# Political Sustainability in Space Exploration Architectures

D. A. Broniatowski* and A. L. Weigel**
*Massachusetts Institute of Technology, Cambridge, MA 02139*

## Abstract

**Political and technical concerns are tightly intertwined in the design of modern space systems. The political environment often responds harshly associated high costs of these endeavors. Political sustainability is therefore at least as important as the technical performance parameters of new space systems under development. This paper outlines a methodology by which a system architect may trace the recursive impacts of political choice on technical choice, and vice versa. Using the implementation of the Vision for Space Exploration as a case study, a policy-technology feedback loop is outlined. This paper then demonstrates how political sustainability may be incorporated into the design process such that a politically savvy system architect may appropriately trade present costs against future costs.**

## Nomenclature

| | | |
|---|---|---|
| *AMCM* | = | Advanced Mission Cost Model |
| *CER* | = | Concept Exploration and Refinement |
| *CEV* | = | Crew Exploration Vehicle |
| *ESAS* | = | Exploration Systems Architecture Study |
| *LEO* | = | Low Earth Orbit |
| *NASA* | = | National Aeronautics and Space Administration |
| *OMB* | = | Office of Management and Budget |
| *RCC* | = | Reinforced Carbon-Carbon |
| *RFI* | = | Request for Information |
| *TPS* | = | Thermal Protection System |
| *VSE* | = | Vision for Space Exploration |

## I. Introduction

The primary purpose of this paper is to illustrate a methodology by which technical and political choices interact in NASA's directive to accomplish the Vision for Space Exploration (VSE) announced by President Bush on January 14, 2004 [1]. This document is aimed at providing the system architect with a tool that may provide some measure of understanding and control of the interactions between a given technical choice and the political process. We focus on interactions between NASA, acting as an agent of the President, and Congress, the organization that reflects the will of the American people and provides NASA funding. We explore how a system architect might influence policy outcomes. In doing so, we hope to explicitly integrate *political sustainability* into system design.

### A. What is Political Sustainability?

The concept of "Political Sustainability" is motivated by the 1987 Report on the World Commission on Environment and Development, the so-called "Brundtland Report". This work asserts that "Sustainable development

* Graduate Research Assistant, Aeronautics and Astronautics/Technology and Policy Program, 77 Massachusetts Ave., Rm. 17-110, and AIAA Student Member.
** Assistant Professor of Aeronautics and Astronautics and Engineering Systems, 77 Massachusetts Ave., Rm. 33-404, and AIAA Member.

is development that meets the needs of the present without compromising the ability of future generations to meet their own needs"[2]

This paper recognizes that political choice requires a constant balance between fulfilling current needs and maintaining relationships for the future. Therefore, we define political sustainability as follows:

**An action is politically sustainable if it allows for the fulfillment of current political goals and resource needs without compromising future goals and needs.**

Politically sustainable actions simultaneously build support for, and advance, an item on the political agenda. Actions that are not politically sustainable advance a current agenda item at the expense of future support.

### B. Framework: The Policy-Technology Feedback Cycle

This analysis focuses on the political sustainability of using legacy components, those used in and designed for previous systems, in the design of the new Crew Exploration Vehicle (CEV). CEV functionality is separated into multiple "blocks" – one for Low Earth Orbit (LEO) capability and one for Lunar and Martian capability. The MIT Concept Exploration and Refinement (CER) Study and NASA's Exploration Systems Architecture Study (ESAS) serve as baselines for this analysis [3, 4]. We focus on Space Shuttle thermal protection tiles and reinforced carbon-carbon as a specific legacy component case study. The intent is to trace the effects of using legacy components through the design process, and therefore to provide a framework under which decisions to use legacy components can be evaluated.

