NASA and the Business of Space

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When President Bush announced the Vision for Space Exploration in January 2004, he made many specific points, including one which has been little noted, but which we here all believe; that the pursuit of the Vision will enhance America's economic, scientific and security interests. He also made it clear that the first step in the plan was to use the Space Shuttle to complete the assembly of the International Space Station (ISS), after which the ISS would be used to further the goals of exploration beyond low Earth orbit. These issues are all closely related, and I believe it is time to discuss in more detail how the ISS will be used to accomplish them, and how it will fit into a broader strategy for 21st century space exploration of the Moon, Mars and beyond in a way that will spur commerce, advance scientific knowledge, and expand humanity's horizons.

We are entering the dawn of the true space age. Our nation has the opportunity to lead the way. It is an opportunity we are eager to pursue, and one which we are unwilling to postpone. But the exploration of the solar system cannot be what we want it to be as an enterprise borne solely by the American taxpayer, or even by the taxpayers of the nations willing to join with us in this enterprise.

If we are to make the expansion and development of the space frontier an integral part of what it is that human societies do, then these activities must, as quickly as possible, assume an economic dimension as well. Government-directed space activity must become a lesser rather than a greater part of what humans do in space. To this end, it is up to us at NASA to use the challenge of the Vision for Space Exploration to foster the commercial opportunities which are inherent to this exciting endeavor. Our strategy to implement the Vision must, and we believe does, have the potential to open a genuine and sustainable era of space commerce. And the International Space Station will provide the first glimpses into this new era.

Before we pursue this thought further, let us summarize a few statistics from the ISS program. On November 2nd, we marked the fifth year of consecutive human occupancy of the Station. The Station has hosted 97 visitors from ten countries in its approximately 425 cubic meters, a volume roughly the size of a typical three-bedroom home. Of these, 29 have been crew members of the twelve ISS expeditions which have flown to date. With the most recent spacewalk by Expedition 12 Commander Bill McArthur and Flight Engineer Valery Tokarev, 63 have been conducted in support of ISS assembly, totaling nearly 380 hours. And through the partnership we have with 15 other nations, we have learned to work together on an incredibly complex systems engineering project. While it certainly has not always gone smoothly, the simple fact of its accomplishment has been an amazing feat. My oft-stated view is that the international partnership is, in fact, the most important long-term benefit to be derived from the ISS program. I think it is a harbinger of what we can accomplish in the future as we move forward to even more ambitious objectives in space.

Indeed, the value of this international collaboration was endorsed once again by a recent vote in Congress, which lessened certain restrictions placed on our ability to cooperate with Russia in the arena of manned spaceflight. This Congressional action helps to ensure the continuous presence of American astronauts on the station. It continues to reflect our government's commitment to nonproliferation objectives, while recognizing the value of international cooperation in space exploration.

So, how can the ISS that we are building today help us to move beyond low Earth orbit tomorrow?

To begin, we are focusing human research on ISS on the highest risks to crew health and other issues we will face on long exploratory missions. This research will help us understand the effects of long duration spaceflight on the human body, such as bone and muscle loss, so that we can develop medical standards and protocols to manage such risks. We have already had some successful anecdotal experience among ISS crewmembers with exercise countermeasures. Perhaps ISS-based research will one day help us to evaluate the efficacy of drugs to counter osteoporosis, or long-term exposure to the radiation environment, or to test advanced radiation detectors. The station will help us learn to deal with crew stress on long missions, to enable them to remain emotionally healthy.

With the ISS as a testbed, we can learn to develop the medical technologies, including small and reliable medical sensors and new telemedicine techniques, needed for missions far from home. A milestone in that arena was achieved a year ago, when the journal *Radiology* published its first research paper submitted directly from the Station, ISS Science Officer Mike Fincke's account of the first use of ultrasound in space for a shoulder examination.

The ISS can host, and test, developmental versions of the new lox/methane engines we will need for the Crew Exploration Vehicle (CEV), and many other systems that we will need for Mars. These include the development and verification of environmental control, life support, and monitoring technologies, air revitalization, thermal control and multiphase flow technologies, and research into flammability and fire safety. As I have often said, when we set out for Mars, it will be like sealing a crew into a submarine and telling them not to ask for help or return to port for several years. We can't do that today. We have to be able to do it before people can go to Mars. We'll learn to do it on the ISS, and later on the Moon. And so, fundamentally, the ISS will allow us to learn to live and work in space.

