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Analysis of Potential Alternatives to Reduce NASA's Cost of Human Access to Space

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Executive Summary: Reducing NASA's Cost of Human-Access to Space

NASA's strategic plan calls for "a renewed focus on scientific research and the development and application of new cutting-edge technologies." In light of the prospects of flat-to-declining agency budgets, NASA must re-allocate its limited resources to focus on its unique core competencies (such as the development of advanced space technologies) and transition operating activities, where possible, to the private sector. NASA should migrate to the role of "customer" for these operating activities from its present role as "owner/operator."

The Shuttle program consumes the largest portion, approximately one fourth, of NASA's total annual budget. The Shuttle is critical to the success of each of NASA's strategic enterprises and creates a thread of interdependencies throughout the agency. Clearly, NASA's ability to effectively implement its strategic plan will be a direct function of its ability to significantly reduce the cost of human access to space.

The key to NASA's success in significantly reducing launch costs over the long-term is the active involvement of the private sector in a substantive risk-sharing role. The effective introduction of private-sector incentives and disciplines, which are driven by the profit motive, is achieved only through the assumption of risk by the private sector.

There are several potential options for NASA to evaluate in considering how to reduce the cost of human access to space. HKA recommends that NASA pursue the Combination Approach, a hybrid approach based on the following assertions: (i) NASA must continue to operate the Shuttle until a proven low-cost alternative for human access to space emerges; (ii) a new human-rated RLV, developed by the private-sector with limited NASA support, represents the best long-term solution to reducing costs; and, (iii) transferring an underutilized Shuttle to a credible private-sector entity may generate valuable commercialization momentum for NASA by creating near-term market awareness of the commercial potential of space and human-rated RLVs.

HKA recommends the Combination Approach for the following reasons:

- The Shuttle's inherently high cost structure prevents it from competing in the commercial market, thereby making it unattractive to the private sector.
- The Shuttle Upgrade will not generate meaningful long-term launch-cost savings.
- The next generation human-rated launch vehicle should be developed, owned and operated by the private sector with commercial-market needs in mind, and NASA as one customer among many.
- Given that NASA's need for a human-rated launch vehicle is currently inconsistent with the commercial market demand for low-cost satellite-launch systems, NASA needs to enable the development of a vehicle that meets both needs cost-effectively.
- Significant private-sector risk sharing will best assure that the new RLV project delivers on its projected costs and capabilities.
- Even if the new human-rated RLV effort does not succeed, the NASA/private-sector research and development efforts can reasonably be expected to have at least accelerated the eventual development of such a vehicle.

Our analysis suggests that the potential benefits to NASA of the new human-rated RLV more than justify its investment in the project, but they can only be achieved through active private-sector participation—NASA will not be able to realize such benefits by undertaking this project on its own. Risk-sharing with the private-sector is far more critical to the success of the new human-rated RLV project than the resources, technical, financial or otherwise, that NASA can commit.

Exhibit I. HKA Background/Summary

HAWTHORNE, KRAUSS & ASSOCIATES, LLC

The Firm

Hawthorne, Krauss & Associates, a financial advisory firm, was formed in October 1997 by the former senior finance officers of Continental Cablevision, Inc. (recently re-named MediaOne), one of the largest cable television operators in the world. The firm's mission is to enable and support the client's competitive strategies by balancing cost, risk and flexibility in its capital structure. The firm draws from the experience of its principals as corporate finance practitioners to assist in developing financial strategy and tactics including sequencing, structuring and executing financial transactions. Due to the experience of its principals, the firm can add unique value in non-investment-grade, cash-flow-driven businesses, leveraged finance and project finance.

The Principals

The firm's principals are Nancy Hawthorne, Continental's longtime Executive Vice President and Chief Financial Officer; Eric Krauss, its Senior Vice President and Treasurer; and Ben Gomez and Larry Christofori, both its Assistant Treasurers. Each member of the team has several years of experience in corporate lending, and collectively the team has over 45 years of experience in the area of highly structured, leveraged financing. See page 3 for more detailed biographies of the principals.

Hawthorne, Krauss & Associates' principals worked as a team to successfully guide Continental, a highly leveraged $2 billion revenue company, through several capital-markets cycles, providing the necessary foundation for the business to aggressively create shareholder value. This team has direct experience in domestic and international transactions; public- and private-market transactions; equity, senior and subordinated debt issuances; project financings, asset-based financings and parent-company financings. The team has also executed numerous mergers and acquisitions, including the acquisition of the Providence Journal Company's cable television assets by Continental for approximately $1.4 billion and the $11.5 billion merger of Continental with U S WEST, Inc. In addition, the team has experience in creating and managing relationships with a diverse set of financial resources including commercial and investment banks, equity investors and analysts, bond investors and analysts, and the rating agencies.

Over the last three years alone, this team financed the following for Continental:

- over $2 billion in acquisitions of domestic cable television properties,
- over $700 million in domestic and international investments in broadband services and related technologies, and
- over $900 million in capital expenditures.

Exhibit I. HKA Background/Summary

Representative Engagements

- We advised a U.S. government agency on capital-markets aspects of various privatization/commercialization options for certain of its operations.
- In partnership with a New York-based investment bank, we advised a Brazilian consortium on structuring and financing bids for cable television franchises in several Brazilian cities.
- We assisted a major domestic telecommunications provider in structuring and closing the divestiture of its major Latin American affiliate.
- We advised a Massachusetts-based telecommunications company in developing a business plan which was used in the sale of the company to a large national telecommunications company.
- We assisted a New York-based investment firm in evaluating an investment in the cable-television industry.

Biographies of Principals

Nancy Hawthorne, CEO & Managing Partner

Nancy Hawthorne joined Continental in 1982 as Treasurer, after several years in media lending at Citibank. She became Chief Financial Officer in 1992. During her career at Continental, Ms. Hawthorne was the principal architect of the financial strategies that fueled Continental's growth from a $100 million regional cable television company to a $2 billion global telecommunications company.

She is a graduate of Wellesley College and Harvard Business School, and serves on the boards of Avid Technology, Commercial Union Insurance Company, New England Zenith Fund and Perini Corporation. Her not-for-profit interests include acting as Vice Chair of the New England Medical Center board and as a board member and Finance Chair of the Wellesley College Centers for Women. She was elected to the YWCA Academy of Women Achievers in 1996.

Eric Krauss, Senior Partner

Eric Krauss served as Continental's Senior Vice President and Treasurer until 1997. He joined the company as Assistant Treasurer in 1990, after several years in media and communications lending at Bank of Boston. During his career at Continental, Mr. Krauss played a key role in the development of Continental's financial strategies and was principally responsible for the execution of a myriad of financial transactions over a period in which Continental raised more than $9 billion in debt and equity funding and made more than $2 billion in asset acquisitions.

Mr. Krauss is a graduate of Dartmouth College. He is a member of the Treasurers' Club and the Financial Executives Institute. His not-for-profit interests include City Year, a national youth community service organization.

Ben Gomez, Partner

Ben Gomez was a lender in the Bank of New York's Communications, Entertainment and Publishing Division before joining Continental in 1994 as Assistant Treasurer. Mr. Gomez played a key role in the development and execution of Continental's financial strategy and was primarily responsible for several of the company's financings, including those in Latin America. He is a graduate of Georgetown University's School of Foreign Service and Columbia Business School.

Larry Christofori, Partner

Larry Christofori joined Continental as Assistant Treasurer in 1994 from Bank of Boston, where he spent five years in Specialized Finance, focusing on structured transportation transactions, including leveraged buy-outs and asset-based financings. Mr. Christofori played a key role in the development and execution of Continental's financial strategy and was primarily responsible for several of the company's financings, including those in Australia and for PRIMESTAR, the company's investment in direct broadcast satellite technology. He is a graduate of Wesleyan University and the Fuqua School of Business at Duke University.

The purpose of this report is to analyze NASA's potential options for significantly reducing the cost of human access to space. The opinions expressed in this report are based on Hawthorne, Krauss & Associates' ("HKA") interaction with NASA and several of its key contractors over the past nine months (See Exhibit I. for a background/summary of HKA). This report is not intended to be an exhaustive quantitative analysis of the various options available to NASA. Instead, its purpose is to outline key decision-related issues that the agency should consider prior to making a decision as to which option to pursue. This report attempts to bring a private-sector perspective to bear on the issue of reducing the cost of human access to space. HKA believes that the key to NASA's success in reducing those costs over the long-term is the involvement of the private-sector in an active risk-sharing role. The introduction of private-sector incentives and disciplines-- which is achieved only through the assumption of risk by the private sector, not through a traditional contractor relationship-- is essential to achieve significant long-term cost reductions.

I. Introduction

One of NASA's key strategic objectives is to significantly reduce the cost of human access to space over the long-term. Launch cost reductions would have wide-ranging implications for the agency due to:

- NASA's limited resources, driven by the prospect of flat to decreasing agency budgets in the future;
- NASA's numerous human space flight mission objectives related to servicing the International Space Station ("ISS");
- NASA's underlying objective of transitioning its resources away from operating activities and toward research and development;
- NASA's goal of encouraging private-sector development and operation of the next generation human-rated launch vehicle;
- NASA's goal of commercializing numerous operating activities, including the ISS; and
- the strong interdependencies among NASA's major programs, due largely to their reliance on launch services.

The extent to which NASA can reduce its cost of human access to space will have a significant impact on all of its major programs and will shape its future well into the next century.

II. NASA's Available Options

It seems clear that NASA will rely on the Shuttle over the next several years to complete the launch and assembly of the ISS. The question, therefore, is what options are available to NASA to reduce the cost of human access to low-earth orbit ("LEO") over the long-term? Potential options include:

- **Existing Shuttle:** Continue to operate the current Shuttle, undertaking non-discretionary upgrades to maintain safety and reliability.
- **Shuttle Upgrade:** Invest in a major Shuttle upgrade, including the development of liquid fly-back boosters ("LFBBs").
- **Shuttle-to-Private Sector:** Transfer one or more Shuttles to private-sector ownership and operation.
- **New Human-Rated RLV:** Invest in the development of a full-scale, human-rated reusable launch vehicle ("RLV") as a follow-on to the existing X-33 project.
- **Alternative RLV:** Invest in alternative RLV technologies (Kistler, Kelly, etc.) which may not necessarily fulfill NASA's mission objectives, including human access to space and servicing the ISS.
- **Combination Approach:** Pursue a carefully managed and structured approach to the New Human-Rated RLV option while operating the Existing Shuttle until such New Human-Rated RLV is fully operable. In addition, the agency would explore opportunities to promote market-driven commercialization efforts in its existing operations, such as the Shuttle-to-Private Sector option, so long as they did not compromise NASA's mission objectives or the development of the New Human-Rated RLV.

III. Evaluation of NASA's Available Options

Existing Shuttle: Continue to operate the current Shuttle, undertaking non-discretionary upgrades to maintain safety and reliability.

Pros

- Capable of meeting NASA's human space flight mission objectives
- Reliability and capability are proven
- ISS launch and assembly requires Shuttle's unique capabilities
- Likely to get agency support since it represents business as usual

Cons

- High cost of Shuttle precludes private-sector involvement as owner/operator (i.e. without subsidies)
- Operating activity which absorbs significant budget resources, potentially at the expense of research and development efforts
- Aging asset which may compromise future safety and reliability
- Currently can not carry commercial payloads on a cost-effective basis
- Limited flight rate capability with increases in flight rates (greater than 11-12 annually) requiring significant investment in major upgrades and infrastructure
- Unique capabilities of Shuttle (i.e. human/cargo interaction) may be in less demand post-ISS assembly

Analysis of Existing-Shuttle Option

The Shuttle has proven both its capabilities and reliability, however, the cost of operating the Shuttle consumes a large portion of NASA's resources, which is problematic in an era of flat to declining agency budgets. In addition, continuing to operate the existing Shuttle does not represent an effective way for NASA to reduce its future launch costs while meeting its mission objectives.

NASA's existing human space flight operations depend entirely on the Shuttle**.** The bulk of the Shuttle's missions over the next several years are dedicated to the launch and assembly of the ISS, an activity for which the Shuttle is uniquely qualified due to its heavy-lift capabilities and its capacity for human/cargo interaction. Post-assembly, ISS missions are unlikely to require these unique capabilities to such an extent, and several launch providers may be capable of accomplishing certain of them (such as re-supply missions, for example). In this environment, cost should be a significant consideration in choosing a launch provider, and, thus, the Shuttle's extremely high cost structure is likely to make it unattractive relative to NASA's other potential options.

Given that NASA's goal as an agency is to further science and exploration through cutting-edge research and development, it seems clear that NASA should seek to reduce the substantial portion of its budget that is primarily operational. A reasonable path for doing this would be to commercialize the Shuttle by seeking to have the private sector own and operate the Shuttle (much like expendable launch vehicles ("ELVs") are handled today). This transition to the private sector would result in cost reductions as well as the potential creation of new markets as the private sector seeks to generate additional revenue streams for human-rated RLV services.

Unfortunately, the private sector has no interest in owning and operating the Shuttle, absent government subsidization, for the reasons cited below. The Shuttle is currently restricted by law from carrying commercial payloads. Even if this law were to change, it is unlikely that the Shuttle's high cost structure would enable it to compete effectively in the commercial launch industry. The Shuttle, with an average cost per flight of roughly $300 million[*]**,** is not cost competitive with existing private- sector ELVs and RLVs and, in all likelihood, will not be cost competitive with future ELVs and RLVs. The Shuttle program has high fixed costs, which are a function of the nature of its activities and a lack of market-driven, private-sector incentives and disciplines. NASA has historically operated the Shuttle giving priority to safety, reliability and mission objectives but not to cost. The Shuttle's cost structure and associated bureaucracy do not encourage private-sector involvement other than in a contractor role or with the benefit of government subsidies. Additional private-sector involvement in the operations of and/or technology upgrades to the Shuttle could yield some operating cost savings. However, any cost savings generated (through private-sector operations, upgrading the Shuttle or both) are likely to be insufficient to enable the Shuttle to operate as a viable stand-alone commercial asset.

In addition, the private sector has focused a significant amount of its own resources on creating reliable, low-cost launch vehicles to meet the booming launch demand of the commercial satellite market. As a result, absent sizeable NASA subsidies and expensive upgrades, the Shuttle is not positioned to compete effectively in this market. There may be some limited opportunities for the Shuttle to carry commercial payloads assuming the law changes, demand for launches exceeds supply (which may be the case today but not likely in the future since the private sector will find a way to meet the demand), or the commercial missions require Shuttle-specific capabilities.

[*] **Based on NASA assumptions of a $2.4 billion annual LEO-transportation budget and 8 flights per year ($2.4 billion divided by 8 flights = $300 million per flight).**

As a result, NASA does not currently have a true commercialization alternative for the Shuttle. This may change in the future if new, more lucrative markets develop for Shuttle's unique capabilities, if significant cost reductions can be achieved through technology breakthroughs or through a combination of both.

Shuttle Upgrade: Invest in a major Shuttle upgrade, including the development of LFBBs.

Pros

- Projected to result in increased flight safety and reliability, higher flight rates and lower launch costs

- Projected to increase payload capabilities to all planned orbits

- Projected to provide first-stage heavy-lift capability (without orbiter) for potential Lunar/Mars missions

Cons

- Upgrades are expensive, with LFBBs estimated to cost in excess of $5 billion

- Keeps NASA actively involved and potentially further entrenched in an operating activity

    - Private-sector is not incentivized to aggressively reduce costs or create new markets
    - Upgrade process is more likely to experience cost overruns and project delays than if Shuttle were a private-sector asset subject to rigid risk/return parameters
    - The lack of a commercialization opportunity limits private-sector involvement in Shuttle upgrade to a contractor role

- Increased flight rate may require additional infrastructure investment in excess of $1 billion

- Shuttle not necessarily competitive from a full-cost or flight frequency perspective after upgrade

Analysis of Shuttle-Upgrade Option

Upgrading the Shuttle does not represent an effective means for NASA to reduce its long-term costs of human access to space. NASA anticipates that a major upgrade of the Shuttle, which includes LFBBs, would, among other things, reduce launch costs, yielding NASA an estimated $400 million to $500 million in annual cost savings.

