Space Shuttle Program (SSP) Retirement and NASA Transition to the Vision for Space Exploration (VSE)

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Dedication

I dedicate this work to my late father-in-law Robert H. Ham, who was steadfast in his support of continuing education and an unwavering advocate of NASA's continued exploration of space, the final frontier. Also to my lovely wife DeAnn for her encouragement and loving support and sacrifice without which this could not have been possible.

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Abstract

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On January 14, 2004, President George W. Bush announced the Vision for Space Exploration (VSE). The goals of the vision include developing a new generation launch capability while completing assembly of the International Space Station (ISS) and retiring the Space Shuttle by 2010. In support of this goal, the Space Shuttle Program (SSP) initiated evaluation of hardware, infrastructure, and workforce skill mix needed to continue Space Shuttle flights until the projected 2010 retirement. The SSP also studied how NASA will deploy personnel from, and use the facilities of, the SSP to ensure that the Space Shuttle operates safely through its final flight, and to ensure personnel and facilities from the SSP are effectively transitioned to NASA's exploration programs.

NASA funding, like other federal agencies, is affected by various factors including domestic and international political environments, current and emerging technologies available to meet agency goals, and sustainability and potential economic return of federal expenditures. In this paper I will present a retrospective analysis of federal budget allocations to NASA as a percentage of the Federal Budget from years 1958 to 2010 (adjusted to 1979 dollars).

The classic method for calculating net present value (NPV) is not well suited for projecting potential value of future R&D technologies. A quantitative analysis of R&D technologies transferred to private industry will be presented, as well as a description of a method of evaluating their significance will discussed relative to current budgetary considerations will likely for past, current and upcoming funding cycles. The opportunity at hand for NASA's transition from SSP to Constellation in support of the VSE initiative is to advocate their culture as R&D innovators and emphasize the future benefit of increased funding.

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INTRODUCTION

America's space program was officially initiated when President Eisenhower established the National Advisory Committee for Aeronautics (NACA) in 1957 in response to the October 4, 1957 launch of "Sputnik", the first man made satellite, into orbit by the Soviet Union to commemorate the 40th anniversary of their country's Bolshevik revolution. It did not take long for the advisory committee to recognize the importance of our country's being at the forefront of research and technology development and support technological breakthroughs as evidenced by the following quote from the head of the newly formed advisory committee.

"It is of great urgency and importance to our country both from consideration of our prestige as a nation as well as military necessity that this challenge [Sputnik] be met by an energetic program of research and development for the conquest of space.... It is accordingly proposed that the scientific research be the responsibility of a national civilian agency.... NACA is capable, by rapid extension and expansion of its effort, of providing leadership in space technology" – NACA Director Hugh Dryden

Chief among collective motivations compelling broad support to our nations' fledgling space industry were sentiments surrounding the pervasive Cold War atmosphere of competition between systems of government and the ideologies they each represented. The nation's prime concern and focus was not on discussing the economic or commercial justifications for pursuing increased support for research and development but clearly asserting the superiority of capitalism over communism. Money didn't have a role in the conversation because America could not again be perceived to be put in a position of "the follower" or "second place". Manifestations of this competitive atmosphere and struggle for preeminence would be played out throughout the cold war era in athletic competitions, build-up of military capabilities, cultivation of political alliances, and development of institutions and infrastructure to support technological innovators. In addition to considerations of ethnocentric prestige, societal benefits and national security the recognition and strong public advocacy of a policy supporting technological leadership vis-à-vis the space program would prove pivotal in garnering the social, political, and moral justification for allocating the necessary support to facilitate the distribution of the funding for such monumental commitments amid the backdrop of other important issues competing for voice in the conversations leading to prioritization of the myriad considerations leading to perceived global superiority.

Currently, in an atmosphere of overarching economic peril, NASA is challenged with establishing the appropriate framework with which to frame the conversation to justify its priority for an appropriate budget allocation and insure today's ambitious new goals and objectives can be met. Amid concerns surrounding compelling evidence of global climate change, increasing global economic instability, and maintaining national security, in the face of threats coming from, not one opposing superpower as in years past but and endless stream of smaller unaffiliated antagonists, the conversation regarding motivating continued robust support to NASA's research and development capabilities has become one of economics.

