Our Brick Moon

William H. Gerstenmaier

In 1869—four years after Lincoln was assassinated and 34 years before the Wright Brothers flew at Kitty Hawk—an author named Edward Everett Hale, born in 1822 in Boston, wrote a short story for the *Atlantic Monthly* called "The Brick Moon."

"The plan was this," Hale wrote. "If from the surface of the earth, by a gigantic peashooter, you could shoot a pea upward, aimed northward as well as upward, if you drove it so fast and far that when its power of ascent was exhausted, and it began to fall, it should clear the earth, and pass outside the North Pole, if you had given it sufficient power to get it half round the earth without touching, that pea would clear the earth forever."

I like that in 1869 he even had our terminology right, with "ascent." What Hale was proposing with his "brick moon" was a man-made companion to the North Star, one that would hang above Greenwich and provide an easy way to measure longitude at a glance—essentially, a primitive GPS.

Hale saw many potential problems with this brick moon. He wrote, "The brick alone will cost sixty thousand dollars. Sixty thousand dollars! There the scheme of the Brick Moon hung, an airy vision, for seventeen years." Actually, a lot of the story is taken up with the characters seeking funding to build their moon. Think of the similarities today. Many great ideas, but how do we fund them?

The story talks about the modular way the brick moon was built, because it was too hard to launch all the bricks at once. It talks about the advantages and opportunities of viewing the earth from such a high place and about how the moon communicates with the earth. It talks about the difficulties in getting supplies to the brick moon, because they keep

This article is adapted from an address presented to the American Institute of Aeronautics and Astronautics (AIAA) in Nashville, TN, on 11 January 2012.

William H. Gerstenmaier is associate administrator for NASA's Human Exploration and Operations Mission directorate, with programmatic oversight for the International Space Station, space shuttle, space communications, and space launch vehicles. He has completed a BS degree in aeronautical engineering from Purdue, an MS in mechanical engineering from the University of Toledo, and doctoral course work from Purdue and has been highly commended by both the public and private sectors.

burning up in the atmosphere or damaging the moon if they do not land softly enough. It even talks about the experiments the people living on the moon run, because their land is so different from the land of the narrator.

In short, the story is about a space station; though, of course, the term did not yet exist. It is precisely our space station today. If you walk into a sixth-grade classroom today, the teacher will be the only person in the room who saw the entire human race on the planet Earth at the same time. Think about that: three to six people have been living off planet on the International Space Station (ISS) for more than 11 years.

It has been said a lot lately that NASA is retreating from space exploration, and nothing could be further from the truth. In fact, we are continuing upon a steadily increasing proficiency in space exploration that leads us up to this very moment.

You already know this, of course, but I want to prove it to you with some statistics. The SpaceShipOne guys spent a little more than an hour's total time in suborbital flight. Next up was the one-man Mercury program, which kept six of the Mercury seven in space for a grand total of two days, five hours, and 53 minutes. After that is China's Shenzhou program, which over three flights has kept its crews in space for eight days and 20 hours. In general, every follow-on program spends more time in space with more people than the one that came before it. We have been learning over the past 40 years how to fly humans in space. The big three have been the space shuttle, Mir, and the International Space Station. Over the course of the 98 shuttle flights that did not go to the ISS, crews spent a total of 1,062 days in space. Keep in mind, that is not man-hours, that is the number of days humans lived in space aboard the shuttle. Mir is next. Over nearly 10 years, rotating crews of usually three stayed on Mir a total of 3,644 days.

As of its anniversary on 2 November 2011, crews had lived aboard the ISS for 4,017 days. The last few years of that total, there have been six people onboard, doubling the amount of crew time ever available on Mir. If we project out to 2020 and even 2030, we can see that the ISS will easily surpass the cumulative experience of humanity in space by a very large margin. We are not retreating from space exploration. "Courage, my friends, we are steadily advancing to the Brick Moon," Edward Hale wrote.

The ISS continues this trend in crewed launches into space. Nearly every follow-on program has launched more crews more times into space for longer periods of time. The ISS is not a retreat. It is continued progress.