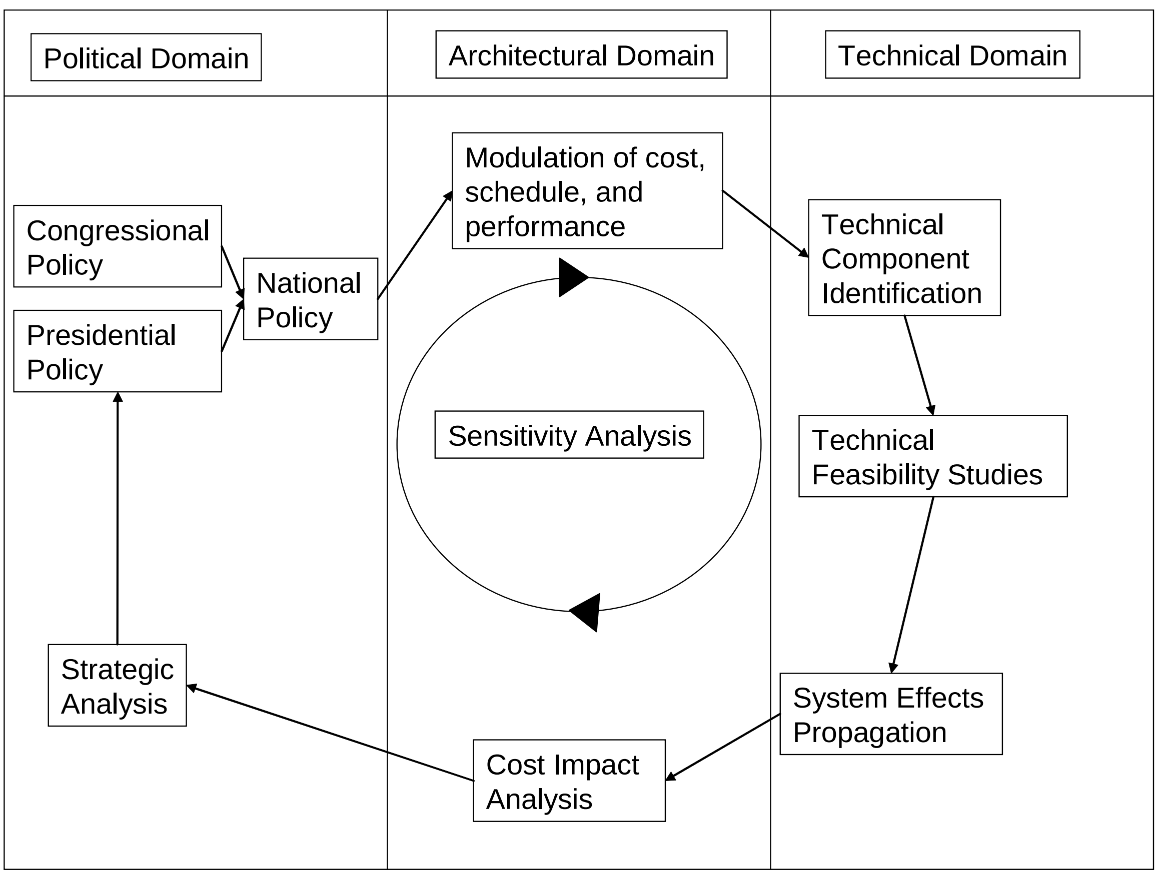


**Figure 1: The Policy-Technology Feedback Cycle represents a framework that the system architect can use to trace the impacts of technical performance on national policy and vice versa.**

The above diagram represents the notion that policy and technology constitute components of a *techno-political system.* Just as a policy change can impact technical parameters, changes to a technical system have the potential to propagate in such a way as to affect change in the political domain [5]. The system architect, as the interlocutor between the political and technical domains, has the capability to trace these impacts through careful analysis. Each section of this paper focuses on a specific set of components of this cycle, articulating how the implementation of the VSE is driven by Congressional and Presidential political concerns, and how technical choices, such as the decision to introduce certain kinds of legacy technology into the system design, can impact the political process. These impacts are traced across three domains, as follows:

*1. The Policy Domain: From Congressional and Presidential Policies to Law*
In order for any proposal to become adopted as national law within the United States of America, it must be passed by the Congress, the government's Legislative branch, and then signed into law by the President, the elected leader of the Executive Branch. The structure of the government is such that each Branch (including the Legislative, Executive and Judicial branches) has a means to countermand an action taken by the others – the so-called "checks and balances" of the US federal system. In practice, this ensures that laws on which the President and the Congress do not agree do not get passed.

