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STIMULATING THE DEMAND-SIDE TO CREATE A NEW SPACE ECONOMY

Thank you for the opportunity to speak today with such a distinguished audience of leaders in the space industry. I see many colleagues present with whom I've had the privilege to work over the past 25 years in the course of designing, assembling, operating, and using the International Space Station. It's been a long and hard-fought road, as any seasoned veteran among you will know, but we now have an incredible capital asset – an approximately 500 metric ton, permanently crewed, full-service, space station ready to perform the multiple missions for which it was originally designed. It has already garnered the prestigious Collier Trophy, among many other awards, and I'm confident the future R&D potential of the ISS is at least as great as the engineering achievements already in hand.

Before I get into today's discussion, on the screen behind, you'll see a graphic record of the 35 stages involved in the buildup of ISS over the period from First Element Launch in November 1998 through the recent Space Shuttle STS-134 mission that just landed on June 1. This series will be followed by a collection of images for the completed space station that were recently obtained by European astronaut Paolo Nespoli as he departed ISS on the Soyuz 25S return leg last month at the end of Expedition 27.

This has been a herculean achievement. And, I remain convinced the best is yet to come, ***provided we don't let opportunity slip through our fingers***. This is the subject that I'll discuss with you today – how do we avoid a multi-billion dollar lost opportunity cost in the event that we fail to use the ISS productively over the next decade. Some will argue, as I have previously, that future U.S. appropriations for human spaceflight may very well be decreased, sustained, or increased depending on the tangible benefits of the national investment in ISS. Others maintain that it's all just a sunk cost and bears no relationship whatsoever to future fiscal decisions. I'll leave you to judge the relative wisdom of these two perspectives.

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NASA and the civil space industry share several clear and common objectives. Among these, we want to create a new space economy in low-Earth orbit that enjoys increasing demand for the infrastructure and services we make available. That seems to be a straightforward enough proposition, but let's inspect it more closely.

The space industry is a seller (or a supplier) of infrastructure and services, not generally a buyer (or a user). Granted, the industry is a buyer in the sense that you purchase goods and services from a network of subcontractors and vendors, in order to offer your products and services. This is also an important element of an overall economy and I don't mean to disparage it in anyway. ***But, it's all on the supply side of the economy.***

Government is almost exclusively the buyer of civil space infrastructure, with the notable exception of telecommunications satellites, which are very good example of a successfully sustained space economy in geostationary Earth orbit. There is little argument however that government demand represents virtually the entire buyer side for the civil market in LEO.

This is troublesome…

Government demand for civil space infrastructure in LEO is likely to contract, rather than expand, over the foreseeable future due to the urgency of U.S. national debt reduction and ever-increasing spending on social entitlements. Perhaps, the government demand for national security space infrastructure will be sustained, but the demand for civil infrastructure seems certain to contract. This is not really even a point of debate – I've noticed recently that most everyone in government and industry acknowledges these dour prospects. While we continue to hope for the best, we must nonetheless plan for something less.

In order to offset the contraction in government demand, a corresponding expansion in non-government demand is needed. I understand this is easier said than done, but ***it is not impossible***, as some may think. So, how do we generate non-government demand for civil infrastructure and services in LEO? How do we create a sustainable new economy in LEO that includes both non-government buyers and sellers – an economy that is similar to the satellite telecommunications model?

As you are all well aware, NASA has already committed to investing $500 million in the Commercial Orbital Transportation Services (COTS) demonstrations. And, of course, there's the additional up to $3.5 billion that's been awarded under the subsequent Cargo Resupply Services (CRS) contracts. Finally, I would be remiss were I not to remind you that NASA has also invested ~ $60 billion to date in building the International Space Station, and plans invest another ~ $20-30 billion over this decade to operate and maintain it. This almost $100 billion total national investment is all in LEO infrastructure and services. In other words, ***almost all of the government's investment is on the supply-side of a LEO economy.***

The good news is that this major government investment in the supply side means we are at least halfway to solving the problem. Now, we really need to start taking some meaningful actions toward…