The cost savings would not be generated without a significant up-front investment: the upgrade is estimated to cost in excess of $5 billion. Another $1 billion would likely be required for infrastructure upgrades if the annual flight rate were to exceed 12 per year. As mentioned earlier, the private sector is not interested in owning and operating the current Shuttle due to its high cost and limited revenue potential. The Shuttle upgrade, if successful, would improve Shuttle's cost structure and revenue potential; however, not to the extent that it would be competitive with other launch service providers. Thus, the upgrade does not encourage private-sector involvement other than as a contractor. For instance, United Space Alliance ("USA"), a private-sector contractor which performs Shuttle-operating and processing services for NASA, has expressed no interest in participating in the upgrade investment. This inability to actively incorporate private-sector disciplines and incentives in the Shuttle upgrade raises the risk that the upgrade will not be completed in a timely and cost-efficient manner, further reducing any potential benefit to NASA.

Significant launch cost savings can be generated only if the private sector owns and operates the launch vehicles. As mentioned earlier, the private sector is not interested in investing in the current or upgraded Shuttle due to the high cost structure. NASA's desire and/or need for some level of operating control and supervision further reduces the private sector's interest in any Shuttle-commercialization process. There may be a role for NASA to subsidize the private sector's ownership and operation of the current or upgraded Shuttle for a period of time until new market opportunities emerge. However, it is highly unlikely that any future private-sector, stand-alone scenario would involve the current or upgraded Shuttle, but rather, a new more cost-efficient launch vehicle.

Shuttle-to-Private Sector: Transfer one or more Shuttles to private-sector ownership and operation.

Pros

- Encourages private-sector ownership and operation of a reusable launch vehicle
- Can be implemented over the near-term
- Demonstrates commercial-market applications for human-rated RLVs
- Could increase awareness of the benefits of commercial research in space, which would benefit both the Shuttle and ISS
- Reduces NASA's cost of maintaining a fourth Shuttle for which it appears to have limited use over the next several years
- NASA/US government could benefit financially from an asset "sale" to the private sector

- Potential to demonstrate the merits of private-sector disciplines and incentives, which may yield benefits to NASA

- Potential lower-cost provider of a portion of Shuttle services to NASA in the future

- Potential catalyst in moving NASA out of Shuttle-ownership role over the long-term

Cons

- NASA would have to subsidize the private sector by providing launch-related services to the private-sector owner/operator on a "direct and incremental cost" basis as opposed to on a "full-cost" basis

- NASA likely to have to subsidize the purchase price of the asset

- Potential near-term cost reductions to NASA may be minimal

- Potential long-term benefit to NASA is unclear and highly speculative – may not materially reduce NASA's operating costs

- Potential to increase accident risk if private sector does not operate Shuttle as safely as it is currently operated

- Could discourage other private-sector RLV initiatives if NASA subsidizes private-sector commercialization efforts

- Lack of availability of a Shuttle as a back-up could potentially compromise ISS launch and assembly schedule

Analysis of Shuttle-to-Private-Sector Option

The Shuttle-to-Private Sector alternative has the potential to increase awareness of the potential commercial benefits of human-rated RLVs. There are several critical issues to consider in evaluating this alternative: (i) the extent to which NASA would have to subsidize the private sector by providing certain launch- and mission-related services on a purely direct and incremental cost basis (i.e. not on a full cost basis); (ii) the extent to which NASA would have to subsidize the private sector's purchase of the asset; (iii) the potential benefits of applying private-sector disciplines and incentives to Shuttle operations; and (iv) the private sector's ability and willingness to create new commercial markets and revenue streams for human-rated RLVs. These interrelated issues are of particular importance because, while the Shuttle has proven in the past that it can effectively deploy commercial payloads from a functional perspective, it has not proven that it can do so on a cost-effective basis.

On the issue of subsidization, it is instructive to note that in the mid-1980's NASA transferred ownership of certain government-developed ELV systems to the private sector without recovering any costs. By law, the US ELV-launch industry currently receives launch-related services from the US government on a "direct and incremental cost" basis. Since these ELV companies would likely be the primary competitors of a "commercialized" Shuttle, a "level playing field" approach would dictate a similar level of subsidy to a private-sector entity who assumed the risk of owning and operating a Shuttle on a commercial basis. None of the parties we spoke with provided us with any data regarding the amount of such "acceptable" subsidies relative to the per-launch cost of a commercialized Shuttle, so we are unable to predict whether this factor would have a material impact on our analysis of this option.

Given the accelerating growth of commercial satellite systems, the Shuttle is a potentially attractive launch vehicle in a market where demand for such services is expected to exceed supply for the foreseeable future. Therefore, if the Shuttle were able to provide satellite launch services at a market competitive price, it is not unreasonable to assume that the Shuttle would be able to capture some portion of the satellite launch market. Assuming a competitive satellite launch price of $200 million per launch and a current cost per launch of approximately $300 million, the private-sector would have to find a way to reduce, at a minimum, the current cost per launch by approximately $100 million (33%), either through direct operating cost reductions and/or cost subsidies (with a heavy reliance on the latter). Whether this can be achieved is unclear. If, however, a credible private-sector business plan is proposed, NASA should take the following into account when reviewing it:

- ***NASA Long-Term Objectives.*** Transferring a Shuttle to the private sector is consistent with NASA's objective of transitioning away from operating activities in order to focus on research and development. While such a transfer may not directly reduce NASA's launch costs in the near-term it would, if successful, lend significant credibility to NASA's objective of transitioning out of operating activities and demonstrate the commercial-market potential for a human-rated RLV. In the least, the transfer of a Shuttle from NASA to the private sector would represent a very strong and significant statement regarding the direction in which NASA is heading with regard to allocating its limited budget resources.

- ***Potential Short- and Long-Term Cost Reductions***. The transfer of a Shuttle to the private sector could generate short-term cost savings in the form of reduced maintenance costs for a fourth Shuttle. In addition, proceeds from the outright sale of a Shuttle to the private sector could have a positive direct or indirect effect on NASA's budget. Finally, the possibility exists that the transfer of a Shuttle to the private sector, if successful, could ultimately result in NASA being out of the Shuttle-ownership role entirely over the long-term, positioning the agency as a "purchaser" of Shuttle services from the private sector, similar to the ELV situation today.

While there are merits to the transfer of a Shuttle to the private sector, they are not without risk. Several risks to consider in connection with the transfer of a Shuttle to the private sector are outlined below:

- ***Performance.*** The private sector's need to operate profitably by optimizing revenues and costs has the potential to increase the risk of a Shuttle accident. While NASA's focus is on risk minimization, not cost minimization, it is possible the private sector might make tradeoffs between risk and cost that differ from those of NASA. The residual effects of a private-sector Shuttle accident may be unacceptable to NASA. However, the profit motive combined with an appropriate level of risk sharing on the part of the private sector should be a strong incentive to fly safely. In addition, NASA could ameliorate this risk by providing an oversight function.

- ***Cost Subsidies and Logistics.*** The private sector would likely require a subsidy from NASA in the form of purchasing launch- and mission-related services on a purely direct and incremental cost basis. This may be acceptable provided there is a balance between incentives and risk sharing. The NASA subsidy should be structured so that the private-sector is motivated to actively create new commercial markets and revenue streams for human-rated RLVs, while retaining a sufficient level of downside risk to ensure safe operation of the Shuttle.

  In addition, this option presents a potential logistics issue: (i) NASA's own flight rate is increasing over the next several years in connection with ISS launch and assembly; and (ii) the transfer of a Shuttle to the private sector could leave NASA without a back-up Shuttle should problems arise with its remaining Shuttles. As a result, it is possible that the amount and duration of such a subsidy together with ISS logistics may make a transfer of the Shuttle to the private sector problematic at this time.

- ***Impact on Other Initiatives.*** The transfer of a Shuttle to the private sector may discourage other private-sector RLV initiatives. As a result, it is possible that private-sector ownership and operation of the Shuttle may work directly against NASA's long-term objective of fostering private-sector involvement in reducing the cost of human access to space. However, a Shuttle that has been transferred to the private sector is not likely to fly more than 3-5 times per year.

Any decision involving the transfer of a Shuttle to the private sector will be difficult. In addition, because this option is not likely to be the long-term means by which to achieve NASA's goal of significantly reducing the cost of human access to space over the long-term, NASA should not pursue it if it adversely impacts its ability to achieve such a goal. The key consideration for NASA in making such a decision is to determine whether the potential benefits of private-sector ownership and operation of a Shuttle are outweighed by the potential risks to NASA of taking such a step.

<u>New Human-Rated RLV</u>: Invest in the development of a full-scale, human-rated reusable launch vehicle as a follow-on to the existing X-33 project.

<u>Pros</u>

- Potential order of magnitude reduction in launch costs
- Private-sector development, ownership and operation of next-generation launch vehicle introduces private-sector incentives and disciplines to the process
- Enhanced US competitiveness in the commercial-launch industry
- Increased commercialization of space (through low-cost access to LEO)
  - Reduced ISS access costs and improved opportunities to commercialize ISS operations and utilization
- Developed from the beginning with both NASA and commercial markets in mind
- Currently, no other private-sector initiatives to develop RLVs which meet NASA's human space flight needs
- NASA could benefit even in the event that the project is unsuccessful

<u>Cons</u>

- Large obstacles to be overcome, including significant technology and project-related risk
- New Human-Rated RLV, as currently designed, does not offer the same capabilities as Shuttle
- Private sector is likely to rely on the government for help in funding all or a portion of any potential cost overruns and delays
- Potential lack of competition in bidding process for the X-33 follow-on initiative due to potential consolidation in aerospace industry
- Conflicts of interest exist within NASA as well as Lockheed Martin and Boeing, due to their position as partners in USA and as the largest ELV manufacturers and operators
- Government funding may discourage development of other (non-government funded) RLVs

- Significant government participation/involvement (potentially on a multi-agency basis) may reduce the benefit of private-sector incentives and disciplines

Analysis of New Human-Rated RLV Option

- Given the Shuttle's limited commercialization potential as well as NASA's goal of transitioning resources away from operating activities, it seems clear that NASA needs to pursue a replacement for the Shuttle. Any replacement for the Shuttle needs to consider the lessons of the past in terms of strategy, development, ownership and operation:

- ***Development.*** Systems that are developed predominately for NASA's needs often become very expensive due to the fact that the development process is not market driven and does not incorporate private sector risk-return incentives and disciplines. An example of this is the Shuttle, which was developed specifically for NASA use and, as a result, has a cost structure that prevents it from effectively competing in the commercial satellite launch market. The consequence of Shuttle's failure to be a competitive launch service provider is significant: NASA must continue to be the major customer for Shuttle services and will find it very difficult to offset some of its future funding requirements by generating revenues, or "reimbursable expenses." from multiple "customers." As a result, the Shuttle's operating costs will continue to consume a substantial portion of NASA's resources, which is problematic in an era of flat to declining budgets. In response to this, NASA should seek to facilitate the research and development efforts of those private-sector companies developing launch systems that are most likely to significantly reduce the cost of human access to space.

- ***Ownership.*** Complex new systems developed by the government often run into problems during development, such as cost overruns and significant delays, largely due to the lack of market-driven economic incentives and disciplines. Both Shuttle and ISS are examples of complex projects whose costs and completion dates went significantly beyond their original estimates. This clearly indicates that government ownership should be limited only to those projects the private sector will not undertake on its own. Currently, Shuttle and ISS probably fit that definition; however, the next generation of human-rated launch vehicles may represent an opportunity for private-sector development and ownership.

- ***Operation.*** The private sector has proven that it is better suited to perform operating activities than the government. The key question is: at what point do NASA's "cutting-edge" research and development efforts become operational in nature and appropriate for transitioning to the private sector. At one time, Shuttle operations did represent cutting-edge research and development, however, the Shuttle now appears to have evolved fully into an operating activity.

After ELVs became operational in nature, their ownership and operation shifted from the government to the private sector. The government, as a customer of ELV services, has benefited significantly from that shift. New ELVs are currently being developed and operated by the private sector (this excludes certain E-ELV projects which are not purely private-sector developed), and several private-sector companies are preparing to develop, own and operate non-human-rated RLVs. In addition, we are aware of at least one "piloted" RLV (i.e. human rated, but not necessarily for NASA purposes) that is currently being developed by the private sector and other private sector-entities may develop human-rated RLVs in the future. As a result, it seems unnecessary for NASA to be fully engaged in the ownership and operation of launch vehicle systems. However, there is a role for NASA in the "cutting-edge" research and development stages of these launch vehicle systems, particularly those that address NASA's needs when they may not be consistent with the needs of the commercial market. Moreover, NASA will be a prime beneficiary of these private sector efforts.

Technology Risk

A key issue regarding the New Human-Rated RLV is the technology risk associated with the project. It remains unclear whether a single-stage-to-orbit RLV can be developed at this time. The X-33, if successful, will mitigate some but not all of these risks. In fact, the Lockheed Martin team was chosen to lead the X-33 effort partly due to the fact that its X-33 proposal mitigated greater technology risk than any other proposal. However, even a successful X-33 effort will leave significant technological risks to be overcome prior to the development of a full-scale, human-rated RLV.

The active participation of the private sector in this effort introduces the positive tension of market incentives and disciplines which increases the probability of successfully developing such a vehicle. In a worst-case scenario in which the technological hurdles associated with this project cannot be overcome at this time, this effort alone should generate knowledge that enhances the prospects for developing such a vehicle in the future. Additional momentum for the development of human-rated RLVs is being indirectly generated by the private-sector's investments in launch vehicles (both ELVs and RLVs) to meet the booming demand for launch services by the commercial satellite market as well as potential new commercial markets created by the successful commercial use of the ISS.

Differing Capabilities

There is a significant difference between the capabilities of the Shuttle and the proposed New Human-Rated RLV. The Shuttle provides heavy-lift payload capability together with human interaction (i.e. the ability of the crew to interact with the cargo). The proposed New Human-Rated RLV, while providing heavy-lift capability, does not offer human/cargo interaction. It will carry humans and cargo, but not both simultaneously. The Shuttle has frequently been used as a microgravity research lab, with human interaction being a key component of that process. A key issue to consider is whether, given the availability of the ISS and its microgravity research capabilities, NASA will continue to need to rely as much on Shuttle's human/cargo interaction capabilities. Once the ISS is assembled and operating, NASA's space flight needs will likely focus on supply and re-boost of ISS, services that do not necessarily require Shuttle's unique human/cargo interaction capabilities.

Alternative RLV: Invest in alternative RLV technologies (Kistler, Kelly, etc.) which may not necessarily fulfill NASA's mission objectives, including human access to space and servicing the ISS.

Pros

- Potential to reduce certain launch costs
- May provide interim step in development of New Human-Rated RLV
- Private sector is currently developing technology on its own, and may not need NASA's assistance

Cons

- Does not necessarily meet NASA's current need: low-cost human access to space
- Potential to delay or even pre-empt the development of a new human-rated RLV if cargo-only capabilities satiate commercial-market demand
- Technological risk is still high, though less than that of a human-rated RLV

Analysis of Alternative-RLV Option

The critical issues to consider in evaluating this option are: (i) the value NASA places on having access to a low-cost, human-rated RLV; (ii) the value NASA places on having access to a low-cost, non-human-rated RLV; (iii) the extent to which the development of a low-cost, non-human-rated RLV advances the ultimate development of a low-cost, human-rated RLV; and (iv) the potential for a low-cost human-rated RLV to be developed solely by the private sector. While the development of a low-cost, non-human-rated RLV is attractive to the private sector which sees it as a potential means of capturing a share of the growing satellite launch market, it seems much less attractive to NASA due to the agency's human space flight needs. The long-term attractiveness of the commercial satellite launch market is already sufficient to justify private investment in the development of a non-human-rated RLV, even without NASA involvement. However, there currently does not appear to be sufficient market demand to encourage the private sector to develop, own and operate a human-rated RLV on its own.