Ignoring unmanned cargo launches, the ISS has had 66 launches with crews onboard—37 space shuttles and 29 *Soyuzes* in 11 years. In 10 years, Mir only saw 39 launches—30 *Soyuzes* and nine shuttles.

To compare the two longest-serving manned vehicles, the total number of manned *Soyuz* launches was 123, versus 135 for the space shuttle. I am willing to bet that number surprises some of you. We actually have more flight experience with manned shuttles than the Russians do with manned *Soyuzes*. They have flown longer but not as often.

Even with the downtime after *Columbia*, we have flown at a far greater rate far more reliably than ever before. The shuttle really was a true space transportation system.

The space station dominates in extravehicular activity (EVA) time as well. International crews wearing US extravehicular mobility units and Russian Orlan suits have spent a cumulative 42 days outside building the ISS. That is 42 24-hour days, not workdays, over the course of 161 spacewalks. It is also only slightly less time spent on EVA than every other manned program in history, worldwide, combined—including Apollo and Mir. We are working in space.

International Cooperation and Research

So what does this all mean? Since the ISS is international in nature, it means we have spent the last 14 years—or 26, depending on how you are counting—learning to live and work together in space. The result has been the most quantitatively prolific space vehicle built by humanity. Now, what are we doing with it?

It has been a long rocket ride from Ronald Reagan's 1984 Space Station *Freedom* announcement to today. Along the way we have had to overcome nearly every conceivable obstacle, from budget cuts to launch failures to technical challenges on-orbit. However, in even the limited amount of research time we have had until recently, when we finished assembly, we have found some impressive results in the unique laboratory of space.

One of our "big science" projects involved the collaboration, skill, and tenacity of scientists and engineers literally around the world. The Alpha Magnetic Spectrometer, or AMS, was launched onboard shuttle *Endeavour* in May 2011, though that is definitely not the start of its history. The first AMS prototype experiment flew on *Discovery* in 1998 and paved the way for the development of the detector that is now on ISS.

Research has shown us that there are more than one hundred hundred million galaxies in the universe. Once again—a hundred, hundred million. Each of those galaxies has perhaps one hundred billion stars in it. And yet, observations have shown that all of those stars and galaxies are less than 5 percent of the total mass of the universe. The theory of dark matter and dark energy has been developed to explain what is basically most of the missing universe. The AMS may help us find all that missing stuff, and I must commend the research team for not aiming too big.

As we all know, the only thing harder than finding nearly all of creation is putting together a team to build the instrument to do so. The AMS's principle investigators are from the United States, Spain, France, Italy, Taiwan, Germany, and Switzerland, leading a team of 60 institutes from 16 countries that was sponsored by the US Department of Energy. I cannot be sure, but this team may perhaps represent 5 percent of all known particle physicists in the universe.

The international aspects were not the only challenge, of course. The AMS was originally developed to have a super-cooled, super-conducting magnet system that would help capture the elusive cosmic rays. Since storage of cryogenic materials in space is an ongoing engineering challenge, the designers recognized that the AMS would have a finite lifetime as the cryogenic fluid boiled off. The magnetic strength of the cryogenically cooled magnet would be an advantage and allow bigger particle deflections and shorter measurement time in space. A weaker permanent magnet would allow for the same quality of data but would require longer time in space to reduce the measurement uncertainties. When the ISS lifetime was extended from 2015 to 2020, it was decided to use a permanent magnet. The AMS could now receive data for the life of the ISS and not the life of the cooling fluid.

Think about that—very close to launch, the team changed a fundamental part of the AMS design. And it worked—the AMS has recorded nearly 10 billion cosmic rays since its launch last May. As with many of the things we are doing on the ISS, the AMS has more than one application. The cosmic rays that it is using to find the missing dark matter are also of interest to teams planning human missions beyond low Earth orbit.

The radiation environment outside the Van Allen belts is not well understood, and observations taken by the AMS will help us develop countermeasures to keep far-flying astronauts safe and healthy. Magnets might play a role in radiation protection.

