NASA's Future in Low Earth Orbit:
Considerations for International Space Station Extension and Transition.

Testimony

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Introduction

Chairwoman Johnson, Ranking Member Lucas, Chairman Beyer, Ranking Member Babin, and members of the subcommittee, thank you for the opportunity to testify before you today. I have been asked to share my thoughts on our country's future in low-Earth orbit, the extension and transition of the International Space Station, and what lessons I have learned over 30 years in the space business that others could apply as our nation seeks to build out a new era in commercializing space. My opinions and insights are informed both by my work on the Mir Space Station and its transition and ultimate deorbit, as well as being the CEO of Nanoracks, which does business on the ISS with customers in over 40 states and 30 countries.

I first testified before this panel and then Chairman Bill Nelson, in 1991 as the Executive Director of the Space Business Roundtables. As I reviewed that testimony, it is heartening to observe the extraordinary progress that has been made in the past three decades. Our main utilization challenge in the early 1990s was NASA's *Space Shuttle* program. How far we have progressed from a single point dependence on space access with the government-owned *Space Shuttle*, to a robust commercial launch industry with names like SpaceX and Rocket Lab that is the envy of the world.

We have transitioned from programs that were routinely funded solely by the government to programs funded by private capital where the government is one of many customers. At Nanoracks, we privately funded our Bishop Airlock in a robust partnership with NASA which is now a permanent addition to the International Space Station.

The common thread in this wonderful renaissance of space services is not advances in technology alone, but also the repeated direction by Congress to support greater commercial participation in NASA's operational space activities. This was first successfully demonstrated with the Commercial Cargo program, through the use of multiple carriers that have assured extraordinary stability for ISS operations, and in the Commercial Crew program supported by SpaceX and, soon, Boeing, which provides crew transportation for LEO activities.

Today the key challenge confronting this Subcommittee is once again when and how to transition a beloved core NASA program. Yes, we have been here before, have we not? This time it is not the *Space Shuttle* but the International Space Station. So many strong arguments were made to keep the *Space Shuttle* program operational. But finally, Congress and the Administration together made the bold and correct decision that opened the door to the current launch vehicle industry that is indeed the envy of the world.

But the stakes are higher today. The space domain is fully integrated into our society and it a vital component of the strategic defense of this nation. More than any other factor, my greatest concern is assuring that we do not confront a gap in the United States having full productive use of a domestic space station. Should we not have a seamless transition from ISS to a new generation of space stations the entire LEO ecosystem of space transportation services, Earth observation satellites and strong private capital investments in space services, will be in jeopardy.

Fortunately, the lessons learned since the 1990s can serve as a policy guide to this Subcommittee and the Administration. Ironically, this includes not only examining lessons learned from the transition from *Space Shuttle* to the current launch vehicle market, and from our increasing commercialization of the International Space station itself, but also from the late 1990s efforts by American entrepreneurs, including myself, to commercialize the then-aging Russian space station, Mir.

Lessons of Mir and MirCorp

One of the first examples of private capital and American entrepreneurs supporting a core government space program in a robust public private partnership took place not with NASA but within the Russian space community after the fall of the Soviet Union.

During the 1990s the Russian Federation confronted the need to commercialize the core assets of their space program, including the Federal launch vehicle programs and the Mir Space Station. Just as today, the satellite deployment market was far further developed and soon enough U.S. industry stepped up to commercialize the launch vehicles. Lockheed Aerospace participated in the creation of International Launch Services (ILS) which commercially marketed the Russian workhorse launch vehicle, the Proton. And Boeing Aerospace successfully participated in the novel Sea Launch program, which utilized the Russian-Ukrainian Zenit from a mobile platform.

These two efforts showed the international community that private companies and government programs could work together to provide efficiencies and funding. But the space station Mir represented a more uncertain marketplace. No one had ever marketed a human-occupied space station. The Russian government allowed the prime government contractor, RSC Energia, to seek commercial non-Federal markets to maintain the crewed space station. Significant revenue came from the Europeans in the form of guest ESA astronauts, and from NASA from the Shuttle-Mir program as well as smaller levels of income from an increasingly vibrant commercial program of advertising and tourism.