…<u>Stimulating</u> the Demand-Side to Create a New Space Economy

I’ve chosen my words carefully. Note that the action verb here is to *stimulate*, not to invest. The government can’t afford to invest another $100 billion, this time into the demand side… and the reason is straightforward. NASA and the space industry also have a greater mission – a “mission to go where no one has ever gone before”, to borrow a popular mission statement from the space genre that sprang from years past. Human and robotic exploration is, and always should be, NASA’s primary objective. In a contracting government fiscal environment, the national investment then should be in preserving NASA’s primary mission – exploration. As a result, neither NASA nor the space industry has the fiscal strength to further invest large sums of money into growing the demand side of a LEO economy. In fact, it’s extremely fortunate that we have already been able to do such a thorough job on the supply side.

This doesn’t mean that we have to abandon the virtuous objective of finishing what we started – i.e., fostering a new private economy in LEO. There are two broad options available:

1. We could do nothing and continue with the current “build it and they will come” strategy. In this scenario, the government, i.e., NASA, remains the sole source of demand. NASA continues to purchase cargo services from private suppliers, and perhaps even crew services in the future as we proceed to invest still more government monies into the supply side. Non-government demand never emerges, because the tangible benefits of the LEO environment are never pursued aggressively, or demonstrated sufficiently, enough to warrant any substantive private purchase of capacity. Government demand contracts over the next decade as previously discussed, and the ***opportunity is lost***.

There is another approach though…

2. Alternatively, we could actively stimulate non-government demand by an aggressive and strategically structured plan of action to engage non-aerospace scientific and industrial R&D organizations that are presently unaware of the benefits to be gained through space-based R&D programs. If we begin immediately, by the middle of this decade we could see a growing and substantive non-government market emerge on the demand side of the LEO economy. This ***opportunity is palpable***.

I know what you’re thinking… what exactly does “palpable” mean? That’s not a technical term. Well, palpable means obvious, or easily perceived. Now, maybe it’s not obvious, or easily perceived by this audience yet, but there is a tremendous competitive advantage inherent in the environment afforded by a full-service, crewed space station.

I want to help you reach this realization here today.

Let’s begin with an easily recognizable theoretical construct. All of our equations of motion -- the Navier-Stokes and Euler equations -- are very familiar to you due to your expertise in the fluid dynamics necessary to master flight. All of these equations include the constant "G" (gravity). What do you suppose happens to the solutions to these equations when "G" goes to zero? ***You get a different solution.***

There it is. That single observation forms the basis for an extraordinary scope of discovery and applications. This wasn't my observation; it was German scientists that first made this observation in 1987[1]. I found their insight to hold tremendous implications for R&D on ISS.

Now, let's consider those implications.

(a) For inorganic systems (e.g., metals, alloys, glasses and ceramics etc.), that are undergoing changes of state, the thermal and mass transfer dynamics are different at the molecular level.

(b) For organic systems (e.g., cytoplasm, cells and membranes), the same is true in biochemical and biophysical processes where molecules migrate due to thermal and density gradients.

Think about this awhile. Motion at the molecular level changes as gravity approaches zero in most physical, chemical and biological systems. While this doesn't hold true at the atomic and nuclear levels, or in cases where electromagnetic forces are present, it is nonetheless pervasive at the molecular scale.

But, what are the practical applications of these new dynamics that weren't accessible prior to spaceflight? Why haven't we yet seen the so-called "killer app" corresponding to Telstar-1 in 1962 that launched the telecommunications satellite industry on such short order? That is an interesting question – to help you answer it, I'll remind you that Telstar came about primarily through the efforts of Bell Laboratories – a private R&D organization, arguably the most successful in history, and they were working in a cooperative relationship with NASA.