Vaccines, Zero "G," and Environmental Control

Of course, low Earth orbit presents its own unique challenges and opportunities for human health. Building on research conducted on the space shuttle in the 1980s and '90s, the National Laboratory Vaccine Survey has been conducting experiments on a number of pathogens for which there is no current vaccine.

It turns out that gene expression in microorganisms is very different in microgravity than it is in a one-g environment. By flying a series of human-infecting microbes in space, researchers have been able to get the space-grown bugs to become very much more virulent, possibly like they do once they infect humans. These virulent pathogens, in turn, can then be used to develop vaccines here on the ground. This is not theoretical. Researchers with a company called Astrogenetix currently have a vaccine under development for eventual human use. These are real diseases, and we are finding real potential cures. The first pathfinder was on Salmonella, a familiar food-borne illness. Salmonella sickens more than 1.4 million people and kills more than 400 every year in the United States alone.

More significantly, researchers also flew an experiment on MRSA—methicillin-resistant *Staphylococcus aureus*. Staph is a very common infection—the National Institutes of Health says that a quarter of us in this room have a staph infection right now, usually living harmlessly on our skin or in our nasal passages. Staph is the cause of many runny noses and sore throats every winter and can cause impetigo and arthritis if it gets under the skin.

Because it is so common, staph has developed resistance to most of the antibiotics used to treat it, up to and including methicillin, one of the nuclear weapons of the hospital arsenal. Methicillin-resistant staph can be fatal to otherwise healthy patients, and can be truly horrific to those it does not kill. Because it is so tough, it spreads throughout hospitals at an alarming rate. The Department of Defense even lists MRSA as an issue of concern to their medical community.[1]

Research in microgravity has now shown us a path to a vaccine for MRSA. Think about that. A real vaccine for a disease that, according to the CDC, infects 1.7 million and kills nearly 99,000 people in the United States every year.[2] There is every reason to believe we can use this technique to find vaccines for many more microbial illnesses. All viruses and bacteria show this same phenomenon. The potential is huge.

We have reached a level of maturity in space-based research where we are beginning to see some of the first real, predictable, and most importantly, tangible results for average people on the ground. In hindsight, we first saw evidence of this property of bacteria in space when we saw increased biofilm buildup in the water cooling lines of our space station. We need to stay really inquisitive to keep learning.

The important distinction here is, these are not spin-offs, like microprocessors or improved heat-resistant materials. Those are great, and we will continue to develop valuable spin-offs as we continue to explore. Here are results we can use to improve life on Earth that were developed using the unique laboratory of microgravity.

The University of Arizona does not want to simply exploit the properties that make viruses and bacteria become stronger in space; it wants to fundamentally understand why this occurs. This research might alter our basic understanding of viruses and bacteria. It could even allow this phenomenon to be exploited on the earth without the need to travel to space.

The space shuttle paved the way for this, and the ISS is now beginning to show the real results. Basic research and development takes time, of course, but we have already done much of the basic R&D. The vaccine development built on prototypes flown for years on the space shuttle—we launched the Salmonella and MRSA experiments with credible evidence that we could produce results. It was not a shot in the dark.

The Alpha Magnetic Spectrometer had also proved its worth on its shuttle flight, which gave credibility to the idea of developing a larger, long-term experiment. The AMS we launched to the space station is actually so sensitive it actually started recording data when we turned it on at Kennedy Space Center. Now it is using 300,000 data channels to record a gigabyte a second, 24 hours a day, year-round, in space.

These focused R&D projects are producing results. Researchers in Japan running protein crystal growth experiments have found a possible path to a treatment for Duchenne's muscular dystrophy, as well as other viruses.

Apple Computers purchased the rights to a material being marketed as Liquidmetal, which has the strength of titanium and the plasticity of, well, plastic. It too was first developed as part of a materials experiment in zero-g.

Of course, the very environment we are working in forces us to continue to innovate new and better ways of simply staying alive. The ISS is not only a great laboratory for developing new drug treatments, materials research, and answers to life, the universe, and everything else; it is also a perfect laboratory for extending our reach into the solar system. Any physical science with a "g" gravity term in its equation can benefit from testing with the "g" removed.