Thus, an investment by NASA in the development of a low-cost, non-human-rated RLV seems unnecessary unless it represents a required interim step in the ultimate development of a low-cost, human-rated RLV. If there is no significant correlation between the development of a non-human-rated RLV and a human-rated RLV, then NASA should apply its limited resources elsewhere.

Combination Approach: Pursue a carefully managed and structured approach to the New Human-Rated RLV option while operating the Existing Shuttle until such New Human-Rated RLV is fully operable. In addition, the agency would explore opportunities to promote market-driven commercialization efforts in its existing operations, such as the Shuttle-to-Private Sector option, so long as they did not compromise NASA's mission objectives or the development of the New Human-Rated RLV.

Pros

- Diversifies risk
- Creates sense of competition
- Creates redundancy during development
- Allows for transition to low-cost launch system over time
- Creates private-sector incentives to commercialize space
- Transitions NASA out of operating activities

Cons

- High risk associated with successful development of New Human-Rated RLV

- New Human-Rated RLV will not offer the same integrated capabilities (i.e. human/cargo interaction) as the Shuttle

- Creates additional potential conflicts of interest within NASA, USA, Lockheed Martin, Boeing, Congress and the Administration

- Could discourage other private-sector development of low-cost RLVs due to NASA assistance to New Human-Rated RLV and NASA "subsidy" of Shuttle-to-Private Sector

- Significant government participation/involvement may dilute the benefit of private-sector incentives and disciplines

Analysis of Combination-Approach Option

The Combination Approach is a hybrid approach based on the following assumptions:

- NASA must continue to operate the Shuttle until a viable and proven low-cost alternative for human access to space emerges;

- the New Human-Rated RLV is a viable long-term solution to reducing NASA's cost of human access to space (see Analysis of New Human-Rated RLV Option); and,

- transferring an underutilized Shuttle to a credible private-sector entity is a potentially attractive means by which to generate awareness of the commercial-market potential of space and the capabilities of human-rated RLVs.

The Combination Approach is attractive from a risk-diversification standpoint as it enables NASA to take a multifaceted approach to reducing the cost of human access to space. However, this approach is heavily reliant on the successful development of the New Human-Rated RLV, which is inherently high risk.

IV. Analytical Review

Methodology

We have chosen to rely largely on a net present value approach in analyzing and comparing several of the proposed alternatives to achieve NASA's long-term objective of reducing the cost of human access to space. In this case, "net present value" represents the value, in current dollars, of the net cost savings that these individual alternatives could generate for NASA relative to the current cost of operating the Shuttle (i.e. the higher the net present value the higher the net cost savings to NASA) after taking into account the up-front investment required to generate such cost savings. We have developed this analysis using assumptions based on readily available data and, in some cases, our own "best estimates." The purpose of this analysis is not to provide a precise quantitative representation of each option, but rather, to provide a sense of the magnitude of the potential cost savings these alternatives can achieve as well as a general understanding of the potential "value" of one option relative to another. This analysis is intended purely to be a tool to support the decision-making process, and should be considered along with a range of other factors in arriving at a decision on how to best reduce the cost of human access to space.

Our analysis includes:

- a net present value analysis of the Shuttle Upgrade option relative to the Existing Shuttle option;
- a net present value analysis of the New Human-Rated RLV option (based largely on a recent VentureStar business case) relative to the Existing Shuttle Option;
- a sensitivity analysis of the key variables that impact NASA's potential cost savings.

Since the Existing Shuttle option represents NASA's current Shuttle operations, we have used it as the basis upon which to compare the other potential options which lend themselves to such a comparison. The Alternative RLV option was not comparable to the Existing Shuttle given that it does not appear that it will offer human-rated capabilities.

Key Assumptions

We have derived our assumptions from a variety of sources which include NASA and related parties, the VentureStar program and related parties and, in some cases, our own estimates based on readily available information. The key assumptions which drive our analysis are outlined below along with the primary source for each such assumption:

Existing Shuttle Basic Assumptions	Source [1]
• Annual Shuttle LEO-transportation budget of $2.4 billion remains flat.	NASA
• 8 flights per year for the period 2004-2020.	NASA
• $300 million cost per launch for the first 8 flights in any given year.	NASA
• $90 million cost per launch for Shuttle flights 9 and 10 in any given year.	NASA
• Minimum "safe" flight rate of 5 per year; maximum flight capacity of 10 flights per year	NASA
• Aggregate $1 billion of required upgrades to be made over the four-year period 1999-2003.	NASA

Shuttle Upgrade Basic Assumptions	Source
• $5.2 billion aggregate investment made over the four-year period 1999-2003.	NASA
• 8 flights per year for the period 2004-2020.	NASA
• $240 million cost per flight versus $300 million pre-upgrade (implied annual post-upgrade launch cost savings of $60 million per flight, which, based on 8 flights per year, equals $480 million).	NASA
• $75 million cost per launch for Shuttle flights 9 and 10 in any given year versus $90 million per launch pre-upgrade (additional investment in infrastructure may be required for more than 10 flights per year).	NASA
• Shuttle Upgrade is fully operational beginning in 2004 (assumes no "Shuttle-overlap" flights while Shuttle Upgrade is being qualified as human-rated for NASA purposes).	NASA
• 7% cost of capital.	NASA

New Human-Rated RLV Basic Assumptions [2]	Source
• $1.75 billion aggregate investment made by NASA over the three-year period 1999-2001.	NASA
• A total of 13 NASA "Shuttle-equivalent" flights per year for the period 2006-2020, consisting of 10 ISS-related flights and 3 non-ISS related flights. Given the fact that the New Human-Rated RLV can not fly humans and cargo simultaneously, unlike the Existing Shuttle, it is assumed that the New Human-Rated RLV would have to make 13 flights for every 8 flights made by the Existing Shuttle.	NASA
• $75 million cost per flight for ISS-related missions; $25 million cost per flight for non-ISS cargo-only missions.	VS

(1) NASA = NASA, VS = VentureStar and related parties, HKA = Hawthorne, Krauss & Associates.
(2) New Human-Rated RLV Assumptions are derived in part from a recent VentureStar business plan.

New Human-Rated RLV Basic Assumptions (continued) **Source**

Assumption	Source
• New Human-Rated RLV is fully operational beginning in 2006. In both 2004 and 2005, it is assumed that the New Human-Rated RLV completes 3 non-ISS cargo-only missions at a cost of $25 million per flight. We have also included three additional scenarios (see Appendix II.(a), Appendix II.(b) and Appendix II.(c) under which it is assumed that the New Human-Rated RLV's human-transport capability is delayed beyond 2006).	NASA
• Existing Shuttle is required to make 5 "Shuttle-overlap" flights per year in both 2004 and 2005 at a cost of $440 million per flight while the New Human-Rated RLV is being qualified as human-rated for NASA purposes. Due to the Existing Shuttle program's high operating leverage, the $440 million represents the cost per flight if only 5 flights are made in a given year (versus $300 million per flight if the flight rate is increased to 8 per year).	NASA
• Existing Shuttle is retired after 2005. Shuttle "close-out" costs of $240 million are charged in 2006.	NASA
• 7% cost of capital.	NASA

We have also assumed that NASA would operate the Existing Shuttle and make an aggregate $1 billion of non-discretionary "upgrades" over the four-year period 1999-2003 regardless of whether it pursued the Shuttle Upgrade option or the New Human-Rated RLV option. Therefore, our analyses of Shuttle Upgrade and New Human-Rated RLV do not include the costs associated with operating and upgrading the Shuttle during the period 1999-2003 because it would be the same regardless of which option NASA chooses to pursue.

Because substantially all of our key assumptions have been provided or confirmed by outside sources, including NASA, we believe that our analysis presents a reasonable representation of the relative "value" of each alternative. In addition, we have sought to be as conservative as possible in our assumptions with the intention of understating, rather than overstating, the potential financial implications of each alternative. It should be noted, however, that the underlying data used to derive certain of our assumptions is subject to change frequently and, as a result, this analysis should updated periodically to reflect such changes.

Results

Shuttle Upgrade. Based on the Shuttle Upgrade Basic Assumptions, the Shuttle Upgrade investment yields a projected negative net present value of approximately $931 million (see Appendix I). Therefore, the $60 million of cost savings per launch generated by the Shuttle Upgrade are not sufficient to justify its $5.2 billion up-front cost, assuming a flight rate of 8 per year over the period 2004-2020. In order to justify such an investment, NASA would need to achieve a lower cost per flight, in the $223 million range, a reduction of approximately 7% from the current projection of $240 million per flight for the Shuttle Upgrade.

Furthermore, while increasing the flight rate has the potential to generate additional cost savings for NASA relative to operating the Existing Shuttle, it can not realistically justify the $5.2 billion investment in Shuttle Upgrade from a net present value perspective. For the net present value of the Shuttle Upgrade to be positive (thus, making the $5.2 billion investment justifiable) the flight rate assumption would have to more than double, to approximately 17 flights per year (versus the current assumption of 8 flights per year) over the period 2004-2020. Based on current information, such an increase in the flight rate is unachievable in the foreseeable future. As a result, this option is not an effective means for NASA to reduce the cost of human-access to space over the long-term in order to re-allocate budget dollars to research and development activities.

See Appendix I. for detailed financial analysis of Shuttle Upgrade option.

New Human-Rated RLV. Based on the New Human-Rated RLV Basic Assumptions, the projected net present value of the potential cost savings is approximately $7.4 billion (see Appendix II). More specifically, $7.4 billion represents the current value of the net cost savings that could be achieved by investing $1.75 billion incrementally in the New Human-Rated RLV and flying 13 "Shuttle-equivalent" flights per year over the period 2006-2020, rather than operating the Existing Shuttle at a rate of 8 flights per year over the same time period. Included in this calculation is the assumption that for a period of two years (2004 & 2005) NASA would have to fly both the Existing Shuttle, at a rate of 5 times per year, and the New-Human Rated RLV, at a rate of 3 times per year (non-ISS cargo-only flights at a cost of $25 million per flight), while the New Human-Rated RLV was being "qualified" as a viable human-rated RLV for NASA purposes. If this assumption was excluded from the calculation, and the New Human-Rated RLV was fully human rated in 2004, the net present value of NASA cost savings would be in the $8.5 billion range.

See Appendix II. for detailed financial analysis of New Human-Rated RLV option.

Additional RLV Scenarios. We produced three additional scenarios in which all but two of the New-Human Human-Rated RLV Basic Assumptions were held constant: (i) the date upon which the New-Human Rated RLV was assumed to be fully operable (i.e. capable of human transport) was extended beyond 2006; and therefore (ii) the "Shuttle-overlap" period was extended accordingly. The impact of these changes is outlined below:

	Basic Assumptions	Scenario 1	Scenario 2	Scenario 3
RLV human-transport ready	2006	2007	2009	2011
Shuttle "Overlap" period (1)	2004-2005	2004-2006	2004-2008	2004-2010
NPV of Cost Savings	$7.4 bil	$6.1 bil	$4.2 bil	$2.5 bil
% Decrease vs. Basic Assump	N/A	(17.6%)	(43.2%)	(66.2%)

(1) Scenarios 1, 2 and 3 assume that the New Human-Rated RLV is capable of ISS cargo-only missions beginning in 2005.

Even in the case of Scenario 3, whereby the New Human-Rated RLV's human-transport capability is delayed until 2011, the investment in the New Human-Rated RLV is justifiable with a positive NPV of net cost savings $2.5 billion (assuming a $1.75 billion up-front investment amount and RLV ISS-related launch costs of $75 million per launch).

See Appendix II.(a), Appendix II.(b) and Appendix II.(c) for detailed financial analysis of Additional RLV Scenarios.

Risk-Adjusted Net Cost Savings

The net $7.4 billion of potential net present value of cost savings to NASA from a $1.75 billion investment in the New-Human Rated RLV may not fully reflect the potential risk associated with the project given the technological and project-related hurdles that must be overcome (see "Analysis of New Human-Rated RLV Option"). This risk can be addressed quantitatively by increasing the discount rate used in the net present value calculation, which is a direct function of the risk/return parameters of the project. Our Basic Assumptions assume a discount rate for both the Shuttle Upgrade and New Human-Rated RLV options of 7%, on the basis of NASA's funding costs and the arguably comparable risk levels of each project. While it may be true that the New Human-Rated RLV faces greater technology risk than the Shuttle Upgrade, it may also be true that the New Human-Rated RLV faces less project-management risk (i.e. completion within projected time, cost, performance, etc. parameters), due to its high degree of private-sector involvement relative to the Shuttle Upgrade project.

Thus, the difficulty and subjectivity associated with assessing the overall risk of each project emphasizes the need to understand the potential impact of the discount rate on each project. For example, if we assume that the overall risk associated with the New Human-Rated RLV is higher than that of the Shuttle Upgrade, we can increase the discount rate to reflect the increased level of risk. If we increase the discount rate for the New Human-Rated RLV option to 10.5% from 7% (a 50% increase), the net present value of cost savings for the New Human-Rated RLV decreases by approximately 41%, to approximately $4.4 billion. Similarly, a 14% discount rate (a 100% increase) yields a net present value of approximately $2.5 billion. The "break-even" discount rate (where the net present value of cost savings equals zero) for the New Human-Rated RLV project is approximately 27%.

Similarly, we can sensitize the impact of the discount rate on the Shuttle Upgrade. For example, if we assume that the overall risk associated with the Shuttle Upgrade is lower than that of the New Human-Rated RLV, we can decrease the discount rate to reflect the decreased level of risk. If we reduce the discount rate to 5.25% (a 25% reduction), the net present value of cost savings would be negative ($367 million. The "break-even" discount rate (where the net present value of cost savings equals zero) for the Shuttle Upgrade project is approximately 4.4%.

Given the sensitivity of the discount rate, NASA must fully assess the overall risk associated with the project, which includes both technology risk and project-related risk, before making an investment decision. The sensitivity of the impact of changes in the discount rate on the net present value of cost savings for both the Shuttle Upgrade and New Human-Rated RLV options is demonstrated below:

NPV of Cost Savings ($millions)

		----------------New Human-Rated RLV----------------			
Discount Rate	**Shuttle Upgrade**	**Basic Assumptions**	**Scenario 1**	**Scenario 2**	**Scenario 3**
4.0%	163.0	11,706.5	10,047.5	7,480.5	5,107.2
7.0%	(930.9)	7,423.9	6,147.4	4,221.1	2,538.6
10.0%	(1,558.7)	4,719.5	3,741.2	2,288.1	1,087.2
13.0%	(1,909.3)	2,971.9	2,227.3	1,126.4	264.2
16.0%	(2,092.2)	1,819.3	1,258.8	421.7	(200.4)
19.0%	(2,172.6)	1,045.5	630.7	(7.5)	(458.2)
22.0%	(2,189.7)	518.3	219.3	(268.1)	(595.6)
25.0%	(2,167.9)	154.8	(51.9)	(424.3)	(662.7)

Sensitivity Analysis

Shuttle Upgrade. Because the Shuttle Upgrade option can not be justified (from a net present value perspective) using the Shuttle Upgrade Basic Assumptions, a sensitivity analysis is less relevant than for the New Human-Rated RLV option. Any increase in the amount of the up-front investment in excess of $5.2 billion will only make the project less justifiable, and, based on the complexity of the project and a lack of private-sector involvement, there is risk that NASA will not be able to accomplish the project for $5.2 billion. However, we can conclude that, for NASA to break-even on a $5.2 billion investment, the Shuttle Upgrade option would have to yield a cost per flight in the $223 million range, assuming a flight rate of 8 per year. In the attached Table I., we have sensitized the impact of changes in up-front investment and launch costs on the net present value of cost savings associated with the Shuttle Upgrade option.