In 1999 Prime Minister Yevgeny Primakov issued a decree formally privatizing the Mir space station, turning ownership from the Russian Federation over to the recently privatized Energia, Russia’s oldest and most respected space organization. Energia turned to international capital, signing a landmark leasing agreement with MirCorp for operating the Mir space station. MirCorp was a company established in Holland, of which I served as the Chief Executive Officer. The

Company was funded by several American investors seeking to transform the station into a fully commercial platform.

In many respects, MirCorp was the industry's first New Space company, funded solely with private capital and ultimately sponsoring the world's first privately funded crew mission of seventy-five days by S.V. Zaletin and A.Yu. Kaleria, during which the Mir was upgraded and cutting edge pharmaceutical drug and materials research was conducted.

Though the company was in the end unsuccessful, I'm proud how the effort to commercially operate the Mir became a critical data point in the evolution of the industry. When MirCorp closed its doors about 2002, it had over $179 million in backlog. Customers in the pipeline included Mark Burnett of the game show *Survivor* and NBC for a game show in space, as well Dennis Tito, the space tourist who later flew to the ISS. Smaller customers included an international government agency and a handful of respects biopharma researchers.

MirCorp was a success in showing that entrepreneurial companies could work with space agencies, both foreign and domestic. Also that private capital could be raised for space station platforms and perhaps most importantly of all, that public excitement could be turned into marketable assets that serve both commercial markets and national policy objectives. MirCorp represented one of the first examples in space exploration of a private company contributing to upkeep and improve a core space program of a national space agency.

It is also important to note that one of the great concerns of all public officials, the loss of key specialized jobs in a given community, never materialized as the Russian space industrial base transferred over to the ISS program.

I witnessed the decline of the Mir station from a productive habitat to a fixer upper. I take away the sobering view that no matter the ability to keep an aging space station in orbit, there comes a time when a vibrant space faring nation like the United States, one not suffering catastrophic budget shortfalls like the post-Soviet Russian Federation, must seek to invest in a new generation of platforms. Over time the laboratory that was the Mir became known more for the repair missions than for the research and exploration. That must never happen to us.

Additionally, as repairs became more numerous, there arose in the Russian space community an entire subset of contractor expertise skilled on repairing an aging station. This may well be wonderful knowledge as we consider voyages to Mars and living on the Lunar surface. But if that will be the role of the ISS a decade from now, then it is even more urgent to establish a new generation of in-space research and manufacturing centers to advance our knowledge base to help us here on Earth before the ISS becomes a repair test bed.

I have no doubt we can keep the ISS functioning for another decade, even longer. But at what price to its core functions? At what price to American leadership as newer stations, from China and Russia and the commercial sector, both domestic and foreign, become centers for cutting edge research, manufacturing and global leadership.

Policy Guidance

Members of this Subcommittee are fortunate that there is far more policy to guide their decisions on when and how to transition from the ISS than two decades ago, when Congress struggled over how to transition from Space Station Freedom to the ISS, next from the *Space Shuttle* program to a commercial marketplace for launch vehicle services and finally, most recently, on how to handle commercial customers onboard the ISS. Those earlier great debates for two great programs ultimately centered on whether continued reliance on NASA and its trusted contractor base could be balanced against a new reliance on entrepreneurial space companies.

Today the answer is known. Programs entrusted to entrepreneurial companies have fared very well. NASA enjoys a well-balanced cargo vehicle program that has moved beyond NASA as the only customer and stimulated the birth of dozens of launch companies backed by private capital where both government agencies and commercial customers are the customers. And the legacy contractors are shifting as well, putting more of their own capital at risk and supporting the smaller, more agile companies in new projects.