The environmental control system onboard, what we call REGEN-ECLSS, recycles upwards of 80 percent of the water used by the crew. Water, unlike oxygen or other gasses, is incompressible, meaning that a gallon of water launched into space takes up just as much room on a supply ship as a gallon of water in your car. Recycling all of the crew's exhaled moisture, dampness from exercise and bathing towels, and urine dramatically reduces the amount of liquid we need to launch into space and dramatically increases the amount of room we have for other cargo.

Not only that, the water we have up there can be used to generate oxygen, which can then be turned into carbon dioxide by the crew, which we can then separate into carbon and oxygen, which we can then combine with waste hydrogen from the oxygen-generating process to form water again.

The rich tapestry that is our oxygen and water system has not been easy, of course. The first period of operations of the urine processing system were plagued by jammed filters and clogged pumps. It took us a while to figure out why. It is well known by now that human bones leach calcium at a high rate in zero-g. It is the healthy astronaut equivalent of osteoporosis. This is a major area of investigation for our human research program, because upon return to Earth, astronauts regenerate this lost bone structure, unlike your 80-year-old grandmother. We do not yet know why they can grow this bone back.

Unfortunately, while they are losing all of their calcium on-orbit, it had to go somewhere, and it went straight into the filters of the water system. While some calcium buildup had been anticipated in the design, our engineers had not accounted for just how much would end up there.

We redesigned the pump, and since the ISS is only a two-day trip away by rocket, we were able to replace the original design and bring the capacity of the water system back to normal. The crew and their station are becoming one system.

The benefits here are twofold, and from two very different disciplines. First, our engineers learned a lesson about designing water recovery systems at a relatively low cost and low impact to the mission. There are many things we design that simply work differently in space that we cannot anticipate on the ground. Fortunately, this one happened close to Earth, which is one of the primary benefits of having the ISS as a test bed.

Secondly, our human medical researchers were able to better quantify the calcium loss thanks to returned samples. They are working on different countermeasures, including diet and exercise, to minimize the amount of calcium loss on-orbit.

As has been said about airplane radar and convection ovens, these two disciplines did not know how much they had to learn from each other. Their intersection gave us the microwave oven. Our functioning home in space has brought two new disciplines together. Courage, my friends, we are advancing to the Brick Moon!

ISS Control, Launch, and Communications

Assembling the ISS in space has almost been the easy part. As you know, the ISS partnership is made up of five space agencies and 15 countries, bound together by treaty-level governmental agreements negotiated almost 20 years ago. The challenges involved in this effort have at times seemed insurmountable, yet we have somehow always overcome. Think about it—Tokyo is a 14-hour flight and 14 time zones behind Washington, DC. Moscow is a 12-hour flight and eight time zones ahead of Washington. Paris is a 7-hour flight and six hours ahead. Even Montreal is still a two-hour airplane ride from Washington. And that is only the NASA-centric view; Tokyo is still a long ride from Moscow, and so on.

That does not begin to address the language barriers we have all faced, or even simply the cultural differences between our five partners. As a young engineer in Ohio, I do not think I ever expected one day to be fully comfortable traveling from Kazakhstan to Moscow to Tokyo in a single trip, but I have done exactly that. The cultural awareness and cultural changes were far greater than the physical travel.

We have learned that we are not nearly as different as it would have appeared in 1993, or even 2003. The biggest evidence of this is orbiting over our heads as we speak. All of those parts we built—all of the laboratories, connecting modules, logistics modules, trusses, solar arrays—all of them fit together on the first try, just like they were designed. That first try, of course, happened in space. I sometimes worry that we do not appreciate quite enough what an achievement that really is.