New Human-Rated RLV. Beyond the technology risk, which can be addressed in part through the discount rate, the key variables to sensitize in analyzing the New Human-Rated RLV option are: (i) the required incremental up-front NASA investment in the project, which is currently assumed to be $1.75 billion; and (ii) the cost per launch that such an investment yields, which we have projected to be $75 million (for ISS-related missions). In the attached Table II, we have demonstrated the sensitivity of these variables relative to their impact on the net present value of cost savings. There are two important conclusions to be drawn from this table:

- Projected launch costs have the greatest impact by far on potential cost savings. For every $10 million increase in projected launch costs, the net present value of cost savings declines by approximately $637 million. This implies that the projected launch costs could increase to approximately $192 million (a 156% increase over the current launch cost projection of $75 million) before the net present value of cost savings was reduced to zero (assuming NASA invests $1.75 billion in the project).

- NASA can justify increasing its incremental up-front investment in the New Human-Rated RLV significantly. For every $100 million increase in the up-front investment required to complete the project, the net present value of cost savings decreases by approximately $87 million. This implies that the up-front investment could be increased by 485%, to approximately $10.2 billion (assuming the projected launch cost remains at $75 million) before the net present value of cost savings was reduced to zero.

Additional RLV Scenarios. In addition, we have sensitized the impact of these variables from an NPV of cost-savings "break-even" perspective, on Scenario 1, Scenario 2, and Scenario 3, each of which assumes that the human-transport capability of the New Human-Rated RLV is delayed beyond 2006. The results of this analysis are summarized below:

(000's)	**Basic Assumptions**	**Scenario 1**	**Scenario 2**	**Scenario 3**
RLV human-transport ready	2006	2007	2009	2011
NPV of Cost Savings	$7,423.9	$6,147.4	$4,221.1	$2,538.6
Break-even Launch Costs	$191.6	$169.4	$144.3	$119.4
% Increase vs. Basic Assump	155.4%	125.9%	92.4%	59.2%
Break-even Investment	$10,236.7	$9,270.9	$7,126.5	$5,103.9
% Increase vs. Basic Assump	485.0%	429.8%	307.2%	191.6%

Even in the case of Scenario 3, in which the New Human-Rated RLV's human-transport capability is delayed until 2011, there is sufficient room to: (i) increase the investment amount beyond $1.75 billion if necessary; and (ii) yield a cost per launch in excess of the projected $75 million, while still generating net cost savings that are justifiable.
See Table II.(a), Table II.(b) and Table II.(c) for further details.

As a general rule, the forgone net cost savings resulting from extending the "Shuttle-overlap" period by an additional year (assuming 5 flights per year) is in the $900 million to $1.2 billion range annually, which merely emphasizes NASA's need to commit to expediting the New Human-Rated RLV's human-transport capability. However, NASA would have to extend the "Shuttle-overlap" period to 2016 (from the current assumption of 2006 years), at a flight rate of 5 per year, in order to merely break-even (i.e. NPV of cost savings is equal to zero) on its $1.75 billion investment in the New Human-Rated RLV (at a flight cost of $75 million per flight).

Summary & Conclusions

From a financial perspective, the Existing Shuttle, Shuttle Upgrade and New Human-Rated RLV options can be summarized as follows:

	Existing Shuttle	**Shuttle Upgrade**	**New Human-Rated RLV**
Up-front Investment	$1.0 billion	$5.2 billion	$1.75 billion
Available Flights per Year	<10	<12 **(1)**	>15
Actual Flights per Year	8	8	13 **(2)**
Actual Cost per Flight	$300 million	$240 million	$75 million/$25 million
Gross Flight Cost/Year	$2.4 billion	$1.9 billion	$825 million
Total Flight Years (2004-2020)	17	17	15 **(3)**
Gross Cum. Flight Costs	$40.8 billion	$32.3 billion	$16.9 billion
NPV of Cost Savings	N/A	($931 million)	$7.4 billion

(1) Annual flight rates in the 11-12 range will likely require an additional infrastructure investment.
(2) Assumes 10 ISS-related flights at $75 million per flight and 3 non-ISS flights at $25 million per flight.
(3) The New Human-Rated RLV scenario assumes that the New Human-Rated RLV will not be fully operable (i.e. human transport capability) until 2006. Therefore, the Gross Cumulative Flight Costs include Existing Shuttle costs of $2.2 billion and RLV costs of $75 million for the years 2004 and 2005 and New Human-Rated RLV costs for the years 2006-2020.

Based on this information, the New Human-Rated RLV option appears to be the most attractive option, despite the technology risk associated with this option. The reason for this is clear: launch costs absorb a significant amount of NASA's total annual budget, and the New Human-Rated RLV has the potential to reduce launch costs far more than any other potential option which meets NASA's current mission requirements. At a Shuttle equivalent flight rate of 13 per year, the New Human-Rated RLV has the potential to reduce NASA's annual launch cost budget by approximately 2/3rds, from $2.4 billion to $825 million.

While the results of this analysis are compelling, it should be used to assist NASA in understanding the potential magnitude of its currently available options and the economic differences between them, but, clearly, not as the sole means by which to make a decision. As a result, NASA must be sure to consider all factors, both qualitative (limited resources, private-sector involvement, etc.) and quantitative, in arriving at a decision as to which option to pursue.

V. Conclusions and Recommendations:

NASA's strategic plan calls for "a renewed focus on scientific research and the development and application of new cutting-edge technologies." In order to achieve such a renewed focus in light of the prospects of flat-to-declining agency budgets, NASA must re-allocate its limited resources to focus on its unique core competencies (such as the development of advanced space technologies) and transition operating activities, where possible, to the private sector. NASA should migrate to the role of "customer" for these operating activities from its present role as "owner/operator."

Logically, NASA views "commercialization" as the primary means by which to transition out of operating activities. Commercialization can engage the private sector in NASA activities and reduce NASA's long-term costs. The active involvement of the private sector, which operates under an inherent set of disciplines and incentives driven by its need to earn an adequate economic return on its investment, is critical to NASA's ability to successfully commercialize many of its operating activities.

The Shuttle program, with an annual budget of approximately $3.2 billion, consumes the largest portion, approximately one fourth, of NASA's total annual budget. The Shuttle is clearly NASA's most recognized asset and is critical to the success of each of NASA's strategic enterprises: *Space Science*, *Earth Sciences*, *Human Exploration and Development of Space* and *Aeronautics and Space Transportation Technology*. Given the Shuttle's overall importance to the agency and its high cost, it seems clear that NASA's ability to reduce its overall costs through the commercialization of many of its operating activities will be a direct function of its ability to significantly reduce the cost of human access to space.

We have identified several potential options for NASA to evaluate in considering how to reduce the cost of human access to space:

- **Existing Shuttle:** Continue to operate the current Shuttle undertaking non-discretionary upgrades to maintain safety and reliability.

- **Shuttle Upgrade:** Invest in a major Shuttle upgrade, including the development of liquid fly-back boosters ("LFBBs").

- **Shuttle-to-Private Sector**: Transfer one or more Shuttles to private-sector ownership and operation.

- **New Human-Rated RLV:** Invest in the development of a full-scale, human-rated reusable launch vehicle ("RLV") as a follow-on to the existing X-33 project.

- **Alternative RLV:** Invest in alternative RLV technologies (Kistler, Kelly, etc.) which may not necessarily fulfill NASA's mission objectives, including human access to space and servicing the ISS.

- **<u>Combination Approach</u>:** Pursue a carefully managed and structured approach to the New Human-Rated RLV option while operating the Existing Shuttle until such New Human-Rated RLV is fully operable. In addition, the agency would explore opportunities to promote market-driven commercialization efforts in its existing operations, such as the Shuttle-to-Private Sector option, so long as they did not compromise NASA's mission objectives or the development of the New Human-Rated RLV.

HKA recommends that NASA pursue the Combination Approach.

The Combination Approach is based on the belief that: (i) NASA must continue to operate the Shuttle until a viable and proven low-cost alternative for human access to space emerges, (ii) the New Human-Rated RLV represents the best current long-term solution to reducing NASA's cost of human access to space (see Analysis of New Human-Rated RLV Option and Analytical Review), and (iii) transferring an underutilized Shuttle to a credible private-sector entity might generate attractive by-products, such as lower operating costs and positive near-term awareness of space's commercial market potential and the capabilities of human-rated RLVs.

Clearly the agency has no alternative but to continue to use the Shuttle until at least the completion of ISS assembly. Thereafter, the agency should transition to a lower cost launch vehicle as quickly as possible. To the extent that the New Human-Rated RLV development process is successful, there will likely be a transition period where the agency continues to fly the Shuttle while also flying the new RLV, perhaps on a limited basis. This allows the agency to retain human space flight capabilities until the safety, reliability and capability of the new RLV is proven. Thereafter, it is highly likely that the new RLV will supplant the Shuttle as NASA's primary (and perhaps only) human-rated launch vehicle.

In the interim, there may be an opportunity to broaden market awareness of the commercial potential of space through the transition of a potentially underutilized Shuttle to a private-sector owner/operator (the Shuttle-to-Private Sector option). Such a transfer, though requiring initial and on-going subsidies from NASA, may accelerate the commercialization of space, thus benefiting the NASA/private-sector New Human-Rated RLV effort over the long-term. This option is not intended to provide an ultimate solution for NASA, but rather, a means by which to foster market awareness and generate momentum for the commercialization process. It should only be undertaken if it does not compromise NASA's on-going mission objectives and the development of the New Human-Rated RLV.

The New Human-Rated RLV, if successful, has the potential to significantly reduce NASA's launch costs and enable movement by NASA away from operating activities and toward research and development. Not only could it generate annual launch cost savings in the $1.5-$2.0 billion range (see Analytical Review), but it could significantly enhance the commercial potential of NASA's other operating activities, particularly the ISS, whose commercial success is heavily dependent on reduced access costs. This is especially significant, given that, on a combined basis, ISS and the Shuttle are projected to consume approximately $5 billion (or 38%) of NASA's annual budget.

Even if the New Human-Rated RLV effort is not successful due to a failure to overcome key technological hurdles, the significant research and development efforts of both NASA and the private sector can be reasonably expected to have accelerated the eventual development of such a vehicle. Thus, at a minimum, the New Human-Rated RLV has the potential to move NASA further along the spectrum of reduced launch costs.

However, NASA must recognize that for the New Human-Rated RLV to be successful in enabling this transition from operating activities to research and development, it must partner at an early stage with the private sector. The New Human-Rated RLV is intended to be a market-driven vehicle, owned and operated by the private sector, with NASA being one of many customers. The private sector, by virtue of its need to realize a return on investment commensurate with the risk associated with such investment, has a set of disciplines and incentives that are critical to the success of this project. NASA's role is to foster the development of the New Human-Rated RLV by providing technical expertise, capital and other resources.

If no credible private-sector business plan for the New Human-Rated RLV is proposed (that includes an acceptable level of risk-sharing between NASA and the private sector), then one alternative for NASA would be to continue to invest in other "X-programs" that further mitigate key technological risks. To the extent that the private sector is only willing to undertake an X-33 follow-on project if NASA assumes substantially all of the risk, it is unlikely that the critical benefits of private-sector involvement will materialize over time. Private-sector incentives and disciplines, and the associated benefits of cost-efficiency and revenue generation, are significantly diluted (if not eliminated) when government assumes essentially all of the risk related to a project. As a result, NASA should avoid explicitly any partnerships in which there is not sufficient risk assumed by the private sector.

As our sensitivity analysis suggests (see Analytical Review), NASA can justify increasing its investment in the New Human-Rated RLV several-fold, if, for instance, incremental capital is required to overcome the technology risk. However, without the incentives and disciplines introduced when the private sector shares in the risk, NASA could spend several billion dollars ineffectively, with no assurance that the New Human-Rated RLV will succeed. ***NASA's ability to partner with the private sector and maximize the level of risk incurred by the private sector is far more critical to the success of the New Human-Rated RLV project than the amount of capital that NASA can commit***.

Significant private-sector risk sharing will best assure that the New Human-Rated RLV delivers on its projected costs and capabilities. Gradually, as the project shifts from development to operations, the private sector should assume increasingly more, if not all, of the risk.

VI. Risk Sharing: Structuring the Business Relationship

The primary reason for NASA's involvement in this effort is to significantly reduce the cost of human access to space and, as a result, NASA will be a primary beneficiary of the New Human-Rated RLV project. Ideally, the New Human-Rated RLV should be a private-sector developed, owned and operated launch vehicle. Unfortunately, the private sector is currently unwilling to invest in a human-rated RLV (i.e. meeting NASA's current mission requirements) on its own due to the current lack of appreciable commercial-market demand for this capability. As a result, to the extent that NASA seeks to accelerate the private sector's active involvement in a new human-rated RLV, it needs to assume a portion of the risk associated with the project. In all likelihood, the private-sector will seek NASA assistance on research and development as well as financial assistance from the US government. As mentioned previously, the private sector must also assume a substantive share of the risk to ensure the presence of private-sector disciplines and incentives in the project. Without the presence of these private-sector incentives and disciplines, the likelihood of completing the project on budget and within its specifications decreases significantly. NASA, however, should be willing to assume a portion of the risk only if it can structure a business relationship with the private sector that maximizes the likelihood of reducing the cost of human access to space.

Potential Risks to the NASA/Private Sector Business Relationship

Based on NASA's underlying goal of significantly reducing the cost of human access to space over the long-term, there are several potential "outcomes" of a business relationship with the private sector that the agency should seek to avoid:

- Creation of a monopoly service provider with autonomy over pricing and availability
- Creation of an "unfair playing field" in the commercial-satellite launch market due primarily to NASA subsidization of the New Human-Rated RLV
- NASA being solely responsible for funding the project's potential cost overruns
- NASA assuming sole-ownership of the project in order to preserve the agency's "sunk cost" if the private-sector abandons the project
- Creation of a financial windfall for the private-sector owners of the New Human-Rated RLV as a direct result of NASA's contributions

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- Making significant contributions to the project only to have the project yield an RLV that does not meet NASA's needs (from either a capability or cost perspective)

While not all of these potential outcomes can be avoided entirely, several measures can be taken to help mitigate the likelihood of such outcomes. Certain of these measures are consistent with what the agency is already doing:

- NASA should solicit proposals from several qualified private-sector participants for the development, ownership and operation of a human-rated RLV.

    - Generally, the private-sector participants should address the following in their proposals:

        - the specific capabilities of the planned RLV;
        - the nature (amount, form, timing, duration, etc.) of the private sector's commitment to and involvement in the process; and
        - the extent to which NASA support is required and the nature (amount, form, timing, duration, etc.) of such support.
        - the proposed ownership structure of the entity formed to undertake the project and the financial wherewithal of such owners (assuming multiple-party ownership);
        - the background and qualifications of the key management personnel that will be managing the project (including their relationships to the owners; there may be merits to an independent management team focused on the success of the entity), as well as information about important contractors from which the entity might purchase services, etc.;
        - the extent to which owners will be providing goods and services to the entity, and, if so, the terms and conditions of such goods and services (which should be no worse than "arms-length"); and
        - the trade-offs (cost, timing, technology, commercial-market implications, private-sector willingness to fund, etc.) associated with any "NASA-specific" requirements and different levels of NASA support.