*2. The Architectural Domain: From Law to Requirements*
Once a law is passed by Congress and signed by the President, it is the role of the systems architect to determine how an agency may best implement this directive. The architect is particularly concerned with such high-level parameters as system cost, performance and schedule. Generally a policy directive will place bounds on all three of these. For example, the VSE directs NASA to retire the Shuttle by 2010, construct a CEV before 2014, and return to the Moon before 2020. Furthermore, this must occur in a "sustained and affordable" manner [6]. The role of the system architect is to translate these policy directives into "0-level requirements", or technical parameters that may eventually be used for conceptual design.

*3. The Technical Domain: From Requirements to Hardware and Back Again*
Once 0-level requirements have been generated, it is the role of a team of system engineers, working together with technical specialists, to generate a specific design concept. This team is then responsible for executing a "requirements flowdown", creating low-level requirements from higher-level requirements. These are eventually intended to move beyond conceptual design into the detailed design phase. Nevertheless, system engineers must be wary of how the complex parts of a technical system interact. In particular, if a policy directive inspires change in a pre-existing design, the savvy system engineer must be aware of how that change will propagate through the system, the effects that such a change might have on the system's ability to operate, and how performance, cost and schedule could be impacted. The system architect must be able to translate the assumptions underlying cost engineering results into a format that an agency's legislative affairs specialists will find actionable. This, in turn, will affect how that agency approaches the Office of Management and Budget (OMB) and Congress, and how national policy is made in the future. This new national policy will again affect architectural and technical requirements, starting the cycle anew.

This paper will trace the process described above; focusing at times on how the use of legacy components might affect the ability of NASA to carry out a potential Congressional directive to reduce the development time of the CEV. The ultimate goal is to illustrate how such a policy change can propagate through the techno-political system, eventually affecting the policy that first called for CEV development, the President's VSE.

It must be stressed that the primary contribution of this paper is not intended to be in the results of the model. Rather, the process by which these results are derived is intended to provide a methodology that system architects may use to evaluate how policies affect technologies and vice versa. The role of technical and political experts cannot be discounted, as they provide the crucial checks of the assumptions underlying this model, thereby grounding it in reality.

## II. Within the Political Domain

### C. Drivers of Political Choice
An understanding of the drivers of political change is necessary to understand the policy making process in the Policy-Technology Feedback Cycle. Whereas technical choice is based upon tractable theory that can be pursued to

a rational and often deterministic end, political choice is marked by an environment of information scarcity wherein many of the options available to a decision-maker are not clear [7]. A political decision-maker is thus forced to choose between a limited number of generally sub-optimal options, often without the time or ability to investigate the full ramifications of these options in detail. As such, an entity that can exercise control over the information available to policy makers can exercise some element of control over the outcomes. In particular, NASA's technical expertise allows a powerful role in defining options that are to be presented as policy choices [8].

It is up to the policy maker to make decisions based upon what information and options are the most salient to his/her own values (cf. [9]). To the policy-maker, agencies, such as NASA, are tools to be used in implementing a specific policy directive. Therefore, an agency will receive attention, and a concomitant budgetary increase, when its work can be used to satisfy a salient directive, or when its goals are instrumental towards achieving the policy-maker's goals [9]. Since goals change, an agency cannot always fulfill a salient concern. During these periods, they are dominated by role-based activity [10]. The budgeting process, in particular, is dominated by a particular type of role-based activity often referred to as "incrementalism", which describes a roughly stable yearly budget unlikely to see large changes in magnitude [11-13]. Furthermore, there is a considerable body of space policy literature characterizing NASA as an incremental organization [14-18]. As such we can expect NASA's budgeting behavior to be largely driven by the same forces that drive most incremental agencies. Generally, these act to maintain the status quo by creating an environment of budgetary scarcity for new projects. In technical terms, this drives the agency to reduce costs of new programs. At the same time, a need to show results encourages the agency to adopt short-term plans and make overoptimistic promises. These twin constraints on cost and schedule can adversely affect performance, leaving NASA as an agency "struggling to do too much with too little" [19].

### D. National Policy: The Accelerated Vision for Space Exploration

The specific policy driving NASA's actions is the Vision for Space Exploration, calling for a sustained and affordable exploration of the Moon, Mars and Beyond. The first steps in implementing this vision include replacement of the Space Shuttle with a Crew Exploration Vehicle (CEV) [1]. Responding to Congressional concerns that the U.S. might lose perceived preeminence in human spaceflight, NASA Administrator Griffin announced his intention to minimize the time between the Space Shuttle's retirement and the deployment of the CEV [20].