NASA deserves praise for taking the first steps towards behaving more as a customer than an operator via the 2008 multi-billion dollar awards to two companies, Orbital Sciences and SpaceX to supply cargo to and from the International Space Station. Many doubted the wisdom of relying on unproven companies to produce unproven launch vehicles. SpaceX was able to transform NASA from a core customer to one customer of many, as proponents hoped. The current valuation of SpaceX, the jobs created and the capital interest is key to the vitality of NASA programs today.

The new public private partnerships have not been limited to human spaceflight programs. For decades, our Earth observation programs utilized expensive large satellites that suffered from key data policy issues. Today, companies like Planet, Spire Global and Maxar offer commercial capabilities to monitor key environmental resources, track maritime traffic and often provide transparency to opaque international activities.

Consider Spire Global. Launched nine years ago, it is now listed on the New York Stock Exchange with a market cap of about $1.37B (as of market close on 9/17/21) operating out of six offices in four countries, serving a global base of government and commercial customers.

At Nanoracks, we are very proud that we deployed from the ISS, using our own privately financed hardware, the first satellites of both Spire and Planet thus paving the way for their own commercial success and that of the launch vehicle community based on the Cubesat revolution.

Congressional legislation and Administration policies have matured to sufficient degree that Spire is by no means a unique example. The entrepreneurial space industry has the legal, regulatory, technical and capital assuring capability to partner with NASA on smaller commercial space stations dedicated to a variety of commercial needs. Industry requires NASA as a customer, one of many; and NASA needs the new platforms for continuity in LEO services. Additionally, our international allies are, with differing degrees of enthusiasm, prepared to transition from the ISS to the commercial platforms.

Foreign Landscape

The Chinese space station is a competitive and political challenge. I have submitted here a list of our allies who are funding projects on the Tiangong. There is no dispute that in space, when America is present, America leads; but only if we bring all of our policy and political resources to bear. I don't fear cooperation and competition with China on civil and commercial space projects, because the United States has an intangible advantage over China and other competitors, our spirit of innovation and entrepreneurship. But if we are going to be successful in this next stage of space economics, we must be all in and be in it to win.

I am a personal supporter of cooperation with China on civil and commercial programs. Yet I do not believe our community understands how strong a competitor and challenger China is to our civil and commercial leadership. Tiangong has competitive strengths and weaknesses, but for political reasons, a growing number of our allies are signing to utilize the Chinese space station. The answer is not to boycott China or cajole our allies; it is to outcompete as we do best by utilizing the agility and efficiently of the private sector for the sort of next-gen platforms envisioned by NASA CLD.

Lessons Learned, Some Observations:

I understand that others on this panel will be addressing the question of the current and future status of the ISS physical structure, critical components and subsystems. I can say we at Nanoracks have suffered already from necessary unexpected repairs. Some make the headlines and some do not.

On lessons learned and observations allow me to suggest several:

1) When you firmly and clearly know it is time to transition from the ISS, it will be too late to prevent a space station gap;
2) The NASA CLD program embodies most of the lessons the agency has learned on commercialization. It is a well thought out blend of agency requirements balanced against industry investments and policy risks;
3) As with Commercial Crew and Commercial Cargo, having multiple companies is vital to assure continuity of services and growth of the LEO ecosystem;
4) Without a doubt, we will never have a modular LEO space station again. We have learned that one cannot have astronauts exercising on the same platform as advanced thin-wafer research and manufacturing. Looking to the future, the CLD free flyers will be better equipped to meet the needs of differing customers, from NASA to the private sector.
5) The dream of NASA to solve key breakthroughs in biopharma and other critical research areas has yet to be realized. Not on the space shuttle, not on the ISS. The ISS is a political, policy and technical marvel. But the best chance for research breakthroughs relies on utilization of in-space research hardware and best practices based on the decade of ISS utilization. I believe those breakthroughs will be realized but not on the ISS. Just as NASA's dream of routine access to and from space has been realized not on the government owned and operated *Space Shuttle*, but via the private sector.