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    - NASA should communicate clearly why, and under what conditions, it is willing to commit resources to such a project. For example:

        - **"NASA's commitment will be made available to the RLV developer/owner/operator whose proposed vehicle best meets NASA's long-term human space flight needs in a cost-efficient manner and with a high likelihood of success."**

        - As part of this communication, NASA should express its willingness to rely on commercially available, "off-the-shelf" technologies in instances where it is possible to do so, in order to achieve cost efficiencies.

In structuring a potential business relationship with the private sector, NASA should consider incorporating several key requirements to its proposed commitment, including:

- Completion guarantees from private-sector entities with financial wherewithal ("commitments with teeth") after certain technological thresholds are met. Options to consider are: (i) fixed-priced and/or performance-based contracts based on the cost-efficient achievement of certain design parameters; (ii) a portion of the compensation in the form of equity in the entity formed to undertake the project rather than cash; and (iii) deferred payment arrangements.

- A commitment that future launch services to NASA be priced at the lesser of "market" (i.e., the price at which the vehicle's launch services are provided to commercial customers for comparable services at any point in time) or a pre-determined "cap." NASA should benefit if market prices decline due to competitive forces; however, NASA should also receive a cap on future launch prices in exchange for providing critical support to the project at the outset. The pre-determined cap could be set after certain technological thresholds are met, but before significant NASA resources have been expended.

- Commitments that a minimum number of flights will be available (subject to the proposed pricing structure discussed above) to NASA for some period of time (i.e. 10 flights/year for five years). NASA might explore a longer-term arrangement (20+ years) depending on its projected needs, or seek to secure "options" to extend flight commitments on similar terms or to purchase additional flights in a given time period.

With respect to the actual funding of the project, NASA should consider incorporating certain requirements such as:

- "staging" its funding over time as opposed to making a large "up-front" advancement of funds;

- making funding contingent on the achievement of critical technological and other project milestones over the course of the project;

- agreeing to fund only those incremental costs related to "NASA-specific" enhancements (keeping in mind that agency should be willing to rely, where possible, on commercially available technologies) and letting the private sector fund the all costs related to "commercial-market" requirements (i.e. private sector funds a commercial market vehicle, NASA pays incremental costs to make it NASA-specific); and

- making contributions in "tandem" with (not before) those of the private sector, perhaps on the basis of a pre-arranged "formula."

These requirements help to mitigate the potential undesirable outcomes of (i) monopoly pricing and control, (ii) a failure to meet minimum performance capabilities and standards, and (iii) an unintended financial windfall to the private sector at NASA's expense. The issues that the agency may not be able to satisfactorily mitigate include: (i) technology risk, (ii) potential cost overruns, and (iii) NASA's involvement creating an unfair commercial-market advantage for one launch provider.

In structuring a business relationship with the private sector, NASA should be prepared to respond to the potential "needs" of the private sector in order to move forward, which may include:

- an "anchor-tenancy" requirement under which NASA commits to "take-or-pay" a pre-determined minimum number of RLV flights per year for some period of time, possibly at fixed or market prices (NASA should give consideration to the duration of this "anchor-tenancy" (i.e. a multi-year arrangement with a NASA option to extend or a "mutual-agreement" to extend clause) and should also consider "qualifying" it in other ways (i.e. remains in place as long as NASA receives most favorable launch costs, etc.));

- a commitment on the part of the US government to guarantee the repayment of a portion of certain debt or other financing that the private sector may incur in developing the New Human-Rated RLV (if NASA agrees to provide such guarantees, there should be mutual agreement in advance as to the appropriate time for them to fall away (i.e. upon the achievement of certain performance milestones));

- a commitment on the part of NASA to make all of its capital contributions "up-front," which has the potential to significantly dilute (or even eliminate) private-sector disciplines and incentives (however, the more NASA commits up-front, the more certainty and savings it should demand when the project is fully operational); and

- a commitment on the part of NASA to fund all or a significant portion of any cost overruns in the project (NASA should consider applying the same "risk-sharing ratio" to cost overruns unless the private sector is primarily responsible for such cost-overruns).

Each of these requirements seeks to shift risk away from the private sector and toward NASA. For example, an anchor-tenancy arrangement, if not structured properly, could enable a private sector owner/operator to realize an attractive, NASA-subsidized return on investment without having to provide market-competitive RLV services to any other customer. Similarly, loan guarantees, if not properly structured, could result in NASA (or the US government) assuming the large majority of the risk of the project, perhaps even being fully responsible for funding a failed project.

On the other hand, if properly structured, NASA could agree to modified versions of these requirements in such a way so as to maximize the likelihood of the project's success. For example, NASA might agree to guarantee the repayment of a portion of certain debt financing if the private sector participates in guaranteeing a portion of such financing as well, or an anchor tenancy agreement may help mitigate problems associated with a monopoly provider.

The key issue to consider for any type of government support for private-sector projects is the impact of that support on the risk-sharing relationship between government and the private sector. To the extent that the government needs to provide loan guarantees or any other type of support to the private sector, the private sector is, in effect, stating that the expected investment returns do not justify the risk. At that point, the government needs to determine whether it is interested in supporting a project that the private sector is unwilling to support on its own. In our view, government support should be limited to situations where the project generates benefits for the government sufficient to justify a "jump-start" to enable the private sector to enter into the project. The government needs to be clear, however, that its role is to enable private-sector involvement, not to provide a long-term subsidy to any given project.

The government should not provide such support in instances where the private sector is willing to "go-it- alone". The reason for this is that the introduction of government support, even when intended as a jump-start, creates distortions that dilute the private-sector incentives and disciplines that are key to a project's successful, timely and on-budget completion.

One often-used type of government support is a loan guarantee. The use of loan guarantees as a method of government support begs the question as to why loan guarantees are needed. The need for loan guarantees implies that the private sector believes that the risk/return equation in a given project does not provide appropriate returns for the level of risk being taken.

Our view is that the government's provision of loan guarantees to a given project, unless structured appropriately, can drastically alter the government/private-sector risk-sharing mix, potentially resulting in the significant dilution of private-sector incentives and disciplines. Loan guarantees, for purposes of analyzing the impact on the private-sector risk-reward trade-off, have the potential to place the government in the position of accepting all (or most of) the risk, with the private sector keeping all (or most of) the reward. This would be a bad outcome.

Many in government view loan guarantees as essentially "low-cost" from a budget perspective and therefore attractive as a tool to support projects the private-sector will not undertake on its own. Loan guarantees, in our view, should be treated as an actual funding commitment by the government. More importantly, loan guarantees, if structured improperly, can have the effect of creating incentives for the private sector to take actions that it otherwise would not undertake with its own resources (i.e. making bets with other people's money).

Spectrum of Potential Loan Guarantees

- Government as Primary Guarantor, with no recourse to the borrower or the project.
    - Creditors can seek repayment directly from government, not from the original borrower, and the government does not have recourse back to the original borrower.
- Government as Primary Guarantor, with recourse to the borrower, the project or both.
    - Creditors can seek repayment directly from government, not from the original borrower, however, the government has recourse to the original borrower and/or the project (i.e. the launch vehicle).
- Government as Primary Guarantor, with recourse to the borrower, the project and any parent companies involved.
    - Creditors can seek repayment directly from government, not from the original borrower, however, the government has recourse to the original borrower, the project (i.e. the launch vehicle) and the borrower's parent company.
- Government as Secondary Guarantor, with no recourse to the borrower or the project.
    - Creditors must seek repayment from the borrower before turning to the government. In other words, the borrower has to be unable to pay before the government gets involved. The government, in this case, does not have recourse back to the original borrower.
- Government as Secondary Guarantor, with recourse to the borrower, the project or both.
    - Creditors must seek repayment from the borrower before turning to the government. In other words, the borrower has to be unable to pay before the government gets involved, however, the government has recourse to the original borrower and/or the project (i.e. the launch vehicle).
- Government as Secondary Guarantor, with recourse to the borrower, the project and any parent companies involved.
    - Creditors must seek repayment from the borrower and any parent companies before turning to the government. In other words, the borrower and any parent companies have to be unable to pay before the government gets involved, however, the government has recourse to the original borrower, the project (i.e. the launch vehicle) and the borrower's parent company.

In all six cases listed above, the government guarantees will result in improved access to capital and lower costs for such capital. However, in the last two examples, the government/private-sector risk-sharing equation is diluted the least (in other words, the private sector assumes a higher level of risk and has a greater incentive to perform). In all six of these examples, the government can alter the risk-sharing equation by providing the guarantees for only a portion of the project (or for a limited period of time, or both), such that the private sector retains significant capital "at-risk".

When structured properly, loan guarantees can serve as a valuable tool to jump-start capital intensive projects by (i) improving access to capital and (ii) reducing the cost of such capital. The key to properly structuring loan guarantees is to achieve the benefits identified above without significantly diluting the private sector's level of risk and incentive to perform in a given project.

Key points for properly structuring loan guarantees:

Do not create a risk-sharing equation where the government assumes all of the risk. Loan guarantees may be useful to improve access to capital and to reduce the cost of that capital, however, the government should not provide the loan guarantees without obtaining support (sharing a portion of risk, collateral, parent guarantees, etc.) from the private sector in return. If the government provides the loan guarantees without obtaining appropriate private-sector support in return, the government will essentially be incurring all of the risk of a given project. This skewed risk-sharing arrangement significantly dilutes the benefits of private-sector incentives and disciplines. Even in situations where the underlying collateral provided to the government is the launch vehicle under development, this does not appear to create enough "risk" for the private sector.

Loan guarantees have the potential to create risk-sharing imbalances, therefore, their use should be limited to situations where all other avenues of support (i.e. access to facilities, research support, anchor tenancy, etc.) are exhausted. As important, the government should view loan guarantees as actual funding commitments to a project, and not based on credit-scoring criteria developed for budget purposes.

There are many other types of government support which may be used to "jump-start" this effort. We have outlined several of these, including the risks and mitigants associated with each, in Appendix III.

Clearly, any business arrangement between NASA and the private sector will have to be structured to accommodate the needs of all of the parties involved. The purpose of these recommendations is not to identify and mitigate every potential risk to NASA in entering into such a business arrangement, but rather to highlight the types of risks that may arise and to help direct NASA's approach to addressing such risks. As a result, NASA's critical focus should be on ensuring that the private sector shares substantively, throughout the life of the project, in the risk associated with the project. Gradually, as the project shifts from development to operations, the private sector should assume increasingly more, if not all, of the risk, while retaining a commensurate level of the return on investment.

Given that the structure of the NASA-private sector business relationship will not fully mitigate any or all of the risks associated with this project, future additional commitments of resources (financial, human, technical) from both NASA and the private sector may be required to complete the project. NASA's decision to make such additional commitments should be made in the context of its long-term objective – to reduce the cost of human access to space – and with the recognition that this can only be achieved through ongoing private-sector involvement.

Therefore, NASA's willingness to make incremental commitments to the development of a new human-rated RLV should only be made in a situation where the private sector is actively involved and has appropriate risk/return incentives. If the private sector is no longer willing to be involved in the project, NASA must consider whether to make additional investment to adjust the private sector's risk/return profile (but not to the point where the private sector's risk is eliminated) or pursue other alternatives. While the agency may be able to justify additional funding of the project as a reasonable investment given its high existing launch costs, the removal of private-sector disciplines and incentives from the project would increase the risk of cost overruns, delays, reduced capabilities and, ultimately, higher than expected (or higher than acceptable) operating costs. Any alternative NASA chooses to pursue should involve the private sector in an active risk-sharing role.

The key to success for NASA is that the next generation launch vehicle be developed, owned and operated by the private sector. The vehicle should be developed to address commercial-market needs, and NASA should be viewed as one customer among many, albeit a significant one. This is the only way that the agency will realize significant long-term cost savings. Given the complexity of the project as well as the fact that NASA's need for a human-rated launch vehicle may be somewhat inconsistent with the commercial market's need for low-cost satellite launch systems, NASA will need to facilitate the development of a vehicle that meets both needs on a cost-efficient basis. However, to the extent that NASA's involvement/requirements result in the development of a vehicle that does not address the needs of the commercial satellite market, the anticipated reductions in the agency's future launch costs may not materialize. In other words, the addition of NASA-specific capabilities to the New Human-Rated RLV may limit the vehicle's ability to compete effectively in the commercial market, thereby limiting its potential benefits to NASA. As a result, NASA's involvement, though critical to the process, must be limited and carefully managed so as not to substantially dilute (or even eliminate) private-sector incentives and disciplines.

VII. Exhibits, Appendices & Tables

Exhibit I. HKA Background/Summary

Appendix I. NPV Analysis: Shuttle Upgrade

Appendix II. Basic Assumptions Scenario. NPV Analysis: New Human-Rated RLV

Appendix II. (a) Scenario 1. NPV Analysis: New Human-Rated RLV (human transport capability in 2007)

Appendix II. (b) Scenario 2. NPV Analysis: New Human-Rated RLV (human transport capability in 2009)

Appendix II. (c) Scenario 3. NPV Analysis: New Human-Rated RLV (human transport capability in 2011)

Table I. Sensitivity Analysis of Net Present Value ("NPV") of Shuttle Upgrade vs. Existing Shuttle

Table II. Basic Assumptions Scenario. Sensitivity Analysis of NPV of New Human-Rated RLV vs. Existing Shuttle.

Table II. (a) Scenario 1. Sensitivity Analysis of NPV of New Human-Rated RLV vs. Existing Shuttle.

Table II. (b) Scenario 2. Sensitivity Analysis of NPV of New Human-Rated RLV vs. Existing Shuttle.

Table II. (c) Scenario 3. Sensitivity Analysis of NPV of New Human-Rated RLV vs. Existing Shuttle.

Table II.

BASIC ASSUMPTIONS

SENSITIVITY ANALYSIS: NPV OF HUMAN-RATED RLV VS. EXISTING SHUTTLE

(assuming RLV is human rated by 2006)

($000'S)

Total Investment	<=============== Equivalent Launch Costs									===============>
	60,000	75,000	90,000	105,000	120,000	135,000	150,000	165,000	180,000	195,000	210,000
1,250,000	8,816,521	7,861,312	6,906,104	5,950,896	4,995,687	4,040,479	3,085,271	2,130,062	1,174,854	219,646	(735,563)
1,750,000	8,379,135	7,423,926	6,468,718	5,513,510	4,558,301	3,603,093	2,647,885	1,692,676	737,468	(217,740)	(1,172,949)
2,250,000	7,941,749	6,986,540	6,031,332	5,076,124	4,120,915	3,165,707	2,210,499	1,255,290	300,082	(655,126)	(1,610,335)
2,750,000	7,504,363	6,549,154	5,593,946	4,638,738	3,683,529	2,728,321	1,773,113	817,904	(137,304)	(1,092,512)	(2,047,721)
3,250,000	7,066,977	6,111,768	5,156,560	4,201,352	3,246,143	2,290,935	1,335,727	380,518	(574,690)	(1,529,898)	(2,485,107)
3,750,000	6,629,591	5,674,382	4,719,174	3,763,966	2,808,757	1,853,549	898,341	(56,868)	(1,012,076)	(1,967,284)	(2,922,493)
4,250,000	6,192,205	5,236,996	4,281,788	3,326,580	2,371,371	1,416,163	460,955	(494,254)	(1,449,462)	(2,404,670)	(3,359,879)
4,750,000	5,754,819	4,799,610	3,844,402	2,889,194	1,933,985	978,777	23,569	(931,640)	(1,886,848)	(2,842,056)	(3,797,265)
5,250,000	5,317,433	4,362,224	3,407,016	2,451,808	1,496,599	541,391	(413,817)	(1,369,026)	(2,324,234)	(3,279,442)	(4,234,651)
5,750,000	4,880,047	3,924,838	2,969,630	2,014,422	1,059,213	104,005	(851,203)	(1,806,412)	(2,761,620)	(3,716,828)	(4,672,037)
6,250,000	4,442,661	3,487,452	2,532,244	1,577,036	621,827	(333,381)	(1,288,589)	(2,243,798)	(3,199,006)	(4,154,214)	(5,109,423)
6,750,000	4,005,274	3,050,066	2,094,858	1,139,650	184,441	(770,767)	(1,725,975)	(2,681,184)	(3,636,392)	(4,591,600)	(5,546,809)
7,250,000	3,567,888	2,612,680	1,657,472	702,264	(252,945)	(1,208,153)	(2,163,361)	(3,118,570)	(4,073,778)	(5,028,986)	(5,984,195)
7,750,000	3,130,502	2,175,294	1,220,086	264,878	(690,331)	(1,645,539)	(2,600,747)	(3,555,956)	(4,511,164)	(5,466,372)	(6,421,581)
8,250,000	2,693,116	1,737,908	782,700	(172,508)	(1,127,717)	(2,082,925)	(3,038,133)	(3,993,342)	(4,948,550)	(5,903,758)	(6,858,967)
8,750,000	2,255,730	1,300,522	345,314	(609,894)	(1,565,103)	(2,520,311)	(3,475,519)	(4,430,728)	(5,385,936)	(6,341,144)	(7,296,353)
9,250,000	1,818,344	863,136	(92,072)	(1,047,280)	(2,002,489)	(2,957,697)	(3,912,905)	(4,868,114)	(5,823,322)	(6,778,530)	(7,733,739)
9,750,000	1,380,958	425,750	(529,458)	(1,484,666)	(2,439,875)	(3,395,083)	(4,350,291)	(5,305,500)	(6,260,708)	(7,215,916)	(8,171,125)
10,250,000	943,572	(11,636)	(966,844)	(1,922,052)	(2,877,261)	(3,832,469)	(4,787,677)	(5,742,886)	(6,698,094)	(7,653,302)	(8,608,511)

Table II (a).