In many ways NASA's reputation and past successes as an innovator make such justifications more difficult when the motivating emphasis for sustaining support has shifted so greatly. An expectation that similar future benefits are guaranteed from maintaining support for established NASA research and development programs at a static level detrimentally affect a conversation for increased support to those programs at the levels that correspond to historically levels which resulted in propagation significant progress. However future space endeavors from the perspective of the current economic focus suffer from the shortcomings of characterizing the net present value (NPV) in classical terms.

The following discussion presents a timeline of NASA's budget allocation throughout the years followed by a representation of some noteworthy technology innovations realized as a result of earlier commitments to NASA research and technology. Finally an analysis illustrating the potential shortcomings of a classic Net Present Value (NPV) treatment to frame discussion of potential benefits gleaned from maintaining a robust commitment to the nation's space industry is presented.

NASA FUNDING

The federal governments funding allocated to NASA, and other agencies, is subject to considerations including the political, social, and technical environments prevailing during continuing budget projection cycles. Figure #1 illustrates the percent of the federal budget allocated to NASA from 1958 to a projected 2010 level adjusted to 1979 dollars.

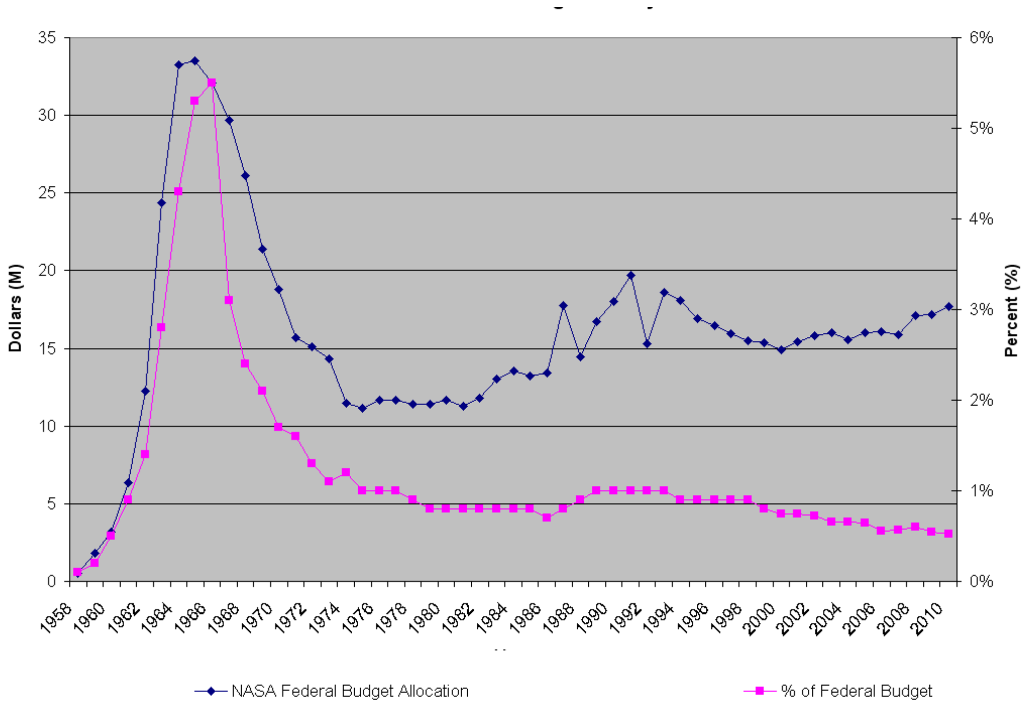

Figure 1: NASA Budget Allocation (1974 adjusted dollars)

Not surprisingly the peak of NASA funding was largely motivated by the Sputnik launch and the competitive environment surrounding the race for social, military and ideological superiority with a rival super power.   As a result of the pervasive competitive environment and the perception that the nation's standing in the world hinged on NASA's progress motivated justification of relatively greater commitment of funding despite concerns with domestic unrest surrounding the country's involvement in conflicts throughout the world. What ensued over the following several years was a heightened awareness of and sensitivity to the country's perceived technological standing in the world. It is likely this unease regarding our country's technological standing spawned and fueled the "space race" marking its highpoint with President John F. Kennedy's May 25, 1961 national address committing the United States' fledgling space program to place a man on the moon by end of the decade. Figure #2

Figure 2: Presidential Announcement of Manned Mission to the Moon

By the May 14, 1973 launch of NASA's first manned space station the 84 ton "Skylab" funding for the nation's space program had been reduced to less than half its mid-1960s zenith. By the July 15, 1975 Apollo / Soyuz rendezvous and the U.S. policy of détente the "space race" and its preferred funding considerations would be a thing of the past. Today's NASA budget contends with pressures from a global recession, continuing involvement in global military actions and a pervasive social unease about the country's precarious position as the world's sole superpower.