And even though this research is focused on the tasks associated with setting up research bases on the Moon and preparing the way for Mars exploration, it will also benefit millions of people here on Earth. What we learn about bone loss mitigation and cardiovascular deconditioning, the development of remote monitoring and medical care, and water reclamation and environmental characterization technology obviously has broader benefits. One certainly would not build a space station to achieve these goals. But given that we have it, we intend to maximize the science return from ISS in ways that will benefit both space exploration and our society at large.

But now let us turn to what I believe will be an even greater benefit of the ISS, and that is its role in the development of space as an economic arena.

In order that we may devote as much of NASA's budget as possible to the cutting edge of space exploration, we must seek to reduce the cost of all things routine. Here in 2005, the definition of "routine" certainly *should* include robust, reliable, and cost effective access to space for at least small and medium class payloads. Unfortunately, it does not, and frankly, this is not an area where it is reasonable to expect government to excel. Within the boundaries of available technology, when we want an activity to be performed reliably and efficiently, we in our society look to the competitive pressures of the free market to achieve these goals. In space, these pressures have been notably lacking, in part because the space “market” has historically been both specialized and small. There have been exceptions – notably in the communications satellite market – but the key word here is “exceptions”. Broadly speaking, the market for space services has never enjoyed either the breadth or the scale of competition which has led, for example, to today’s highly efficient air transportation services. Without a strong, identifiable market, the competitive environment necessary to achieve the advantages we associate with the free market simply cannot arise.

I believe that with the advent of the ISS, there will exist for the first time a strong, identifiable market for “routine” transportation service to and from LEO, and that this will be only the first step in what will be a huge opportunity for truly commercial space enterprise, inherent to the Vision for Space Exploration. I believe that the ISS provides a tremendous opportunity to promote commercial space ventures that will help us meet our exploration objectives and at the same time create new jobs and new industry.

The clearly identifiable market provided by the ISS is that for regular cargo delivery and return, and crew rotation, especially after we retire the shuttle in 2010, but earlier should the capability become available. We want to be able to buy these services from American industry to the fullest extent possible. We believe that when we engage the engine of competition, these services will be provided in a more cost-effective fashion than when the government has to do it. To that end, we have established a commercial crew/cargo project office, and assigned to it the task of stimulating commercial enterprise in space by asking American entrepreneurs to provide innovative, cost effective commercial cargo and crew transportation services to the space station.

This fall, NASA will post a draft announcement which seeks proposals from industry for flight demonstrations to the International Space Station of any combination of the following: external unpressurized cargo delivery and disposal, internal pressurized cargo delivery and disposal, internal pressurized cargo delivery and recovery, and crew transport.

As these capabilities are demonstrated in the years ahead, we will solicit proposals for ongoing ISS transportation services from commercial providers. This announcement offers the opportunity for industry to develop capabilities that, once proven, NASA will purchase with great regularity, just as we regularly purchase launch services for our robotic spacecraft today. Once the announcement is on the street, we will receive proposals by late January, with the intent to execute agreements by May of next year.

This competition will be open to emerging and established companies, with foreign content allowed, consistent with American law and policy. Proposals can include any mix of existing or new designs and hardware. NASA does not have a preferred solution. Our requirements will be couched, to the maximum extent possible, in terms of performance objectives, not process. Process requirements which remain will reflect matters of fundamental safety of life and property, or other basic matters. It will not be government "business as usual". If those of you in industry find it to be otherwise, I expect to hear from you on the matter.

With this plan, and providing of course that we retain the support of the Congress necessary to carry it out, we will put about a half-billion dollars in play over the five years to promote competition that is good for the private sector and good for the public interest. I'm confident that this kind of financial incentive, on different terms than are usual with NASA, or indeed with any government entity, will result in the emergence of substantial commercial providers. Such successes will, in their turn, serve as a justification for even greater use of such "non-traditional" acquisition methods. As I have said in other venues, my use of the words "non-traditional" here is somewhat tongue-in-cheek, because what we are talking about is *completely* traditional in the bulk of our economy which is *not* driven by government procurement. In this larger economy, when there exist customers with specific needs and the financial resources to satisfy these needs, suppliers compete avidly to meet them. We need more of this in the space enterprise.

But as stated earlier, this is only the first step. An explicit goal of our exploration systems architecture was to provide an avenue for the creation of a substantial space economy by suitably leveraging government investment to meet its stated mission requirements. The architecture we announced in September was designed so that NASA would provide, but would provide only, the essential transportation elements and infrastructure to get beyond low Earth orbit. The heavy lift launchers and crew vehicles necessary to journey beyond LEO cannot, in anything like the near future, be provided by any entity other than NASA, on behalf of the U.S. government. The analogy I have used elsewhere is that NASA will build the "interstate highway" that will allow us to return to the Moon, and to go to Mars.