SCENARIO 1

SENSITIVITY ANALYSIS: NPV OF HUMAN-RATED RLV VS. EXISTING SHUTTLE

(assuming human transport capability is delayed until 2007)

($000'S)

Total	<== Equivalent Launch Costs ==>									
Investment	75,000	85,000	95,000	105,000	115,000	125,000	135,000	145,000	155,000	165,000	175,000
1,250,000	6,556,136	5,905,245	5,254,355	4,603,465	3,952,575	3,301,685	2,650,795	1,999,904	1,349,014	698,124	47,234
1,750,000	6,147,446	5,496,555	4,845,665	4,194,775	3,543,885	2,892,995	2,242,105	1,591,214	940,324	289,434	(361,456)
2,250,000	5,738,756	5,087,865	4,436,975	3,786,085	3,135,195	2,484,305	1,833,415	1,182,524	531,634	(119,256)	(770,146)
2,750,000	5,330,066	4,679,175	4,028,285	3,377,395	2,726,505	2,075,615	1,424,725	773,834	122,944	(527,946)	(1,178,836)
3,250,000	4,921,375	4,270,485	3,619,595	2,968,705	2,317,815	1,666,925	1,016,035	365,144	(285,746)	(936,636)	(1,587,526)
3,750,000	4,512,685	3,861,795	3,210,905	2,560,015	1,909,125	1,258,235	607,345	(43,546)	(694,436)	(1,345,326)	(1,996,216)
4,250,000	4,103,995	3,453,105	2,802,215	2,151,325	1,500,435	849,545	198,654	(452,236)	(1,103,126)	(1,754,016)	(2,404,906)
4,750,000	3,695,305	3,044,415	2,393,525	1,742,635	1,091,745	440,855	(210,036)	(860,926)	(1,511,816)	(2,162,706)	(2,813,596)
5,250,000	3,286,615	2,635,725	1,984,835	1,333,945	683,055	32,165	(618,726)	(1,269,616)	(1,920,506)	(2,571,396)	(3,222,286)
5,750,000	2,877,925	2,227,035	1,576,145	925,255	274,365	(376,525)	(1,027,416)	(1,678,306)	(2,329,196)	(2,980,086)	(3,630,976)
6,250,000	2,469,235	1,818,345	1,167,455	516,565	(134,325)	(785,215)	(1,436,106)	(2,086,996)	(2,737,886)	(3,388,776)	(4,039,666)
6,750,000	2,060,545	1,409,655	758,765	107,875	(543,015)	(1,193,906)	(1,844,796)	(2,495,686)	(3,146,576)	(3,797,466)	(4,448,356)
7,250,000	1,651,855	1,000,965	350,075	(300,815)	(951,705)	(1,602,596)	(2,253,486)	(2,904,376)	(3,555,266)	(4,206,156)	(4,857,046)
7,750,000	1,243,165	592,275	(58,615)	(709,505)	(1,360,395)	(2,011,286)	(2,662,176)	(3,313,066)	(3,963,956)	(4,614,846)	(5,265,736)
8,250,000	834,475	183,585	(467,305)	(1,118,195)	(1,769,085)	(2,419,976)	(3,070,866)	(3,721,756)	(4,372,646)	(5,023,536)	(5,674,426)
8,750,000	425,785	(225,105)	(875,995)	(1,526,885)	(2,177,775)	(2,828,666)	(3,479,556)	(4,130,446)	(4,781,336)	(5,432,226)	(6,083,116)
9,250,000	17,095	(633,795)	(1,284,685)	(1,935,575)	(2,586,465)	(3,237,356)	(3,888,246)	(4,539,136)	(5,190,026)	(5,840,916)	(6,491,806)
9,750,000	(391,595)	(1,042,485)	(1,693,375)	(2,344,265)	(2,995,156)	(3,646,046)	(4,296,936)	(4,947,826)	(5,598,716)	(6,249,606)	(6,900,496)
10,250,000	(800,285)	(1,451,175)	(2,102,065)	(2,752,955)	(3,403,846)	(4,054,736)	(4,705,626)	(5,356,516)	(6,007,406)	(6,658,296)	(7,309,187)

Table II (b).

SCENARIO 2

SENSITIVITY ANALYSIS: NPV OF HUMAN-RATED RLV VS. EXISTING SHUTTLE

(assuming human transport capability is delayed until 2009)

($000'S)

Total Investment	<===				Equivalent Launch Costs		===>				
	75,000	85,000	95,000	105,000	115,000	125,000	135,000	145,000	155,000	165,000	175,000
1,750,000	4,221,114	3,612,315	3,003,516	2,394,717	1,785,918	1,177,119	568,320	(40,478)	(649,277)	(1,258,076)	(1,866,875)
2,000,000	4,024,838	3,416,039	2,807,240	2,198,441	1,589,642	980,843	372,045	(236,754)	(845,553)	(1,454,352)	(2,063,151)
2,250,000	3,828,562	3,219,763	2,610,964	2,002,165	1,393,366	784,568	175,769	(433,030)	(1,041,829)	(1,650,628)	(2,259,427)
2,500,000	3,632,286	3,023,487	2,414,688	1,805,889	1,197,090	588,292	(20,507)	(629,306)	(1,238,105)	(1,846,904)	(2,455,703)
2,750,000	3,436,010	2,827,211	2,218,412	1,609,613	1,000,815	392,016	(216,783)	(825,582)	(1,434,381)	(2,043,180)	(2,651,978)
3,000,000	3,239,734	2,630,935	2,022,136	1,413,338	804,539	195,740	(413,059)	(1,021,858)	(1,630,657)	(2,239,455)	(2,848,254)
3,250,000	3,043,458	2,434,659	1,825,860	1,217,062	608,263	(536)	(609,335)	(1,218,134)	(1,826,933)	(2,435,731)	(3,044,530)
3,500,000	2,847,182	2,238,383	1,629,585	1,020,786	411,987	(196,812)	(805,611)	(1,414,410)	(2,023,208)	(2,632,007)	(3,240,806)
3,750,000	2,650,906	2,042,108	1,433,309	824,510	215,711	(393,088)	(1,001,887)	(1,610,685)	(2,219,484)	(2,828,283)	(3,437,082)
4,000,000	2,454,630	1,845,832	1,237,033	628,234	19,435	(589,364)	(1,198,163)	(1,806,961)	(2,415,760)	(3,024,559)	(3,633,358)
4,250,000	2,258,355	1,649,556	1,040,757	431,958	(176,841)	(785,640)	(1,394,438)	(2,003,237)	(2,612,036)	(3,220,835)	(3,829,634)
4,500,000	2,062,079	1,453,280	844,481	235,682	(373,117)	(981,915)	(1,590,714)	(2,199,513)	(2,808,312)	(3,417,111)	(4,025,910)
4,750,000	1,865,803	1,257,004	648,205	39,406	(569,393)	(1,178,191)	(1,786,990)	(2,395,789)	(3,004,588)	(3,613,387)	(4,222,186)
5,000,000	1,669,527	1,060,728	451,929	(156,870)	(765,668)	(1,374,467)	(1,983,266)	(2,592,065)	(3,200,864)	(3,809,663)	(4,418,461)
5,250,000	1,473,251	864,452	255,653	(353,145)	(961,944)	(1,570,743)	(2,179,542)	(2,788,341)	(3,397,140)	(4,005,939)	(4,614,737)
5,500,000	1,276,975	668,176	59,377	(549,421)	(1,158,220)	(1,767,019)	(2,375,818)	(2,984,617)	(3,593,416)	(4,202,214)	(4,811,013)
5,750,000	1,080,699	471,900	(136,898)	(745,697)	(1,354,496)	(1,963,295)	(2,572,094)	(3,180,893)	(3,789,691)	(4,398,490)	(5,007,289)
6,000,000	884,423	275,625	(333,174)	(941,973)	(1,550,772)	(2,159,571)	(2,768,370)	(3,377,169)	(3,985,967)	(4,594,766)	(5,203,565)
6,250,000	688,147	79,349	(529,450)	(1,138,249)	(1,747,048)	(2,355,847)	(2,964,646)	(3,573,444)	(4,182,243)	(4,791,042)	(5,399,841)
6,500,000	491,872	(116,927)	(725,726)	(1,334,525)	(1,943,324)	(2,552,123)	(3,160,921)	(3,769,720)	(4,378,519)	(4,987,318)	(5,596,117)
6,750,000	295,596	(313,203)	(922,002)	(1,530,801)	(2,139,600)	(2,748,399)	(3,357,197)	(3,965,996)	(4,574,795)	(5,183,594)	(5,792,393)
7,000,000	99,320	(509,479)	(1,118,278)	(1,727,077)	(2,335,876)	(2,944,674)	(3,553,473)	(4,162,272)	(4,771,071)	(5,379,870)	(5,988,669)
7,250,000	(96,956)	(705,755)	(1,314,554)	(1,923,353)	(2,532,151)	(3,140,950)	(3,749,749)	(4,358,548)	(4,967,347)	(5,576,146)	(6,184,944)

Table II (c).

SCENARIO 3

SENSITIVITY ANALYSIS: NPV OF HUMAN-RATED RLV VS. EXISTING SHUTTLE

(assuming human transport capability is delayed until 2011)

($000'S)

Total Investment	<================================ Equivalent Launch Costs ================================>										
	55,000	65,000	75,000	85,000	95,000	105,000	115,000	125,000	135,000	145,000	155,000
1,750,000	3,682,650	3,110,615	2,538,580	1,966,546	1,394,511	822,477	250,442	(321,593)	(893,627)	(1,465,662)	(2,037,697)
2,000,000	3,493,422	2,921,387	2,349,352	1,777,318	1,205,283	633,249	61,214	(510,821)	(1,082,855)	(1,654,890)	(2,226,925)
2,250,000	3,304,194	2,732,159	2,160,124	1,588,090	1,016,055	444,021	(128,014)	(700,049)	(1,272,083)	(1,844,118)	(2,416,153)
2,500,000	3,114,966	2,542,931	1,970,896	1,398,862	826,827	254,793	(317,242)	(889,277)	(1,461,311)	(2,033,346)	(2,605,381)
2,750,000	2,925,738	2,353,703	1,781,668	1,209,634	637,599	65,565	(506,470)	(1,078,505)	(1,650,539)	(2,222,574)	(2,794,609)
3,000,000	2,736,510	2,164,475	1,592,440	1,020,406	448,371	(123,664)	(695,698)	(1,267,733)	(1,839,767)	(2,411,802)	(2,983,837)
3,250,000	2,547,282	1,975,247	1,403,212	831,178	259,143	(312,892)	(884,926)	(1,456,961)	(2,028,995)	(2,601,030)	(3,173,065)
3,500,000	2,358,054	1,786,019	1,213,984	641,950	69,915	(502,120)	(1,074,154)	(1,646,189)	(2,218,223)	(2,790,258)	(3,362,293)
3,750,000	2,168,826	1,596,791	1,024,756	452,722	(119,313)	(691,348)	(1,263,382)	(1,835,417)	(2,407,451)	(2,979,486)	(3,551,521)
4,000,000	1,979,598	1,407,563	835,528	263,494	(308,541)	(880,576)	(1,452,610)	(2,024,645)	(2,596,679)	(3,168,714)	(3,740,749)
4,250,000	1,790,370	1,218,335	646,300	74,266	(497,769)	(1,069,804)	(1,641,838)	(2,213,873)	(2,785,907)	(3,357,942)	(3,929,977)
4,500,000	1,601,142	1,029,107	457,072	(114,962)	(686,997)	(1,259,032)	(1,831,066)	(2,403,101)	(2,975,135)	(3,547,170)	(4,119,205)
4,750,000	1,411,914	839,879	267,844	(304,190)	(876,225)	(1,448,260)	(2,020,294)	(2,592,329)	(3,164,363)	(3,736,398)	(4,308,433)
5,000,000	1,222,686	650,651	78,616	(493,418)	(1,065,453)	(1,637,488)	(2,209,522)	(2,781,557)	(3,353,592)	(3,925,626)	(4,497,661)
5,250,000	1,033,458	461,423	(110,612)	(682,646)	(1,254,681)	(1,826,716)	(2,398,750)	(2,970,785)	(3,542,820)	(4,114,854)	(4,686,889)

Table I.