The announcement by NASA of a contract award for the new generation launch system, known as the Commercial Orbital Transportation Services (COTS), to service future space exploration beyond the proposed SSP retirement in 2010 signaled a new direction in for our country's space program and was cause for much speculation surrounding the future of NASA's commitment to ISS. It also opened the door to allow for new vehicles as well as systems beyond the Russian's Soyuz and Progress to support ongoing ISS activities and future space exploration.

Historically after announcing a new direction in the development of new space systems, especially man-rated space systems, they routinely experience difficult development and test challenges, which escalate costs, and slip operational schedules. Additionally, funding to support the ISS between the Shuttle retirement and COTS operation, projected for 2015, falls short of the required resources to maintain ISS functionality at its current level thereby potentially inhibiting full utilization of the space station. Even despite NASA's international partner's Japanese (HTV) and European (ATV) vehicles recent certification to augment cargo capability to the ISS in the shortfall may represent a significant impediment to ongoing research aboard the now nearly completed ISS.Figure#3

Figure 3: International Space Station (ISS) Cargo Capable Systems

Reduced federal budget allocations, less clearly articulated mandates surrounding funding commitments to NASA research and operational requirements combined with government initiatives to improve efficiency and shift responsibility to a greater extent to commercial industry systems and practices have effectively accelerated the pace of development of space systems compared to years past. More importantly the accelerating pace is driven by and at the same time hindered with new opportunities in science and technology. Future systems must respond to requirements to deliver higher reliability, greater responsiveness, and the increased need for interoperability yet still comply with well established rigorous certification, verification and acceptance criteria. Additionally these proposed new generation modern systems are being asked to be delivered in less time and at reduced cost to potential taxpayers or private investors[1]

HISTORY AND CULTURE OF NASA TECHNOLOGY COLLABORATIONS

Federal research institutions and collaborating partners comprise a significant portion of the research and development infrastructure and capability in the United States (US). They include large "National Labs" such as The Department of Energy's Los Alamos facility as well as "intramural" federally funded research and development centers which are typically operated by a private firm, non-profit organization or university. An example of one such intramural facility is the NASA funded Jet Propulsion Laboratory operated by The California Institute of Technology. With the Space Act of 1958, Congress gave NASA direction for leading the space program and mandated the newly formed agency to include an emerging industry which was expanding its role supporting the U.S. military industrial complex. When the infrastructure for NASA and collaborating facilities was established careful consideration was given to the social and economic impact such a significant investment would impart to the geographic area surrounding the facilities. More than 40 years later, this partnership—NASA's technology transfer and commercialization program—has generated exciting new technologies in the United States and abroad that positively impact our economy and boost our global competitiveness.[1]

Today, the pace of developing spacecraft systems has greatly accelerated due in part to continued legislation targeting increased technology transfer to amplify the effects of collaborative systems of R&D. Such effects were exemplified when NASA began developing its initial research, operations, and manufacturing capability and targeted areas that not only satisfied requirements for their operational considerations, but targeted areas that would benefit most from the establishment of such significant infrastructure. It was illustrated from those activities that such programs may be used to propagate ancillary growth and stimulate regional and local economies. For example the effect NASA research facilities and the appropriation of funding to motivate universities to respond to a need for highly technical personnel to support a R&D center spawned a metamorphosis in several areas across the country. Within a short period of time areas that had previously been relatively less productive were soon expanding and a variety of industries responded to support the. The potential benefits from the expansion of R&D program are not limited to industry Table#1 illustrates an array of potentially beneficial effects establishment or expansion of technology centers may impart.

Economic	Societal	Strategic
■ **Payment** - $ - trigger - schedule	■ **Environment** - prevention - remediation	■ **Licensor advantage** - competitive - brand
■ **Royalty** - % - basis - schedule	■ **Human life** - saves - physical - mental	■ **Licensee advantage** - competitive - brand
■ **Equity** - % - liquidity - dilution	■ **Job creation** - # - pay - tax impact	■ **National advantage** - competitive - brand
■ **Other** - tax credits	■ **Other** - life quality	■ **Other** - political

Table 1: Benefits of Technology Transfer

ECONOMIC IMPACT OF NASA TECHNOLGY

Economics is “an inquiry into the nature and cause of the wealth of nations”[2], additionally economics analyzes the production, distribution, and use of material goods and services. There is a long history of the use of patents to understand the processes associated with invention, innovation and the social and economic impacts and contributions of technology to a particular field of research.

