing the legacy of the Apollo Moon missions and Wernher von Braun's dreams of Mars exploration published in his *Das Marsprojekt*. It then discusses the trajectories and the rocket engines involved in actually getting to Mars. In fact, Turner spends three of his nine chapters describing the ins and outs of chemical rockets, electric thrusters and fission thrusters. This, incidentally, affirms the background and interests of the author, who has also written a book entitled *Rockets and Spacecraft Propulsion* with the same publisher. His attitude towards nuclear propulsion (and space-based nuclear power) is refreshing and reflects the growing realization that the only sensible way to advance space exploration is through this technology. The author makes his opinion of uneducated detractors clear in a sentence: "Many, of course, will fundamentally object to its use; this book contains only the facts."

The final three chapters really get down to the Mars mission, though strangely in reverse order, beginning with "The return from Mars" and ending with "How do we get there, from here?" Nevertheless, the story retains the reader's interest and some of the pictures, drawn by NASA artists, are truly inspirational – at least to an engineer. My particular favorite is a functional, four-legged "Mars habitat" lander with an "inflatable extension to provide more space," which is somehow reminiscent of a caravan or recreational vehicle with an awning attached. The notion that its occupants might be camping out on Mars is thought-provoking in itself.

The author acknowledges that there have been many books on planetary exploration but adds that his "excuse" for writing this one is that it examines and considers "the physics of the expedition, the engineering challenges, and the implications of the results." The book thus includes a few equations, but the author assures us that very little will be lost by skipping them. As a whole, the book is well illustrated with black-and-white photographs and a center section of color plates. There is also a short index.

Interestingly, this book was written just before President Bush made his "vision speech," which promised the return of humans to the Moon and a future manned mission to Mars. The author missed out on being able to mention this event, but at least it has made the book timely. In calling for a manned Mars mission, the author writes, "It is time to stop playing about on the fringes of space, and take the necessary step that will lead humanity beyond the confines of the Moon's orbit." I couldn't agree more. ■

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Space Tourism *(continued from page 12)*

potential for space tourism is literally infinite. Hotels in orbit and vacations on the Moon, Mars, and asteroids are possible if and when launch costs can be significantly reduced. Only then will the future of space tourism launch in earnest. ■

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Space Age Benefits *(continued from page 17)*

existed in space. Three years later, NASA launched OAO-3, which provided data on the physical conditions of interstellar gas within the Milky Way's ultraviolet region.

Conclusion

Most people regard the space age as a time in which the United States successfully landed humans on the lunar surface. However, the real importance of the Apollo program was not the physical act of getting humans to the Moon but the creation of technology that allowed NASA to accomplish this goal by the end of the 1960s. This technology led to improvements in medicine, oceanography, synthetic materials, aviation, and communications. The space-related research also improved humanity's understanding of the solar system. By the conclusion of the Apollo program, some NASA officials noted that they did not view the greatest achievement of the space program as successfully landing a human on the Moon; rather, they regarded NASA's efforts to utilize technology that would ultimately benefit humankind as a more noteworthy accomplishment. ■

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UPCOMING EVENTS

AAS Events Schedule

November 15–16, 2005
AAS National Conference and 52nd Annual Meeting
"Building Bridges to Exploration: The Role of the International Space Station"
South Shore Harbour Resort
Houston, Texas
www.aashouston.org

See page 23 for details!

November 30 - December 2, 2005
***ISU's 10th Annual International Symposium**
"Space Exploration: Who, What, When, Where, Why?"
Strasbourg Central Campus
Strasbourg, France
www.isunet.edu

January 22-26, 2006
***AAS/AIAA Space Flight Mechanics Winter Meeting**
Westin Innsbruck Golf Resort
Tampa, Florida
www.space-flight.org

**AAS Cosponsored Meetings*

February 4-8, 2006
29th Rocky Mountain Guidance and Control Conference
Beaver Run Resort
Breckenridge, Colorado
www.aas-rocky-mountain-section.org

March 14-15, 2006
44th Robert H. Goddard Memorial Symposium
Greenbelt Mariott Hotel
Greenbelt, Maryland
www.astronautical.org

June 2006
***Student CanSat Competition**
Washington, D.C. Area
www.cansatcompetition.com

August 21–24, 2006
***AIAA/AAS Astrodynamics Specialist Conference and Exhibit**
Keystone Resort & Conference Center
Keystone, Colorado
www.aiaa.org

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