The Great Pyramid of Giza took an estimated 20 years to build. Notre Dame Cathedral in Paris took more than 150 years. The space station is perhaps the single most complicated engineering project ever undertaken by humanity, and we did it in 13 years of actual assembly in space, with every major part working as designed. Actually, the more I reflect on it, the more I think the engineering was actually the easy part. We have five partners—that is five governments, really 15 if you count all of the European Space Agency partners—that all have to agree on a plan and a budget and a schedule. As we have seen in the United States alone this year, even getting a single country's government to agree is no easy task. Yet, through the dedication of everyone in the program in every agency, and in part to what I like to think of as the singleness of our mission, we managed. All of our governments agreed this space station was worth their time and treasure and endless meetings and negotiations. The methods we have developed for managing the ISS, I believe, are a model for future large international science and engineering collaborations. It took years for us to get a system in place to manage this vehicle and its fleet of support ships that are coming and going, on average, once every three weeks.

Twice a week, we conduct the International Mission Management Team meeting. This is a telephone conference run by our working-level people from each agency where they discuss their tactical strategy for managing daily operations. Once every few months, we have a Space Station Control Board meeting, which is where the ISS program managers get together, usually in a video call, to discuss their medium-term tactical and strategic management strategy. A few times a year, we have a Multilateral Coordination Board meeting, which is chaired by my counterparts and me, usually in person, where we discuss our long-term strategic plans for ISS.

I detail all these meetings to emphasize that the way we manage the station, and in my opinion the only way to manage it, is by communication. It is all about communication. Communication between the partners is most critical; it is more important than any single launch, any single module, and any single spacewalk. Without daily communications between each partner, we simply would not be able to execute this program.

Let me make clear to anyone who might someday manage our next big international mission, maybe to the moon, maybe to Mars—communication is the most important part of your program. From this communication comes trust—and there must be a level of trust. We cannot fully understand the details of another partner's design. At some point we must trust that they have fully worked the design and its operation and understand how it will work with the ISS.

Challenges in Space and on the Ground

This type of communication has helped us overcome the many challenges we have faced in assembling the ISS. I would like to mention a few of these challenges now, because they help inform the way we will manage the program in the future.

This may shock you, but budget is actually not one of our biggest challenges right now, at least for the space station program. It could be, if the Washington budget folks listen to this speech and hear me say budget is not a problem. They would see this as an opportunity to cut our budget. They also want more return for each dollar spent.

We have spent enough time working with the Congress and helping them understand the program that we have actually gotten to the point where we, and more importantly, they, understand what we need to fund our O&M costs reliably.

More is almost always better, of course, and a more robust budget would enable us to fund a more robust research program. The research funding could be increased and is very small compared to the assembly and operations costs. However, with our National Lab partners, we have been able to develop a plan that helps spread research costs around while maintaining a reasonable utilization schedule.

Keep in mind, I am only talking about the budget for operating the station. Our next biggest challenge is transportation, which is both a technical and budgetary challenge. As you all know, since we retired the space shuttle, our only access to the crew has been through the Russian *Soyuz*. I would also like to clarify something the media has yet to get right. They like to point out that since we do not have the shuttle, we are now solely reliant upon the Russians. This is true, but it misses the point. We have always been solely reliant upon the Russians for crew transportation. Emergency return capability on station has always been via the *Soyuz*. Even when we rotated crews with the shuttle, they had a seat on the docked *Soyuz* in case of an emergency. We actually had not even rotated a crew on the shuttle for the last few years of the program.

So from this perspective, the new world is the same as the old world. However, it does put us in a more precarious position politically. The Russians have had a trying year, experiencing several launch failures, including one cargo ship which was bound for the ISS. I consider the Russians among the world's foremost rocket engineers, and while the *Soyuz* capsule has only flown 123 times, the *Soyuz* rocket has flown more than 1,800 times in its various iterations. To say once more, 1,800 times. That is a lot of flight history in a rocket design, to be sure.

I have confidence in our Russian partners to find and correct the problems they seem to have been having lately, and I am comfortable continuing to launch our crews aboard their vehicles for as long as we need to. However, additional redundancy would be nice.

Commercial Partnerships

One of our guiding principles on the ISS is the concept of dissimilar redundancy. We have a lot of duplication on-orbit—two oxygen generators, two carbon dioxide removal systems, a whole fleet of different cargo delivery ships, all of which provide the same function in different ways, so that no single failure or design flaw can affect the others.