We as a nation once had the systems to build this "interstate highway" leading out into the solar system, we should have retained and evolved them, but we did not. So we need to rebuild them. But the "highways" themselves are not, and are not supposed to be, the interesting part. What is interesting are the destinations and, particularly to the point of the present discussion, the service stations, hotels, and other businesses and accommodations that we will find at the "exit ramps" of our future "interstate highways" in space. It is here that a robust commercial market can develop to support our exploration goals, and eventually to go beyond them. I think we are at the start of something big, somewhat akin to what we saw with the personal computer 25 years ago.

To my point, NASA's exploration architecture does what it must. It fulfills the mission required of it by the President, according to the terms of a major speech and written policy. It does so in a fashion which some have labeled as "boring" or "lacking pizzazz", but which others have observed makes efficient use of the building blocks that we as a nation own today, and in which the pieces "fit together like a fine Swiss watch". I believe these seemingly divergent views are merely two sides are the same coin, reflecting the fact that the plan delivers what it must, without including what it need not. Nothing else is acceptable in these fiscally challenging times.

But the building blocks of our architecture could easily be used to accomplish much more, with the right leverage from commercial providers. To see how this is so, observe first that our "1.5 launch solution" separates the smaller crew launch from that of the heavy, high-value cargo, both on Shuttle-derived launch vehicle variants. While this approach *allows* us to meet lunar return mission requirements with U.S. government systems – no external entities are in the critical path for mission accomplishment – it does not *exclude* such entities, and indeed provides several "hooks" and "scars" by which their services can be used to facilitate or enhance the mission.

By the time we are ready to return to the Moon, the ISS will have been completed and will be in receipt of routine commercial resupply and crew rotation service for, we hope, several years. So, if the plan for stimulating the development of ISS commercial crew rotation capability is successful, it becomes possible to envision the crew launch phase of the lunar mission being carried out on commercial systems. This would be a service we could purchase commercially, leaving the very heavy lift requirements to the government system, for which it is less likely that there will be other commercial applications during this period.

Whether or not this occurs, other options are also possible. Astute observers will note that the Shuttle-derived heavy lift vehicle (SDHLV) that we have proposed is not, as a rocket, being optimally utilized for its lunar mission. This is because some of the fuel in the so-called "Earth departure stage" is used to lift the lunar payload into Earth orbit, but additional fuel must yet be retained for the translunar ignition burn of over 3 km/s. From a purely architectural point of view, the SDHLV is an expensive vehicle, most aptly utilized for lifting only expensive cargo, such as the man-rated systems it carries. But in our architecture, some of its lift capacity must be utilized to carry fuel into low Earth orbit. This is unsatisfying, because when on the ground, fuel is about the cheapest material employed in any aspect of the space business. Its value in orbit (at least several thousand dollars per pound) is almost completely a function of its location rather than intrinsic to its nature. In contrast, the value of, say, the Lunar Surface Access Module (LSAM) brought up on the heavy-lifter will be well over $100 K per pound, most of which represents its intrinsic cost. The additional value it acquires when transported to its new position in LEO remains a small part of the total value.

Logically, then, we should seek to use the SDHLV only for the highest-value cargo, and specifically we should desire to place fuel in orbit by the cheapest means possible, in whatever manner this can be accomplished, whether of high reliability or not. However, in deciding to embark on a lunar mission, we cannot afford the consequential damage of not having fuel available when needed. Recognizing that fact, our mission architecture hauls its own Earth-departure fuel up from the ground for each trip. But if there were a fuel depot available on orbit, one capable of being replenished at any time, the Earth departure stage could after refueling carry significantly more payload to the Moon, maximizing the utility of the inherently expensive SDHLV for carrying high-value cargo.

But NASA's architecture does not feature a fuel depot. Even if it could be afforded within the budget constraints which we will likely face – and it cannot – it is philosophically the wrong thing for the government to be doing. It is not "necessary"; it is not on the critical path of things we "must do" to return astronauts to the Moon. It is a highly valuable enhancement, but the mission is not hostage to its availability. It is exactly the type of enterprise which should be left to industry and to the marketplace.