SHUTTLE UPGRADE

SENSITIVITY ANALYSIS: NPV OF SHUTTLE UPGRADE VS. EXISTING SHUTTLE

($000'S)

Total Investment	210,000	220,000	230,000	240,000	250,000	260,000	270,000	280,000	290,000	300,000
4,000,000	1,725,605	1,168,722	611,838	54,955	(501,929)	(1,058,812)	(1,615,695)	(2,172,579)	(2,729,462)	(3,286,346)
4,100,000	1,643,447	1,086,563	529,680	(27,204)	(584,087)	(1,140,971)	(1,697,854)	(2,254,738)	(2,811,621)	(3,368,504)
4,200,000	1,561,288	1,004,404	447,521	(109,362)	(666,246)	(1,223,129)	(1,780,013)	(2,336,896)	(2,893,780)	(3,450,663)
4,300,000	1,479,129	922,246	365,362	(191,521)	(748,405)	(1,305,288)	(1,862,171)	(2,419,055)	(2,975,938)	(3,532,822)
4,400,000	1,396,971	840,087	283,204	(273,680)	(830,563)	(1,387,447)	(1,944,330)	(2,501,214)	(3,058,097)	(3,614,980)
4,500,000	1,314,812	757,929	201,045	(355,838)	(912,722)	(1,469,605)	(2,026,489)	(2,583,372)	(3,140,256)	(3,697,139)
4,600,000	1,232,653	675,770	118,886	(437,997)	(994,880)	(1,551,764)	(2,108,647)	(2,665,531)	(3,222,414)	(3,779,298)
4,700,000	1,150,495	593,611	36,728	(520,156)	(1,077,039)	(1,633,923)	(2,190,806)	(2,747,689)	(3,304,573)	(3,861,456)
4,800,000	1,068,336	511,453	(45,431)	(602,314)	(1,159,198)	(1,716,081)	(2,272,965)	(2,829,848)	(3,386,732)	(3,943,615)
4,900,000	986,177	429,294	(127,590)	(684,473)	(1,241,356)	(1,798,240)	(2,355,123)	(2,912,007)	(3,468,890)	(4,025,774)
5,000,000	904,019	347,135	(209,748)	(766,632)	(1,323,515)	(1,880,398)	(2,437,282)	(2,994,165)	(3,551,049)	(4,107,932)
5,100,000	821,860	264,977	(291,907)	(848,790)	(1,405,674)	(1,962,557)	(2,519,441)	(3,076,324)	(3,633,207)	(4,190,091)
5,200,000	739,701	182,818	(374,065)	(930,949)	(1,487,832)	(2,044,716)	(2,601,599)	(3,158,483)	(3,715,366)	(4,272,250)
5,300,000	657,543	100,659	(456,224)	(1,013,108)	(1,569,991)	(2,126,874)	(2,683,758)	(3,240,641)	(3,797,525)	(4,354,408)
5,400,000	575,384	18,501	(538,383)	(1,095,266)	(1,652,150)	(2,209,033)	(2,765,917)	(3,322,800)	(3,879,683)	(4,436,567)
5,500,000	493,226	(63,658)	(620,541)	(1,177,425)	(1,734,308)	(2,291,192)	(2,848,075)	(3,404,959)	(3,961,842)	(4,518,725)
5,600,000	411,067	(145,817)	(702,700)	(1,259,583)	(1,816,467)	(2,373,350)	(2,930,234)	(3,487,117)	(4,044,001)	(4,600,884)
5,700,000	328,908	(227,975)	(784,859)	(1,341,742)	(1,898,626)	(2,455,509)	(3,012,392)	(3,569,276)	(4,126,159)	(4,683,043)
5,800,000	246,750	(310,134)	(867,017)	(1,423,901)	(1,980,784)	(2,537,668)	(3,094,551)	(3,651,435)	(4,208,318)	(4,765,201)
5,900,000	164,591	(392,293)	(949,176)	(1,506,059)	(2,062,943)	(2,619,826)	(3,176,710)	(3,733,593)	(4,290,477)	(4,847,360)
6,000,000	82,432	(474,451)	(1,031,335)	(1,588,218)	(2,145,101)	(2,701,985)	(3,258,868)	(3,815,752)	(4,372,635)	(4,929,519)

Appendix I.

NPV ANALYSIS: SHUTTLE UPGRADE [1]

SHUTTLE UPGRADE

(000's)

Line[2]	Estimate of Current Shuttle Launch Costs	
1	Annual Shuttle LEO Transportation Budget	$2,400,000
2	Number of Shuttle Flights per Budget	8
3	Est. Launch Costs per Flight (first 8 flights)	$300,000
4	Est. Variable Launch Cost per Launch (9 thru 12)	$90,000

Line	Shuttle Upgrade	
5	Number of Shuttle Flights per Budget	8
6	Est. Post-Upgrade Cost per Launch (up to 8 flights)	$240,000
7	Est. Post-Upgrade Variable Cost/Launch (9 thru 12)	$75,000

Line			Dec-99	Dec-00	Dec-01	Dec-02	Dec-03	Dec-04	Dec-05	Dec-06	Dec-07	Dec-08	Dec-09	Dec-10	Dec-20
8	Projected Number of Shuttle Launches - Post-Upgrade		-	-	-	-	-	8	8	8	8	8	8	8	8
9	Estimated Shuttle Upgrade Investment	$5,200,000	10.00%	30.00%	25.00%	25.00%	10.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
10	Proj Shuttle Upgrade Investment Funding Schedule		(520,000)	(1,560,000)	(1,300,000)	(1,300,000)	(520,000)	-	-	-	-	-	-	-	-
11	Proj Launch Costs Based on Current Shuttle Costs		-	-	-	-	-	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
12	Proj Launch Costs - Post-Upgrade		-	-	-	-	-	(1,920,000)	(1,920,000)	(1,920,000)	(1,920,000)	(1,920,000)	(1,920,000)	(1,920,000)	(1,920,000)
13	**Shuttle Upgrade Net Cash Flows**		**(520,000)**	**(1,560,000)**	**(1,300,000)**	**(1,300,000)**	**(520,000)**	**480,000**	**480,000**	**480,000**	**480,000**	**480,000**	**480,000**	**480,000**	**480,000**

Line		
14	Discount Rate	7.00%
15	**Net Present Value of the Shuttle Upgrade Program [3]**	**($930,949)**

Represents the Present Value of Estimated Cost Savings Generated by Shuttle Upgrade less the Present Value of the Initial Funding Costs of Shuttle Upgrade.

Line	"Breakeven" Analysis - Shuttle Upgrade Launch Costs	
16	Current Assumed Cost Per Launch - Shuttle Upgrade	$240,000
17	Maximum Increase/(Decrease) in SU Cost per Launch	($16,717)
18	**Breakeven Shuttle Upgrade Cost per Launch**	**$223,283**
19	Max SUCosts per Launch/Current Proj. Launch Costs	-7.0%

Line	"Breakeven" Analysis - Shuttle Upgrade Investment	
20	Current Assumed Up-Front Investment - Shuttle Upgrade	$5,200,000
21	Maximum Increase/(Decrease) in SU Investment	($1,133,111)
22	**Breakeven SU Up-Front Investment**	**$4,066,889**
23	Max Up-front Investment/Current Proj. Up-front Investment	-21.8%

Footnotes:

(1) This model was developed for demonstrative purposes only and contains many assumptions which are simply "best estimates" and not based on factual data.

(2) See attached page for explanations of key line items numbered 1-23 above.

(3) Shuttle Upgrade Net Cash Flows have been discounted over the period 1999-2020. This includes the period 2011-2019, which does not appear in this Appendix I for presentation purposes only.

Appendix II.

NPV ANALYSIS: NEW HUMAN-RATED RLV [1]

BASIC ASSUMPTIONS SCENARIO (RLV is human-rated by 2006)

(000's)

Line[2]	Estimate of Current Shuttle Launch Costs	
1	Annual Shuttle LEO Transportation Budget	$2,400,000
2	Number of Shuttle Flights per Budget	8
3	Est. Launch Costs per Flight (first 8 flights)	$300,000
4	Est. Variable Launch Cost per Launch (9 thru 12)	$90,000

Line	New Human-Rated RLV	
5	Estimated NHRRLV Cost per Launch - ISS	$75,000
6	Estimated NHRRLV Cost per Launch - Other	$25,000

Line			Dec-99	Dec-00	Dec-01	Dec-02	Dec-03	Dec-04	Dec-05	Dec-06	Dec-07	Dec-08	Dec-09	Dec-10	Dec-11	Dec-20
7	Proj Number of Shuttle "Overlap" Launches (until NHRRLV is Human Rated)		-	-	-	-	-	5	5	-	-	-	-	-	-	-
8	Projected Number of Existing Shuttle Launches		-	-	-	-	-	8	8	8	8	8	8	8	8	8
9	Equivalent Number of New Human-Rated RLV Launches - ISS		-	-	-	-	-	-	-	10	10	10	10	10	10	10
10	Equivalent Number of New Human-Rated RLV Launches - Other		-	-	-	-	-	3	3	3	3	3	3	3	3	3
11	Required NASA Up-Front Investment in NHRRLV	$1,750,000	33.33%	33.33%	33.33%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12	Estimated Equity Funding Schedule		(583,333)	(583,333)	(583,333)	-	-	-	-	-	-	-	-	-	-	-
13	Proj Launch Costs Based on Current Shuttle Costs = Cost Savings		-	-	-	-	-	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
14	Estimated Shuttle "Overlap" Launch Costs (until RLV is Human Rated)		-	-	-	-	-	(1,500,000)	(1,500,000)	-	-	-	-	-	-	-
15	Incremental Shuttle "Overlap" Costs and Shuttle Closeout Costs		-	-	-	-	-	(700,000)	(700,000)	(240,000)	-	-	-	-	-	-
16	Projected New Human-Rated RLV Launch Costs		-	-	-	-	-	(75,000)	(75,000)	(825,000)	(825,000)	(825,000)	(825,000)	(825,000)	(825,000)	(825,000)
17	**New Human-Rated RLV Net Cash Flows [3]**		**(583,333)**	**(583,333)**	**(583,333)**	**-**	**-**	**125,000**	**125,000**	**1,335,000**	**1,575,000**	**1,575,000**	**1,575,000**	**1,575,000**	**1,575,000**	**1,575,000**
18	Discount Rate	7.00%														
19	**Net Present Value of the NHRRLV Net Cost Savings**	**$7,423,926**	Represents the Present Value of Estimated Cost Savings Generated by NHRRLV less the Present Value of NASA's Share of the Initial Funding Costs of NHRRLV													

Line	"Breakeven" Analysis - NHRRLV Projected Launch Costs	
20	Current Assumed Cost Per Launch - NHRRLV	$75,000
21	Maximum Incr/(Decr) in NHRRLV Costs per Launch	$116,581
22	**Breakeven NHRRLV Cost per Launch - ISS**	**$191,581**
23	Max NHRRLV Costs per Launch/Current Proj. Launch Costs	155.4%
24	Breakeven NHRRLV Cost per Launch - Other	63,860

Line	"Breakeven" Analysis - NHRRLV Up-Front Investment	
25	Current Assumed Up-Front Investment - NHRRLV	$1,750,000
26	Maximum Incr/(Decr) in NHRRLV Investment	$8,486,698
27	**Breakeven NHRRLV Up-Front Investment**	##########
28	Max Up-front Investment/Current Proj. Up-front Investment	485.0%

Footnotes:

(1) This model was developed for demonstrative purposes only and contains many assumptions which are simply "best estimates" and not based on factual data.

(2) See attached page for explanations of key line items numbered 1-26 above.

(3) New Human-Rated RLV Net Cash Flows have been discounted over the period 1999-2020. This includes the period 2012-2019, which does not appear in this Appendix II for presentation purposes only.

Appendix II. (a)

NPV ANALYSIS: NEW HUMAN-RATED RLV [(1)]

SCENARIO 1 **(RLV human-transport capability delayed until 2007)**

(000's)

Line[(2)]	Estimate of Current Shuttle Launch Costs	
1	Annual Shuttle LEO Transportation Budget	$2,400,000
2	Number of Shuttle Flights per Budget	8
3	Est. Launch Costs per Flight (first 8 flights)	$300,000
4	Est. Variable Launch Cost per Launch (9 thru 12)	$90,000

Line	New Human-Rated RLV		Dec-99	Dec-00	Dec-01	Dec-02	Dec-03	Dec-04	Dec-05	Dec-06	Dec-07	Dec-08	Dec-09	Dec-10	Dec-11	Dec-20
5	Estimated NHRRLV Cost per Launch - ISS	$75,000														
6	Estimated NHRRLV Cost per Launch - Other	$25,000														
7	Proj Number of Shuttle "Overlap" Launches (until NHRRLV is Human Rated)		-	-	-	-	-	5	5	5	-	-	-	-	-	-
8	Projected Number of Existing Shuttle Launches		-	-	-	-	-	8	8	8	8	8	8	8	8	8
9	Equivalent Number of New Human-Rated RLV Launches - ISS [(3)]		-	-	-	-	-	-	6	6	10	10	10	10	10	10
10	Equivalent Number of New Human-Rated RLV Launches - Other [(4)]		-	-	-	-	-	3	3	3	3	3	3	3	3	3
11	Required NASA Up-Front Investment in NHRRLV	$1,750,000	21.43%	21.43%	21.43%	11.90%	11.90%	11.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12	Estimated Equity Funding Schedule [(5)]		(375,000)	(375,000)	(375,000)	(208,333)	(208,333)	(208,333)	-	-	-	-	-	-	-	-
13	Proj Launch Costs Based on Current Shuttle Costs = Cost Savings		-	-	-	-	-	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
14	Estimated Shuttle "Overlap" Launch Costs (until RLV is Human Rated)		-	-	-	-	-	(1,500,000)	(1,500,000)	(1,500,000)	-	-	-	-	-	-
15	Incremental Shuttle "Overlap" Costs and Shuttle Closeout Costs		-	-	-	-	-	(700,000)	(700,000)	(700,000)	(240,000)	-	-	-	-	-
16	Projected New Human-Rated RLV Launch Costs		-	-	-	-	-	(75,000)	(525,000)	(525,000)	(825,000)	(825,000)	(825,000)	(825,000)	(825,000)	(825,000)
17	**New Human-Rated RLV Net Cash Flows [(6)]**		**(375,000)**	**(375,000)**	**(375,000)**	**(208,333)**	**(208,333)**	**(83,333)**	**(325,000)**	**(325,000)**	**1,335,000**	**1,575,000**	**1,575,000**	**1,575,000**	**1,575,000**	**1,575,000**
18	Discount Rate	7.00%														
19	**Net Present Value of the NHRRLV Net Cost Savings**	**$6,147,446**	Represents the Present Value of Estimated Cost Savings Generated by NHRRLV less the Present Value of NASA's Share of the Initial Funding Costs of NHRRLV													

Line	"Breakeven" Analysis - NHRRLV Projected Launch Costs	
20	Current Assumed Cost Per Launch - NHRRLV	$75,000
21	Maximum Incr/(Decr) in NHRRLV Costs per Launch	$94,447
22	**Breakeven NHRRLV Cost per Launch - ISS**	**$169,447**
23	Max NHRRLV Costs per Launch/Current Proj. Launch Costs	125.9%
24	Breakeven NHRRLV Cost per Launch - Other	56,482

Line	"Breakeven" Analysis - NHRRLV Up-Front Investment	
25	Current Assumed Up-Front Investment - NHRRLV	$1,750,000
26	Maximum Incr/(Decr) in NHRRLV Investment	$7,520,915
27	**Breakeven NHRRLV Up-Front Investment**	**$9,270,915**
28	Max Up-front Investment/Current Proj. Up-front Investment	429.8%

Footnotes:

(1) This model was developed for demonstrative purposes only and contains many assumptions which are simply "best estimates" and not based on factual data.
(2) See attached page for explanations of key line items numbered 1-26 above.
(3) In years where 6 flights are projected, it is assumed that the human-transport capability does not exist. Where 10 flights are projected, it is assumed that 6 are cargo-only and 4 are manned.
(4) These are non-ISS flights at a cost of $25 million per flight.
(5) All investment after 2001 is for human-transport capability.
(6) New Human-Rated RLV Net Cash Flows have been discounted over the period 1999-2020. This includes the period 2012-2019, which does not appear in this Appendix II.(a) for presentation purposes only.