6) Industry needs more than a Congressional commitment for minimal funding for the CLD program. Guidance is required to NASA to set a date by which NASA, as a customer, transitions to the new platforms. NASA may well use the ISS as a repair test bed or to deploy the modules elsewhere in some non-competitive manner or as raw material for additive manufacturing of new hardware in space. But, at some defined point, as is included in the NASA CLD RFP, the US Government as a customer must utilize the commercial platforms.
7) This year marks the genuine opening of private capital investment for commercial space operations. Companies representing a range of the new commercial space markets have gone public. With this opportunity comes challenges and that could well be the subject of another hearing by this Subcommittee. But it is important to note that the private capital markets are investing in both US and non-US space companies. Industry can, in partnership with NASA and other government agencies, dream and implement great space missions.
8) Space tourism is not the critical ingredient for the future for our commercial space stations. Tourism may be the most exciting publicly, but legislation enacted by Congress and policy put forth by the Executive Branch have paved the way for the LEO ecosystem, of which tourism is one of many sources of revenue. And a stable and growing LEO ecosystem will drive the Lunar commercial landscape.
9) It is clear that the shift to commercial platforms will also mean a shift of jobs from the government to private industry. As with the transition of jobs from the government to the private launch industry, we are seeing companies like Sierra Space, Axiom and Nanoracks hiring from the ISS community.

Conclusions

The challenge to assure a seamless transition is more urgent than when Congress was confronted with the aging *Space Shuttle* program. There is no room for error lest we cede long-held and hard-earned leadership to our adversaries.

These are difficult issues that mix data, policy and emotion. Our choice is clear: either push the ISS modules far beyond the anticipated lifespan or open the door to a new chapter of American leadership that will realize smaller commercial space stations dedicated solely to research and in-space manufacturing or space tourism.

I choose the latter because recent history has shown that multiplicity in space assets is the safest and cost efficient pathway. And that the private sector, working with NASA, produces cost-efficient and reliable results.

Members of the Subcommittee, now is the time for Congress to be all in on the commercialization of low-Earth orbit through NASA's CLD program to ensure there is no space station gap, to ensure the success of American ingenuity and entrepreneurship, and to ensure that no matter who decides to move into LEO with us, that we are leading the way.

The future of LEO is that of private commercial space stations funded with a mix of public and private funding, backed up with the full diplomatic and political force of Congress and the

Administration. Our parent company, Voyager Space, is prepared to invest significant capital in a private space station dedicated to innovative space research. And unlike other NASA programs that depend on commercial practices for efficiencies but are still fundamentally dependent on government funding, the Nanoracks led team is developing a commercial space station that depends on commercial industry for the majority of funding, where. And we are not alone. Industry is ready to lead. I consider the CLD program a pathway to assuring continuation of American leadership in LEO and indeed perhaps of the ISS program itself, with a new generation of cost-efficient hardware which will also continue the ISS tradition of STEM education.

We lack the luxury of our previous challenges. The space domain is today interwoven into the fabric of our society and its continued health is every American's continued health. The lessons learned are clear, we must do all to prevent yet another gap in our basic space capabilities.

With your help Madame Chairwoman and Mr. Ranking Member and all members of the Subcommittee, we will continue to evolve America's core values and ideals into low-earth orbit and beyond.

Addendum – Chinese Space Station Projects

List of selected space science experiment projects for the 1st cycle concerning UN/China cooperation on the utilization of China Space Station
联合国\中国围绕中国空间站应用开展空间科学实验
第一批入选项目清单