Over the last two decades, the development of microgravity applications has been severely constrained by multiple factors. There were competing NASA infrastructure development programs – initially ISS and later Constellation. These pressures drove "re-phasing" and "re-focusing" of available research funds. However, those programs were not the sole culprits by any means. In addition, there were multiple cancelations of microgravity applications programs. Science offices took these steps, in order to re-direct funds exclusively to basic research, and this was accomplished by issuing grants to university scientists. The figure of merit for success when you employ this approach is the number of grants issued, or the number of scientific papers published in peer-reviewed journals. *This works for basic scientific research, but it is not as effective in advancing research to practical applications.* This critical aspect is so well recognized that it was the subject of a pointed analysis as recently as last Sunday's Washington Post, where the opening proposition of an article on innovation was, and I quote, "***If university***

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[1] Legros, J.C., et al, Fluid Sciences and Material Science in Space, (H.U. Walter, ed), Springer-Verlag, Germany, p.89 (Table II), 1989.

research were a business, it would be bankrupt*.[2]" The conclusion of this particular Harvard law school analyst was that exchanges between the academic and industrial sectors should be less rigid and more open to collaboration. While the bankruptcy metaphor may be somewhat extreme, it serves to shine an urgent light on an issue of vital importance to our national prosperity – ***R&D is the basis for long-term economic growth. It's not troubled asset relief programs, or Princetonian monetary policy, or stimulus funds – these may well be appropriate tactics for managing short-term recoveries under extreme circumstances. But, over the long-term, R&D is the root cause for economic growth. The critical role for the academic sector is then to ensure the human capital is available to sustain growth. We have to get this R&D prescription right again, if we are to reclaim the industrial growth that catapulted the U.S. into global leadership in the 20th century.

The International Space Station is primed and waiting for this purpose.

(Incidentally, the citations for any references made in the discussion today are provided in my written remarks for anyone who is interested.)

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Despite the persistent obstacles, microgravity applications have still emerged and risen to the surface where they are becoming more evident every year. So, let me take some time to just review a few notable examples:

- The rotating wall bioreactor was a major technological innovation that is now used widely in ground-based research with over 5,000 bioreactors sold to date based on the NASA design. And, this design only vaguely mimics on the ground the far superior results obtained in space. Three-dimensional cell culturing in space allows conditions matching cell growth in humans on the ground that have never before been available. In 2003, cancerous tumor tissue grown under microgravity conditions was an order of magnitude larger in size than had ever been achieved on the ground. This is analogous to the emergence in 1931 of the electron microscope in terms of sheer analytical strength. The potential for gaining new insights into the bio-dynamics of disease growth and spreading is very well documented. ***Yet, following this successful demonstration, the program was cancelled.***

- Structure-based drug design is a contemporary technique for developing pharmaceutical and therapeutic compounds. It relies on discovery of the fine molecular structure of complex macromolecules, such as proteins, polysaccharides and nucleic acids. We pursued macromolecular crystal growth in space for 15 years at NASA. But, we always recognized, as did Nobel laureate Herbert Hauptman, that 30-90 day crystal growth periods

[2] Wadha, V., (Sr. Research Associate, Harvard Law School), "Making Research Pay", Washington Post Sunday Edition, p. G2, June 12, 2011.

would be needed for practical application. ***As the ISS Laboratory, Destiny, was being christened in 2001, this program was cancelled.*** Subsequently, in 2007, our Japanese colleagues, working in the Russian segment, successfully crystallized an enzyme in the causative biochemical chain of reactions leading to muscular dystrophy. They solved the structure, designed a drug to block the reaction, and announced their success in developing a therapy to slow the rate of muscular dystrophy at last year's International Astronautics Congress in Prague, Czechoslovakia. My congratulations to our Japanese colleagues.