Appendix II. (b)

NPV ANALYSIS: NEW HUMAN-RATED RLV [1]

SCENARIO 2 **(RLV human-transport capability delayed until 2009)**

(000's)

Line[2]	Estimate of Current Shuttle Launch Costs	
1	Annual Shuttle LEO Transportation Budget	$2,400,000
2	Number of Shuttle Flights per Budget	8
3	Est. Launch Costs per Flight (first 8 flights)	$300,000
4	Est. Variable Launch Cost per Launch (9 thru 12)	$90,000

	New Human-Rated RLV	
5	Estimated NHRRLV Cost per Launch - ISS	$75,000
6	Estimated NHRRLV Cost per Launch - Other	$25,000

Line			Dec-99	Dec-00	Dec-01	Dec-02	Dec-03	Dec-04	Dec-05	Dec-06	Dec-07	Dec-08	Dec-09	Dec-10	Dec-11	Dec-20
7	Proj Number of Shuttle "Overlap" Launches (until NHRRLV is Human Rated)		-	-	-	-	-	5	5	5	5	5	-	-	-	-
8	Projected Number of Existing Shuttle Launches		-	-	-	-	-	8	8	8	8	8	8	8	8	8
9	Equivalent Number of New Human-Rated RLV Launches - ISS [3]		-	-	-	-	-	-	6	6	6	6	10	10	10	10
10	Equivalent Number of New Human-Rated RLV Launches - Other [4]		-	-	-	-	-	3	3	3	3	3	3	3	3	3
11	Required NASA Up-Front Investment in NHRRLV	$1,750,000	21.43%	21.43%	21.43%	0.00%	0.00%	11.90%	11.90%	11.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
12	Estimated Equity Funding Schedule [5]		(375,000)	(375,000)	(375,000)	-	-	(208,333)	(208,333)	(208,333)	-	-	-	-	-	-
13	Proj Launch Costs Based on Current Shuttle Costs = Cost Savings		-	-	-	-	-	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
14	Estimated Shuttle "Overlap" Launch Costs (until RLV is Human Rated)		-	-	-	-	-	(1,500,000)	(1,500,000)	(1,500,000)	(1,500,000)	(1,500,000)	-	-	-	-
15	Incremental Shuttle "Overlap" Costs and Shuttle Closeout Costs		-	-	-	-	-	(700,000)	(700,000)	(700,000)	(700,000)	(700,000)	(240,000)	-	-	-
16	Projected New Human-Rated RLV Launch Costs		-	-	-	-	-	(75,000)	(525,000)	(525,000)	(525,000)	(525,000)	(825,000)	(825,000)	(825,000)	(825,000)
17	**New Human-Rated RLV Net Cash Flows [6]**		**(375,000)**	**(375,000)**	**(375,000)**	**-**	**-**	**(83,333)**	**(533,333)**	**(533,333)**	**(325,000)**	**(325,000)**	**1,335,000**	**1,575,000**	**1,575,000**	**1,575,000**

18	Discount Rate	7.00%
19	**Net Present Value of the NHRRLV Net Cost Savings**	**$4,221,114**

Represents the Present Value of Estimated Cost Savings Generated by NHRRLV less the Present Value of NASA's Share of the Initial Funding Costs of NHRRLV

	"Breakeven" Analysis - NHRRLV Projected Launch Costs	
20	Current Assumed Cost Per Launch - NHRRLV	$75,000
21	Maximum Incr/(Decr) in NHRRLV Costs per Launch	$69,335
22	**Breakeven NHRRLV Cost per Launch - ISS**	**$144,335**
23	Max NHRRLV Costs per Launch/Current Proj. Launch Costs	92.4%
24	Breakeven NHRRLV Cost per Launch - Other	48,112

	"Breakeven" Analysis - NHRRLV Up-Front Investment	
25	Current Assumed Up-Front Investment - NHRRLV	$1,750,000
26	Maximum Incr/(Decr) in NHRRLV Investment	$5,376,505
27	**Breakeven NHRRLV Up-Front Investment**	**$7,126,505**
28	Max Up-front Investment/Current Proj. Up-front Investment	307.2%

Footnotes:

(1) This model was developed for demonstrative purposes only and contains many assumptions which are simply "best estimates" and not based on factual data.

(2) See attached page for explanations of key line items numbered 1-26 above.

(3) In years where 6 flights are projected, it is assumed that the human-transport capability does not exist. Where 10 flights are projected, it is assumed that 6 are cargo-only and 4 are manned.

(4) These are non-ISS flights at a cost of $25 million per flight.

(5) All investment after 2001 is for human-transport capability.

(6) New Human-Rated RLV Net Cash Flows have been discounted over the period 1999-2020. This includes the period 2012-2019, which does not appear in this Appendix II.(b) for presentation purposes only.

Appendix II. (c)

NPV ANALYSIS: NEW HUMAN-RATED RLV [1]

SCENARIO 3 (RLV human-transport capability delayed until 2011)

(000's)

Line[2]	Estimate of Current Shuttle Launch Costs	
1	Annual Shuttle LEO Transportation Budget	$2,400,000
2	Number of Shuttle Flights per Budget	8
3	Est. Launch Costs per Flight (first 8 flights)	$300,000
4	Est. Variable Launch Cost per Launch (9 thru 12)	$90,000

Line	New Human-Rated RLV	
5	Estimated NHRRLV Cost per Launch - ISS	$75,000
6	Estimated NHRRLV Cost per Launch - Other	$25,000

Line			Dec-99	Dec-00	Dec-01	Dec-02	Dec-03	Dec-04	Dec-05	Dec-06	Dec-07	Dec-08	Dec-09	Dec-10	Dec-11	Dec-20
7	Proj Number of Shuttle "Overlap" Launches (until NHRRLV is Human Rated)		-	-	-	-	-	5	5	5	5	5	5	5	-	-
8	Projected Number of Existing Shuttle Launches		-	-	-	-	-	8	8	8	8	8	8	8	8	8
9	Equivalent Number of New Human-Rated RLV Launches - ISS [3]		-	-	-	-	-	-	6	6	6	6	6	6	10	10
10	Equivalent Number of New Human-Rated RLV Launches - Other [4]		-	-	-	-	-	3	3	3	3	3	3	3	3	3
11	Required NASA Up-Front Investment in NHRRLV	$1,750,000	21.43%	21.43%	21.43%	0.00%	0.00%	0.00%	0.00%	11.90%	11.90%	11.90%	0.00%	0.00%	0.00%	0.00%
12	Estimated Equity Funding Schedule [5]		(375,000)	(375,000)	(375,000)	-	-	-	-	(208,333)	(208,333)	(208,333)	-	-	-	-
13	Proj Launch Costs Based on Current Shuttle Costs = Cost Savings		-	-	-	-	-	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000	2,400,000
14	Estimated Shuttle "Overlap" Launch Costs (until RLV is Human Rated)		-	-	-	-	-	(1,500,000)	(1,500,000)	(1,500,000)	(1,500,000)	(1,500,000)	(1,500,000)	(1,500,000)	-	-
15	Incremental Shuttle "Overlap" Costs and Shuttle Closeout Costs		-	-	-	-	-	(700,000)	(700,000)	(700,000)	(700,000)	(700,000)	(700,000)	(700,000)	(240,000)	-
16	Projected New Human-Rated RLV Launch Costs		-	-	-	-	-	(75,000)	(525,000)	(525,000)	(525,000)	(525,000)	(525,000)	(525,000)	(825,000)	(825,000)
17	**New Human-Rated RLV Net Cash Flows [6]**		**(375,000)**	**(375,000)**	**(375,000)**	**-**	**-**	**125,000**	**(325,000)**	**(533,333)**	**(533,333)**	**(533,333)**	**(325,000)**	**(325,000)**	**1,335,000**	**1,575,000**

Line		
18	Discount Rate	7.00%
19	**Net Present Value of the NHRRLV Net Cost Savings**	**$2,538,580**

Represents the Present Value of Estimated Cost Savings Generated by NHRRLV less the Present Value of NASA's Share of the Initial Funding Costs of NHRRLV

Line	"Breakeven" Analysis - NHRRLV Projected Launch Costs	
20	Current Assumed Cost Per Launch - NHRRLV	$75,000
21	Maximum Incr/(Decr) in NHRRLV Costs per Launch	$44,378
22	**Breakeven NHRRLV Cost per Launch - ISS**	**$119,378**
23	Max NHRRLV Costs per Launch/Current Proj. Launch Costs	59.2%
24	Breakeven NHRRLV Cost per Launch - Other	39,793

Line	"Breakeven" Analysis - NHRRLV Up-Front Investment	
25	Current Assumed Up-Front Investment - NHRRLV	$1,750,000
26	Maximum Incr/(Decr) in NHRRLV Investment	$3,353,865
27	**Breakeven NHRRLV Up-Front Investment**	**$5,103,865**
28	Max Up-front Investment/Current Proj. Up-front Investment	191.6%

Footnotes:

(1) This model was developed for demonstrative purposes only and contains many assumptions which are simply "best estimates" and not based on factual data.
(2) See attached page for explanations of key line items numbered 1-26 above.
(3) In years where 6 flights are projected, it is assumed that the human-transport capability does not exist. Where 10 flights are projected, it is assumed that 6 are cargo-only and 4 are manned.
(4) These are non-ISS flights at a cost of $25 million per flight.
(5) All investment after 2001 is for human-transport capability.
(6) New Human-Rated RLV Net Cash Flows have been discounted over the period 1999-2020. This includes the period 2012-2019, which does not appear in this Appendix II.(c) for presentation purposes only.

Appendix I (page 2). Explanation of Key Line Items for NPV Analysis: Shuttle Upgrade

Line Item	Explanation of Line Item	Source [4]
1	Estimated annual budget for Shuttle Program	NASA
2	Estimated number of Shuttle flights annually based on annual budget dollars	NASA
3	Shuttle Annual Budget divided by Estimated Number of Shuttle Flights per Budget (Line Item 1/Line Item 2)	NASA
4	Estimated variable cost per Shuttle flight after 7 flights have been flown - the projected cost per flight of flights 8-12 in a given year	NASA
5	Same as Line Item 2	NASA
6	Estimated Cost per Launch post-Shuttle Upgrade	NASA
7	Estimated variable cost per flight, post-Shuttle Upgrade, after 7 flights have been flown	NASA
8	Projected number of annual Shuttle Upgrade flights	NASA
9	Estimated up front investment required for Shuttle Upgrade	NASA
10	Estimated period over which up-front investment is to be made	HKA
11	Estimated cost savings from not having to operate Existing Shuttle (Line Item 3 x Line Item 8)	N/A
12	Cost of Shuttle Upgrade Launches (Line Item 6 x Line Item 8)	N/A
13	Annual Net Cash Flows representing the annual cost savings less the up-front investment amount less the launch costs for the Shuttle Upgrade (Line Item 10 + Line Item 11 + Line Item 12)	N/A
14	The discount rate at which the Net Cash Flows (Line Item 13) are being discounted in the Net Present Value calculation.	NASA
15	The Net Present Value of Cost Savings (the present value of Line Item 13)	N/A
16	The current assumption for Shuttle Upgrade Cost per Launch (same as Line Item 6)	NASA
17	The amount by which the Shuttle Upgrade cost per Launch (Line Item 16) would have to increase/(decrease) to make the Net present Value of Cost Savings (Line Item 15) equal to zero.	N/A
18	The Shuttle Upgrade Cost per Launch which makes the Net Present Value of Cost Savings (Line Item 15) equal to zero	N/A
19	The percentage increase/(decrease) in the Current Assumed Cost per Launch (Line Item 16) required to make the Net Present Value of Cost Savings (Line Item 15) equal to zero ((Line Item 18/Line Item 16) - 1)	N/A
20	The assumed amount of NASA investment required to complete the Shuttle Upgrade (Same as Line Item 9)	NASA
21	The amount by which the Current Assumed Up-front Investment (Line Item 20) would have to increase/(decrease) to make the Net present Value of Cost Savings (Line Item 15) equal to zero.	N/A
22	The Estimated Shuttle Upgrade Investment amount which makes the Net Present Value of Cost Savings (Line Item 15) equal to zero	N/A
23	The percentage increase/(decrease) in the Current Assumed Up-front Investment (Line Item 20) required to make the Net Present Value of Cost Savings (Line Item 15) equal to zero ((Line Item 22/Line Item 20) - 1)	N/A

Footnotes:

(4) HKA = Hawthorne, Krauss & Associates; NASA = NASA; N/A = Not Applicable (a calculation)

Appendix II (page 2). Explanation of Key Line Items for NPV Analysis: New Human-Rated RLV
(Based on VentureStar Assumptions)

Line Item	Explanation of Line Item	Source [4]
1	Estimated annual budget for Shuttle Program	NASA
2	Estimated number of Shuttle flights annually based on annual budget dollars	NASA
3	Shuttle Annual Budget divided by Estimated Number of Shuttle Flights per Budget (Line Item 1/Line Item 2)	NASA
4	Estimated variable cost per Shuttle flight after 7 flights have been flown - the projected cost per flight of flights 8-12 in a given year	NASA
5	Estimated New Human Rated RLV Cost per Launch represents the recent projected VentureStar cost per launch of $75 million. This represents the estimated cost of access to ISS.	VS/HKA
6	The estimated cost per launch for access to non-ISS destinations. Assumed to be one third the cost of ISS launches, even for sensitivity analyses.	NASA
7	Shuttle "Overlap" launches to be flown while the New Human-Rated RLV is being qualified as human-rated for NASA purposes (see Analytical Review: New Human-Rated RLV Basic Assumptions)	NASA
8	Projected number of Existing Shuttle Launches per year assuming no development of a New Human-Rated RLV	NASA
9	Estimated New Human-Rated RLV launches for access to ISS.	NASA
10	Estimated New Human-Rated RLV launches for access to non-ISS destinations.	NASA
11	Estimated up front investment required for RLV	VS/HKA
12	Estimated period over which up-front investment is to be made. Investment made after 2001 is for human-transport capability.	NASA
13	Estimated cost savings from not having to operate Existing Shuttle (Line Item 3 x Line Item 7)	N/A
14	Cost of Shuttle "Overlap" Launches (Line Item 3 x Line Item 7). See Line Item 15.	NASA
15	Other costs associated with the operation of the Existing Shuttle at less than its "optimum" capacity of 8 flights per year. For example, if the Existing Shuttle were to be launched only 5 times per year the cost per flight would be $440 million per laun	NASA
16	Cost of New Human-Rated RLV Launches ((Line Item 5 x Line Item 9) + (Line Item 6 x Line Item 10))	N/A
17	Annual Net Cash Flows representing the annual cost savings less the up-front investment amount, less Shuttle "overlap" costs, less the launch costs for the New Human-Rated RLV (Line Item 12 + Line Item 13 + Line Item 14 + Line Item 15 + Line Item 16)	N/A
18	The discount rate at which the Net Cash Flows (Line Item 17) are being discounted in the Net Present Value calculation.	HKA
19	The Net Present Value of Cost Savings (the present value of Line Item 17)	N/A
20	The current assumption for New Human-Rated RLV cost per Launch (same as Line Item 5)	VS/HKA
21	The amount by which the New Human Rated RLV cost per Launch (Line Item 15) would have to increase/(decrease) to make the Net present Value of Cost Savings (Line Item 19) equal to zero.	N/A
22	The New Human-Rated RLV Cost per ISS Launch which makes the Net Present Value of Cost Savings (Line Item 19) equal to zero	N/A
23	The percentage increase/(decrease) in the Current Assumed Cost per Launch (Line Item 20) required to make the Net Present Value of Cost Savings (Line Item 19) equal to zero ((Line Item 22/Line Item 20) - 1)	N/A
24	The estimated "breakeven" cost per launch for access to non-ISS destinations. Assumed to be one third the cost of ISS launches (Line 22 divided by 3)	NASA/HKA
25	The assumed amount of NASA investment required to complete the New Human-Rated RLV (Same as Line Item 11)	N/A
26	The amount by which the Current Assumed Up-front Investment (Line Item 25) would have to increase/(decrease) to make the Net present Value of Cost Savings (Line Item 19) equal to zero.	N/A
27	The Required NASA Up-front Investment amount which makes the Net Present Value of Cost Savings (Line Item 19) equal to zero	N/A
28	The percentage increase/(decrease) in the Current Assumed Up-front Investment (Line Item 25) required to make the Net Present Value of Cost Savings (Line Item 19) equal to zero ((Line Item 27/Line Item 25) - 1)	N/A

Footnotes:

(4) VS = VentureStar and related parties; HKA = Hawthorne, Krauss & Associates; NASA = NASA; N/A = Not Applicable (a calculation)