No. 序号	Project Title 项目名称	Name of Organization 申请单位	Country of Organization 申请国家	Research Area 研究领域
1	POLAR-2: Gamma-ray burst polarimetry on the CSS POLAR-2: 中国空间站上的伽玛暴偏振探测仪	1. University of Geneva 2. National Centre for Nuclear Research (NCBJ) 3. Max Planck Institute for Extraterrestrial Physics 4. Institute of High Energy Physics, Chinese Academy of Sciences 1.日内瓦大学（瑞士） 2.国家核研究中心（波兰） 3.麦克斯普朗克外层空间物理研究所（德国） 4.中国科学院高能物理研究所（中国）	1. Switzerland 瑞士 2. Poland 波兰 3. Germany 德国 4. China 中国	Astronomy in Space 空间天文学
2	Spectroscopic investigation of nebular gas 星云气体的光谱研究	1. Indian Institute of Astrophysics 2. Institute of Astronomy of the Russian Academy of Sciences (INASAN) 1.印度天体物理研究所（印度） 2.俄罗斯科学院天文研究所（俄罗斯）	1. India 印度 2. Russia 俄罗斯	Astronomy in Space 空间天文学
3	Behavior of partially miscible fluids in microgravity 部分混相流体在微重力下的行为研究	1. Indian Institute of Technology (BHU) 2. University of Brussels 1.印度理工学院（印度） 2.比利时布鲁塞尔自由大学（比利时）	1. India 印度 2. Belgium 比利时	Microgravity Fluid Physics and Combustion 微重力流体物理与燃烧
4	BARIDI SANA - High performance Micro 2-Phase cooling system for space applications 高性能微两相冷却系统的空间应用	1. Sapienza University of Rome 2. Machakos University 3. In Quattro s.r.l., Italy 1.意大利罗马萨皮恩扎大学 2.肯尼亚马查科斯大学 3.意大利 In Quattro s.r.l.公司	1. Italy 意大利 2. Kenya 肯尼亚	Microgravity Fluid Physics and Combustion 微重力流体物理与燃烧
5	Mid infrared platform for Earth observations 中红外地面观测平台	1. National Institute of Astrophysics Optics and Electronics (INAOE) 2. Benemérita Universidad Autónoma de Puebla (BUAP) 1.墨西哥国家天体物理光学电子研究所(墨西哥) 2.普埃布拉自治大学(墨西哥)	Mexico 墨西哥	Earth science in space 地球科学
6	Flame instabilities affected by vortices and acoustic waves (FIAVAW) 受涡流和声波影响的火焰不稳定性研究	1. Tsinghua University 2. The University of Tokyo 1.清华大学 2.东京大学	1. China 中国 2. Japan 日本	Microgravity Fluid Physics and Combustion 微重力流体物理与燃烧
7	Development of multi-junction GaAs solar cells for space applications 用于空间应用的多结 GaAs 太阳能电池的开发	1. National Center for Nanotechnology and Advanced Materials 2. King Abdulaziz city for Science and Technology (KACST) 1.国家纳米技术和先进材料中心(沙特) 2.阿卜杜勒阿齐兹国王科学和技术城(沙特)	Saudi Arabia 沙特	Space Utilization Technology 应用新技术
8	Tumors in space: Signatures of early mutational events due to space-flight conditions on 3D organoid cultures derived from intra-individual healthy and tumor tissue 太空肿瘤: 来自个体内健康和肿瘤组织的 3D 类器官培养物由于空间条件导致的早期突变特征研究	1. Norwegian University of Science and Technology 2. International Space University (ISU) 3. Vrije University Amsterdam 4. Belgium Nuclear Research Centre 1.挪威科技大学（挪威） 2.国际空间大学（法国） 3.阿姆斯特丹自由大学(荷兰) 4.比利时核研究中心（比利时）	1. Norway 挪威 2. France 法国 3.The Netherlands 荷兰 4. Belgium 比利时	Space Life Sciences and Biotechnology 空间生命科学与生物技术
9	Effect of microgravity on the growth and biofilm production of disease-causing bacteria 微重力对致病菌生长和生物膜产生的影响	1. The Mars Society – Peru Chapter 2. The Mars Society - Spain Chapter 1.火星学会秘鲁分会（秘鲁） 2.火星学会西班牙分会（西班牙）	1. Peru 秘鲁 2. Spain 西班牙	Space Life Sciences and Biotechnology 空间生命科学与生物技术