So let us look forward ten or more years, to a time when we are closer to resuming human exploration of the Moon. The value of such a commercially operated fuel depot in low Earth orbit at that time is easy to estimate. Such a depot would support at least two planned missions to the Moon each year. The architecture which we have advanced places about 150 metric tons in LEO, 25 MT on the Crew Launch Vehicle and 125 MT on the heavy-lifter. Of the total, about half will be propellant in the form of liquid oxygen and hydrogen, required for the translunar injection to the Moon. If the Earth departure stage could be refueled on-orbit, the crew and all high-value hardware could be launched using a single SDHLV, and all of this could be sent to the Moon.

There are several ways in which the value of this extra capability might be calculated, but at a conservatively low government price of $10,000/kg for payload in LEO, 250 MT of fuel for two missions per year is worth $2.5 B, at government rates. If a commercial provider can supply fuel at a lower cost, both the government and the contractor will benefit. This is a non-trivial market, and it will only grow as we continue to fly. The value of fuel for a single Mars mission may be several billion dollars by itself. Once industry becomes fully convinced that the United States, in company with its international partners, is headed out into the solar system for good, I believe that the economics of such a business will attract multiple competitors, to the benefit of both stockholders and taxpayers.

Best of all, such an approach enables us to leverage the value of the government system without putting commercial fuel deliveries in the critical path. If the depot is there and is full, we can use it. But with the architecture we have advanced, we can conduct missions to the Moon without it. The government does not need to have oversight, or even insight, into the quality and reliability of the fuel delivery service. If fuel is not delivered, the loss belongs to the operator, not to the government. If fuel is delivered and maintained in storage, the contractors are paid, whether or not the government flies its intended missions. If long-term delivery contracts are negotiated, and the provider learns to effect deliveries more efficiently, the gain is his, not the government's. Since fuel is completely fungible, it can be left to the provider to determine the optimum origin, size and method of a delivering it. And finally, though I would rather not do it, it is even possible that we could develop such a market in stages, with the first fuel tank provided by the government, and then turned over to a commercial provider to store and maintain fuel for future missions, and to expand the tank farm as warranted by the market.

To maintain and operate the fuel depot, periodic human support may be needed. Living space in Earth orbit may be required; if so, this presents yet another commercial opportunity for people like Bob Bigelow, who is already working on developing space habitats. So the logistics needs of the fuel depot may provide more of the same opportunities that we will pioneer with ISS.

Fuel and other consumables will not always be most needed where they are stored. Will orbital transfer and delivery services develop, with reusable "space tugs" ferrying goods from centralized stockpiles to other locations?

The fuel depot operator will need power for refrigeration and other support systems. This might well be left to specialty suppliers who know nothing of the storage and maintenance of cryogenic tank farms, but who know a lot about how to generate and store power. Could these be standard power modules, developed and delivered for a fee to locations specified by the user?

In the course of conducting many fuel replenishment missions and associated operations, commercial launch and orbital systems of known and presumably high reliability will be developed and evolved. Government mission planners will be able to take advantage of these systems, which will become "known quantities" by virtue of their track record rather than through the at best mixed blessings of government development oversight.

There will also be a private sector role in supporting a variety of lunar surface systems and infrastructure, including lunar habitats, power and science facilities, surface rovers, logistics and resupply, communications and navigation, and *in situ* resource utilization equipment. There may or may not be gold on the Moon – I'm not sure we care – but we may well witness a 21st century gold rush of sorts when entrepreneurs learn to roast oxygen from the lunar soil, saving a major portion of the cost of bringing fuel to the lunar surface. Will a time come when it is more economical to ship liquid oxygen from the lunar surface to low Earth orbit, then to bring it up from Earth?

This will all start to become "really real" in 10 years or so. As I see it, these are exactly the kinds of enterprises to which government is poorly suited, but which in the hands of the right entrepreneur can earn that person a cover on *Fortune* magazine. But it will take enlightened government management to bring it about, management as much in the form of what not to do, as to do. In the coming years and decades, NASA must focus on its core government role as a provider of infrastructure broadly applicable to the common good, and too expensive for any single business entity to develop. NASA must remain on the frontier, and must conscientiously architect its plans to favor the inclusion of entrepreneurs through arms-length transactions wherever possible, restricting the use of classic “prime contracts” to situations where they are the right tool, not the default tool.

With the beginning of space station operations five years ago, we are now at a point children born at the beginning of the 21st century will live their lives knowing that there will always be people living and working in space. And the number of people who will be engaged in such activity will grow by leaps and bounds if we in government are faithful in executing our role in helping the private sector to step up to these new opportunities. I hope there are many entrepreneurs in this audience who have the vision to help us help them pioneer the commercial space frontier. You, and all those engaged in the quest that we are undertaking, have my sincere thanks and appreciation.