A patent is a temporary monopoly awarded to and inventor, group of inventors, or institution for the commercial use of a novel invention. For a patent to be granted the invention must be non-trivial, not obvious to a skilled practitioner in the field of the relevant technology and posses utility that represents an appreciable advance in a process or an innovation in technology to a novel or pre-existing body of knowledge, which means that it may have potential commercial value relative to the market pressures prevailing at the time of the patent filing.

When a patent is granted the information, associated with what is contended to distinguish the proposed innovation from the current body of knowledge and distinguish it as novel and not obvious, is publically recorded. The public record details information about the invention, the inventor, and the organization to which the property rights, if any, are assigned is generated and made available for review. Not only is the innovative aspects of a novel process of technology documented in the public record but the technological antecedents of the invention are detailed in the record as well. This progressive accumulation and evolution of ideas propagated by the initial seed of a novel process or technology is oftentimes referred to as a “spin-off”.

Government Research and Development (R&D) dollars are expended to address specific agency goals. Any benefits to private industry beyond the immediate goals or intent are realized via technology transfer and known as a spin off meaning that collaborating universities, companies, or individuals are given the opportunity to license technology which differs from private R&D efforts in that it follows a “push” strategy. Conversely, the “pull” strategy of privately funded research pursuing their goals directly with their own funding sometimes results in a similar flow of technology or processes being incorporated into a federally funded program or spin in.[3] Figure #4

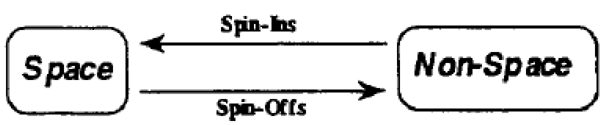

Figure 4: Aerospace Technology Transfer

As these “references” or citations appear in a patent’s public record and the technological descendants of cited inventions are elucidated they may be used to draw inferences about the process of technological transfers, and about the importance of a particular invention.[4] Figure#5 illustrates a historical progression of patent citations referenced by later patent records as a five year moving average.

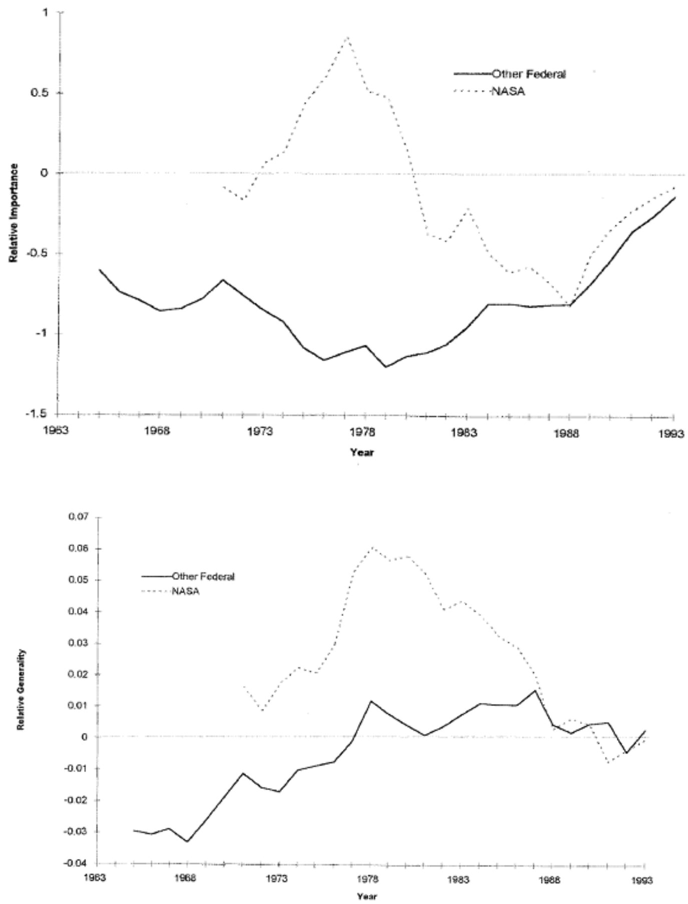

Figure 5: Patent Citations Importance (top) and Generality (bottom)