## III. Modulation of Cost, Schedule and Performance in Response to Policy Change

It is the role of the system architect to translate political directives to technical directives [5]. A savvy architect will trace political directives through to their eventual impact on the technical design parameters that engineers must change. The use of legacy components is one heuristic strategy that system architects have traditionally used in when budgetary resources are scarce.

NASA's budget constraints make use of legacy components an attractive option to accelerate the CEV. From a performance standpoint, use of legacy components has the potential to reduce development cost, schedule and risk. From the perspective of the political environment, this behavior will also reduce the pace of the changes in workforce and industrial-base distribution that can be dangerous to new R&D programs [21]. The intended CEV acceleration makes this option almost indispensable. Nevertheless, care must be taken to ensure that the unintended system costs of such a choice do not outweigh the benefits to be gained.

## IV. Within the Technical Domain

### E. Technical Component Selection

Some legacy components, such as the Solid Rocket Boosters used on the Crew Launch Vehicle, represent an investment that will last throughout the entire lifecycle of the CEV launch system. Similarly, the External Tank will be reused as part of the Cargo Launch Vehicle. Once these elements are re-used, they will continue to provide value for many years to come across a range of missions extending from LEO to Mars [3].

Not all legacy components have such clear benefits. Consider a hypothetical decision to use Space Shuttle Thermal Protection System (TPS) tiles and reinforced carbon-carbon on the CEV. [22] note that a LEO-only CEV Thermal

Protection System based upon reuse of Shuttle TPS components could enable a successful acceleration of a “Block 1” CEV, intended only for use in LEO, while allowing more time for the development of a heat shield for “Block 2”, that can withstand reentry from the Moon. This option is particularly salient given the fact that no human-rated heat-shield materials currently exist that can return astronauts safely from the Moon or Mars [4, 22, 23]. Although NASA has released a Request for Information (RFI) soliciting non-Shuttle LEO-only TPS concepts, the Shuttle TPS is currently planned as a baseline [3, 24].

### F. Technical Feasibility Studies and System Effects Propagation

Re-use of Shuttle TPS elements is not technically feasible for lunar and Mars missions [23]. As such, a new TPS would have to be developed when NASA begins to execute its lunar missions. Furthermore, use of Shuttle TPS elements will require changes that propagate throughout the entire system. For example, use of these components would necessitate a trade between landing site targeting accuracy, maximum heat rate endured by the entry vehicle, and total system mass and volumetric efficiency. This demonstrates the more general point that inclusion of some types of legacy components can come with unintended consequences that can adversely affect performance or reduce expected cost and schedule savings.

The next section attempts to characterize the cost tradeoffs associated with the use of legacy components. This information is used to determine how a decision to accelerate the CEV through the use of legacy components might affect the overall system and upgrade cost. This will allow for a comparison of the costs of upgrading to Block 2 at some point in the future vs. building in a lunar capability now.

## V. Cost Estimation in the Architectural Realm

Significant uncertainty surrounds the process of estimating the cost of complex space vehicles. Nevertheless, rough order of magnitude cost modeling techniques, such as NASA’s Advanced Mission Cost Model (AMCM) can provide insight into how annual cost might be modulated by legacy component use and the deployment date of specific components [25]. Present per annum costs associated with developing a LEO-only Block 1 CEV might be reduced by delaying the development of lunar Block 2 CEV elements, such as a new TPS. Similarly, using legacy components can reduce the costs of the Block 1 CEV, nevertheless necessitating a new heat shield design for the lunar Block 2 upgrade. Both of these methods will increase future per annum while reducing present costs. This potentially undermines political sustainability (i.e., these costs become so high that Congress refuses to provide funding). On the other hand, future per annum costs can be reduced by commencing Block 2 development earlier. By performing the most difficult development tasks early, the future costs of upgrade can also be reduced. Since the development of these components is spread out over more time, the per annum cost is also lower. Thus, overall per annum cost may be modulated by decisions regarding which components to use and when to use them. The question remains as to how best to enable political sustainability through cost modulation. In particular, the savvy system architect requires insight into when it is appropriate to trade present costs against future costs. In order to answer this question, the next section returns to an analysis of the political environment in which NASA is situated. In particular, we examine how NASA and Congress may engage in strategic interactions in such a way as to enable a politically sustainable fulfillment of the Presidential Vision for Space Exploration goals and the Congressional desire to maintain American pre-eminence in human spaceflight.