Right now we are violating this principle of dissimilar redundancy by having only one way to launch crews into space. The *Columbia* tragedy showed us the value of redundancy. Our Russian partners understand this as much as we do.

This is a transitional time for NASA as we watch commercial cargo come on line. SpaceX is hoping for their first rendezvous and docking with the ISS next month, and Orbital should launch their cargo ship later this year. We have a cargo margin already onboard the ISS, which means we do not require the immediate success of these companies. Three current cargo ships, the *Progress*, the H-II Transfer Vehicle (HTV), and the Automated Transfer Vehicle (ATV), are sufficient for now to give our new commercial partners time to grow. The upcoming launches this year are test flights, and I want to stress that. These companies will be operating where historically only governments have, and I think it will be interesting to watch.

We are trying to continue this effort with our commercial crew program at NASA. We have selected a number of partners for this program, and by providing limited funding, we are hoping to accelerate their development of private space vehicles that can take crew to and from orbit.

This is another one of our challenges. The more budget we have to help these partners, the sooner we can help them begin flying safely and reliably. Once they begin flying safely and reliably, we will be back to our core principle of dissimilar redundancy for access to station.

Another challenge we face is the utilization of the ISS. This year we selected the Center for the Advancement of Science in Space, or CASIS, to manage the US portion of the ISS as a national laboratory. This is one of the most important research developments of the past few years. While NASA will continue to do the kinds of research that are directly relevant to us—like long-duration human exposure to microgravity and long-duration systems development—we simply cannot use all of the facilities of the ISS. It is too big.

Instead, we have selected an outside partner to act as the referee to figure out how best to use the vast capacity of the station. The vaccines I talked about earlier were developed in this way—by an outside entity partnering with NASA. In the future, exactly this kind of research will continue, but it will be managed through CASIS.

The NASA-CASIS interfaces are still being worked out, which is why I list this among our challenges. Getting the word out to the research community of this incredible resource is another one of our challenges, one that I look forward to working with CASIS to address. In the future, I expect one of our challenges will be figuring out how to down-select from the many research proposals we receive.

The goal of CASIS is to show typically nonspace commercial companies the advantages of using the space station as a research environment. Any equation with "g" in it can gain additional insight into the process represented by the equation by going into microgravity. New insight into combustion can be done in the combustion research rack on the ISS. CASIS is to expose the commercial sector to the advantages of space-based research to their industry. Space could become a new economic engine for this nation.

Finally, figuring out what to do with the ISS for our own uses is the last of our biggest challenges. We have a tacit agreement among the ISS partners that our next step is to move humans out into the solar system. However, we all recognize that we simply cannot do this in a safe and effective way without developing on station the systems that will take us there. It is a lot easier to troubleshoot a faulty oxygen generator two hours from home than it is two months from home.

The problem here, as the problem is everywhere else, is one of resources. This year, at our Multilateral Coordination Board meetings and possibly at a meeting of the heads of all the space agencies, we are hoping to establish a well-thought-out plan of research and development to begin to take us there. Technology development is critical to these efforts, and it will be better for all of us if we attack this as a unified partnership rather than as a loose confederation.

Another one of the topics we will be discussing is the best way to use the actual station components to support research. We have been floating some ideas about possibly using station modules that are on-orbit to support a new exploration vehicle—literally disassembling a few pieces of the space station, putting them together in a new configuration, and blasting them right out of the current orbit.

As odd as it seems to start talking about taking the thing apart right after we finished putting it together, the actual missions will not happen for years yet, but the planning needs to begin now. Our entire experience on station has shown us that our estimates on the life of nearly every component have been very conservative. The vehicle is outperforming anything we could have hoped for, and it would be foolish of us to not plan to use it to its fullest. Courage, my friends, we are advancing to the Brick Moon!