- In 1997, using an electromagnetic levitator built in Germany, Caltech scientist Bill Johnson discovered the thermo-physical properties necessary to form metallic glasses on the ground in bulk. These complex "liquidmetal ©" alloys have a yield strength and elastic limit more than double that of titanium. Some experts believe this signals the coming of the 3rd wave in the materials revolution – a revolution that began with steel, was followed by plastics, and may well lead to broad applications of metallic glasses in this century. Last August, Liquidmetal Technologies, Inc. granted an exclusive worldwide license to Apple, Inc. to produce and market this technology for the field of consumer electronic devices. ***In 2004, the microgravity materials science program was reduced in scope by more than 80%.***

- Over the last ten missions of the Space Shuttle, the private firm Astrogenetix, working under a Space Act Agreement with NASA, has developed candidate vaccines for both salmonella induced food poisoning and methicillin-resistant staphylococcus (MRSA) infections. This work is of such interest that a 2nd agreement has now been signed with the Arizona State University Bio Design Institute to develop a vaccine for pseudomonas. Bacterial pathogens are a significant contributor to infectious disease and the opportunity is emerging for effective management through microgravity-based protocols for therapeutic drug development.

So, why aren't these applications more widely known and accepted?

To achieve broad acknowledgement of the benefits, a dedicated and professionally skilled organization is needed. That organization must be strategically structured to work across the entire value chain from formation of the initial scientific hypothesis to development of market-ready products and services. That is what is necessary to develop the microgravity environment, and ***that is how to stimulate the demand side of a new economy in LEO.***

Both the Congress and the White House recognized this solution. In Section 504 of the NASA Authorization Act of 2010 (P.L. 111-267), Congress required that NASA enter into a cooperative agreement with a non-profit entity to pursue R&D on the ISS with organizations other than NASA. In response, the Office of Management and Budget issued a “High Priority Performance Goal” for FY 2011 to award the agreement by the end of this fiscal year, ***without further delays***. The President also proposed $15 million per year in assistance funding in order to secure a base for the non-profit’s operations.

So this brings us reasonably up to date. I can’t discuss many more details because we’re still in the competitive phase of acquiring this cooperative agreement, but I can say that NASA has received multiple proposals from a strong and highly competitive field. The selection decision is imminent, and you can expect an award announcement later this summer upon successful completion of final negotiations.

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There is still one last trap door in this 25-year long gauntlet that has to be avoided, or we could still irretrievably miss the opportunity.

The ISS was deliberately designed and built as a multi-mission spacecraft. There was never any intent that *only* scientists, or *only* engineers, or *only* industrialists could use it. All of these communities have great merit and skill; ***no one sector should hold an exclusive on the R&D agenda***. The space station was designed to accommodate the entire range of uses through a diversified and actively managed R&D portfolio. That is sound investment practice – in fact, it’s among the “first principles” of management.

I had the good fortune some time ago to study the management of federal policy development under Dick Darman. Dick was OMB Director from 1989-93, and over the course of his public career served five U.S. Presidents. He was also a strong advocate for space flight having been first inspired as a youth by JFK’s lunar mission challenge. Dick was the one who wrote Ronald Reagan’s famous commitment to build a space station in the 1984 state-of-the-union address. I gave him the complete NASA history series Exploring the Unknown, and he spent many hours with me discussing how to structure the ISS program for its most productive uses.

While there were many valuable lessons I learned from Dick, one stands out as particularly crucial to success in this instance. ***Federal policy must be inclusive of multiple interest groups and constituencies, not only to be effective but also to survive the test of time***. Developing inclusive policy requires the work of an “honest broker” – one that is capable of working across the stakeholder communities and equitably representing all affected interest groups.

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Let me wrap this up by saying that I hope you will leave today with three realizations:

1. High-value microgravity applications are ***entirely realistic***, and hold tremendous economic potential ***if only allowed to thrive***.

2. ***It is possible to create a new space economy*** within this decade, because the supply side is almost in place, and the demand side can be stimulated at a small marginal cost.

3. ***No single interest group should be allowed to politically capture exclusive control of the ISS R&D agenda.***

Neither our space program, nor our great nation can afford to miss the opportunity for which the space station was originally designed.

Thank you for your attention… I'll be happy to take a few questions if there is time.

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"The study of the World would be lame and defective were no practical results to follow."

– Cicero, "On Obligations" 44 B.C.