NASA's technologies have contributed to various areas and can be directly attributed to improvement in general quality of life, public safety, and stimulation of economic growth. Their contributions have yielded innovations in diverse sectors such as Public Health and Medicine, Transportation, and Computer Technology. A few examples of some well recognized examples of NASA spin offs include: development, in the 1970s, of a novel fabric incorporated into astronaut spacesuits which contained Teflon-coated. This same material has been used to improve the insulation characteristics of roofing materials, as well as other useful building materials. In the 1980s the undergarment used in conjunction with an astronaut's spacesuit was equipped with liquid cooled ventilation technology developed by NASA's Ames Research Center in order to provide protection from excessive lunar temperatures that often reached 250°F. It has been used to develop portable cooling systems for treatment of various medical conditions including: burning limb syndrome, multiple sclerosis, and sports injuries and remains one of NASA's most widely recognized spin offs. The 1990s saw a Chicago based company gain nearly half of the market for school bus chassis by incorporating three NASA developed technologies to create a safer more reliable transportation system. They were able to mathematically analyze and design and advanced chassis which holds up better under stress. By 2001 the first complete robotic surgical operation was performed using an innovative medical device known as AESOP (Automated Endoscopic System for Optimal Positioning), which holds a surgical instrument known as a laparoscope and manipulates it using a controller operated by the surgeon. NASA technologies that have been spun off and resulted in a benefit to private industry are literally too numerous to list and assigning a monetary, social, or political value to these innovations is also a daunting task.

ECONOMIC MEASURE OF RETURN ON INVESTMENT (RIO)

The argument NASA is now challenged with having to deal with an environment where the U.S. is the sole “superpower” and emphasis has shifted from asserting global dominance through heated competition in sport, technology and social arenas for ideological purposes and to a classic discussion of economics and return on investment (RIO) Stated simply RIO =(net benefits/total cost) and is a calculation of the “attractiveness” of an investment stated in terms of the tangible financial gains expected to be received from an investment versus the cost of implementation[5].

The calculation techniques for ascertaining cost versus benefit aimed at choosing one project as opposed to another involves determining the net present value (NPV) of a dollar under current market conditions and making estimates regarding how to discount future dollars appropriately so that each set of potential cash flows associated with the costs (C) and benefits (B) generated by the projects being weighed or NPV=PV(C)-PV (B).are appropriately understood and articulated. This classic treatment applied to potential contributions from future NASA developed technologies is not as reliable a measure as when applied to a more straightforward analysis.

An inherent disadvantage of using NPV analysis to establish the ROI of potential benefits surrounding long-term research and development payoffs is their sensitivity to discount rate. The nature of NASA projects is that they are long term and precipitate technology returns so diffuse, as illustrated by Figure 6 , the associated risk of uncertainty is greater relative to, for example, a large

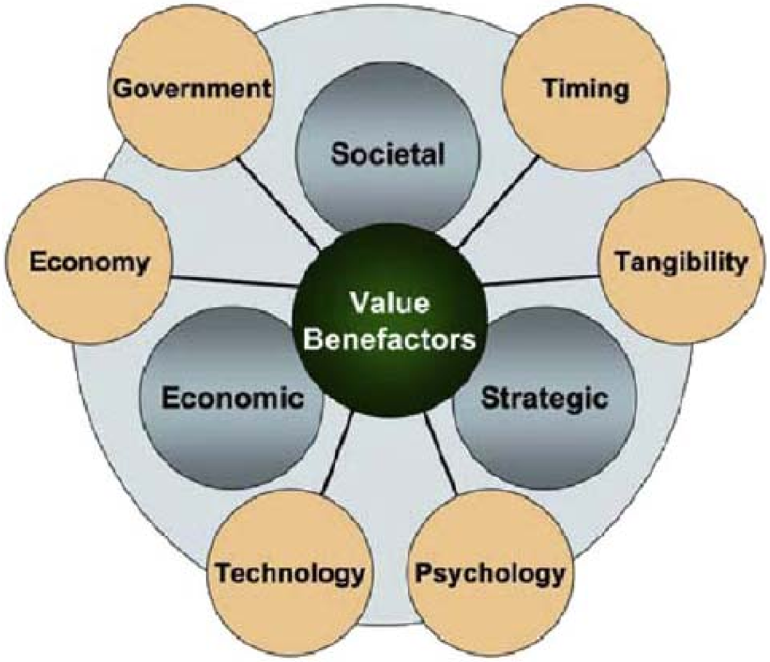

Figure 6: Value Elements, Benefactors, and Value Influencing Forces

construction project. The NPV calculations are basically a summation of multiple discounted cash flows and are sensitive to the discount rate assigned. Additionally, the unique NASA culture of cultivating innovative technologies derived from the challenges presented by exploring truly unknown worlds does not lend itself to easy projections such projections because the level of risk of the investment likely will not be constant throughout the life cycle of the project.