Exploring Space—the Final Frontier

In 1804, Pres. Thomas Jefferson commissioned an expedition to find a navigable water route to the other side of North America—the fabled Northwest Passage. Meriwether Lewis and William Clark were selected to lead the expedition. Lewis, Clark, and their team left the East Coast in 1804, bound for points west. Along the way they discovered a wealth of knowledge that had great value scientifically, commercially, and politically, though they never did find the Northwest Passage.

Jefferson originally requested $2,500 from Congress for the expedition. The final cost of the trip was closer to $50,000. History has certainly shown that the investment was worthwhile. The Lewis and Clark expedition nearly single-handedly opened the American West for expansion, which was one of the primary economic engines that drove the United States for nearly 150 years.

Think ISS. . . .

In 1838, the US government sponsored a round-the-world trip of six ships, called the US Exploring Expedition [Ex-Ex]. It was the first government-sponsored nautical journey and consumed somewhere between one-quarter and one-third of the federal budget. Think about that—a third of the federal budget. This was before the rise of most of the government services we take for granted today, but that is still an enormous commitment to exploration and discovery on the part of the Congress.

The US Ex-Ex charted much of the Pacific Ocean, as well as large parts of the coast of Antarctica. It brought back tens of thousands of plant and animal specimens, which in large part convinced Congress to fully back the founding and funding of the Smithsonian Institution to categorize and preserve them. Some of the charts created by the Ex-Ex were still in use a hundred years later in the Pacific Theater in World War II. Is exploration worth the cost?

In 1919, a hotel owner named Raymond Orteig offered the princely sum of $25,000 to the first airplane to fly nonstop between New York and Paris. Eight years later, it was claimed by Charles Lindbergh in one of aviation's greatest triumphs.

I bring this all up to illustrate a point. In our business, we like to say that we are going places and doing things that no one has ever done before. This is true. However, it is also important for us to remember that we are the latest in a long line of explorers, scientists, engineers, and entrepreneurs that stretches back hundreds of years. We are not different; we are merely continuing the work they began.

The US government has historically funded bold and expensive exploration and research programs. Thomas Jefferson originally proposed a Lewis and Clark–type expedition in the 1780s—before the signing of the Constitution. The US Ex-Ex was primarily a trip to show the flag around the world and conduct science if possible. The scientific returns were immeasurable.

The Orteig prize had a modern parallel in the X-Prize, which was directly modeled after the success of the transatlantic flight. The X-Prize was even claimed eight years after it was announced—the same amount of time as the Orteig prize.

What we do is what we have always done, and hopefully what we will always continue to do: explore. The work on the International Space Station is helping to find new vaccines, new materials, and new ways of looking at our home planet that will directly affect the lives of millions on the ground. These are not spin-offs. These are direct results of focused research that is building on decades of experience working in space. Thirty-one countries are currently conducting investigations onboard, representing hundreds of researchers. This is the way humanity conducts serious space exploration.

At the same time, the ISS is helping us fill in the blanks on the specific ways humanity will finally leave the confines of low Earth orbit in a sustainable, robust way. When the crew of some future starship *Enterprise* looks back at the history that got them their ship, I believe they will see our work today in the same way we see Lindbergh, Lewis, Clark, and even Columbus—as foolhardy, fragile, brave, audacious, and utterly necessary.

Günter Wendt called this the "unbroken chain," and we are doing our part to ensure that we are a link in the middle, and not the bitter end.

Courage, my friends, we are advancing to the Brick Moon! SSQ

Notes

1. "Preventing and Controlling MRSA Infections in the Military Health Care Setting," *Force Health Protection and Readiness*, 29 December 2010, http://fhp.osd.mil/new.jsp?newsID=20.

2. R. Monina Klevens, DDS, MPH; Jonathan R. Edwards, MS; Chesley L. Richards Jr., MD, MPH; Teresa C. Horan, MPH; Robert P. Gaynes, MD; Daniel A. Pollock, MD; and Denise M. Cardo, MD, "Estimating Health Care-Associated Infections and Deaths in U.S. Hospitals, 2002," *Public Health Reports* 122, no. 2 (March–April 2007): 160–66, http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1820440/?tool=pmcentrez.