It is these ambiguities associated with establishing NPV and ROI on NASA research and technology projects that make future developments and their potential contributions difficult to crystallize into a coherent justification for allocation of funding. Finally an additional shortcoming of NPV analysis is that it does not consider the magnitude of projects being scrutinized which doesn't correspond well to discussions surrounding the large initial costs of implementing forays into the unknown weighed against allocating resources to challenges that are more easily characterized and therefore possibly perceived as being a better understood alternative.

RECOMMENDATION

NASA needs to address and confront challenges surrounding framing a conversation of what future commitment our nation may be willing to commit to despite shortcomings presented by discussing potential returns of developing intellectual property which does not lend itself well to characterization in economic terms, an approach that bridges the gap between the applicability of economic valuation techniques and the realities of technology valuation opportunities[6]. One optimistic direction NASA should cultivate, incorporate and emphasize in articulating their future R&D funding needs is the fact that the cumulative discounted cash flows associated with and NPV treatment for a particular project do not provide a mechanism to evaluate potential augmentative effects that NASA R&D commitments in the past have reliably displayed.

The unique nature and structure of NASA's research and development collaborations leverage technology transfer opportunities to private industry and bridge a gap to effectively broaden the scope of future benefits. The direct contribution of establishing or augmenting a technology center is realized at the local, regional and potentially global level and is augmented by the ripple effect of additional technical personnel being required in immediate proximity which motivates ancillary stimulus to surrounding educational institutions required to maintain and grow a technical workforce. The additional housing and services required to support an influx of workers supporting an R&D center provide additional economic advantage that may not be elucidated in an initial straightforward NPV analysis.Figure#7 Furthermore, the political ramifications surrounding demographic changes described inherently alter the dynamic of the conversation surrounding the funding conversation. Factors such as tax revenues, local, state, and national representation can potentially be altered from these type investments.

Figure 7: NASA Technology Transfer Augmentation Effect

An additional aspect that needs to be brought into the valuation discussion of technological potential and advances is that a significant portion of past innovations that are now recognized as well established technological contributions would have been missed in a classic valuation exercise because their antecedents were only just emerging during initial discussions. Many daunting challenges mentioned earlier that now face our nation and the world may be overcome or, at least, provided alternate avenues of being addressed by future technological spin offs and advances. One example of such potential advances considers "thin film" solar collecting cells that may one day be combined with innovations in microwave transmission technology and provide a clean energy production capability from space generating and transmitting power to collection sites that could be constructed throughout the world. A capability such as that would affect positive change on various well recognized local, regional and global problems facing society.

The broad ranging applicability and potential benefit to such a large cross section of society again emphasizes how difficult it is for NASA to articulate an economic value for continued support for their R&D programs. However focusing on NASA's unique culture and how it has led to a record of reliable innovation and advancement of technologies benefiting a wide cross section of society is a strength that few other competitors could offer up in considering ROI. The very diffuse nature and broad applicability of potential future NASA technologies can make it an attractive consideration for sustained or expanded support even within a context of an economic conversation prevailing in the current framework surrounding allocation of scarce global resources in the face of so many daunting challenges.

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Vita

Carlos Joel Reyes was born in Santa Fe, New Mexico on March 6, 1963, the son of Cora Reyes and Jose F. Reyes. After completing his work at J. Frank Dobie High School, Houston, Texas, in 1981, he entered The University of Houston where he received the degree of Bachelor of Science in May, 1988 and subsequently a Master of Science in May 1991 from the School of Science and Computer Engineering (SCE). During the following years he was employed as a NASA contractor at Johnson Space Center (JSC), Houston TX in various science and engineering capacities. Currently he is employed as an Engineering Manager by Hamilton Sundstrand in support of JSC's engineering directorate's robotics division (ER3). In September, 2007, he entered the Graduate School at the University of Texas at Austin.

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