## VI. Strategic Analysis

As an Executive Branch agency, NASA is bound to execute the directives of the President. These include construction of a CEV by 2014 and a return to the Moon by 2020. Recent Congressional testimony indicates that key members of Congress value an American human presence in space [26-35]. A temporary removal of this presence due to a gap between the retirement of the Space Shuttle and the deployment of the Crew Exploration Vehicle justifiably concerns these members of Congress, particularly given the schedule overruns that NASA has exhibited in the past when developing new vehicles. These same members have also indicated that the ability to accelerate the CEV is “largely a question of resources”, suggesting a willingness to provide funding should NASA request it [36-39]. In effect, the absence of American presence in space raises the salience of space exploration in Congress, allowing for a deviation from NASA’s baseline incremental funding.

Given the current “go as you can pay” paradigm for space exploration, there is no guarantee that future Congresses will be willing to provide the funding required to engage in lunar exploration. This is particularly true since, once the CEV is executing missions in LEO, the American presence in space will be restored. Just as there was no Congressional directive to return to the Moon prior to the *Columbia* accident, there is unlikely to be a Congressional directive to do so following the CEV’s deployment. As previously stated, NASA’s standard *modus operandi* is as an incremental agency. During periods where NASA’s goals are not of primary importance to Congress (i.e., they are ancillary, instead of primary, policy), we can expect funding to be scarce. Thus, if NASA is to successfully implement the President’s directive to return to the Moon by 2020, development of the lunar capability must occur when there is funding available to support it.

NASA is the primary organization that possesses the technical expertise and credibility, and therefore the ability, required to determine the CEV architecture. Furthermore, NASA is the primary organization that can credibly determine when, and how much it will cost, to deploy the CEV. Assuming that Congress does indeed value the ability to send American astronauts to LEO sufficiently to provide extra funding for the acceleration of the CEV, and that once the CEV has been deployed, Congress does not significantly value a return to the Moon, it is in NASA’s best interests, in implementing the President’s directive, to develop a CEV that can be upgraded for lunar capability at minimal future cost. For example, this case suggests that NASA should develop a new heat-shield rather than using Shuttle TPS elements on the CEV. More generally, it is unclear whether funding will be available in the future to execute the necessary upgrades needed to explore the Moon. Thus, the politically sustainable course of action would be to build a CEV that minimizes future upgrade costs. Taken to an extreme, this suggests that NASA develop a CEV with lunar capability up-front rather than engage in multi-block deployment. To the extent that Congress is willing to provide support above an incremental level, future costs would be reduced. As such, modulating the cost of a given architecture allows NASA to have an impact on Congressional, and therefore national, policy.

Political sustainability is intimately tied with goals, values and interests. In particular, a program will be sustained if it is delivering value to the stakeholders who are contributing the resources necessary to keep it going. Value delivery is a necessary condition, but it is not a sufficient condition. This is particularly true in situations in which there are limited budgetary resources and many worthy goals to address with those resources. Such a situation is encountered on a regular basis by any number of government programs attempting to obtain federal funding from Congress. A program is unlikely to receive additional funding if it is perceived that the program can maintain a consistent pattern of operation without it. In particular, NASA provides Congress (and by extension, the American people) with human spaceflight capability. Until that capability is absent, Congress is unlikely to support a funding increase for human spaceflight, and may even reallocate funding in the face of more pressing concerns. The intuition for this conclusion is that Congress, already receiving human spaceflight capability at a lower funding level, may tend to take it for granted, driving budgetary incrementalism. Put simply, Congress will not pay more to receive what it is already getting. If, however, there is a perception that the capability is under threat, Congress will be willing to provide support up to the point where a determination is made that the benefits no longer outweigh the costs. In order to maintain political sustainability, a successful case must be made on a yearly basis for why funding is necessary to accomplish certain objectives that are consistent with both Presidential and Congressional goals. If the objectives of NASA do not coincide with those of Congress, incremental funding will result as other, more salient, priorities are met.

## VII. Tying It All Together

Whereas a program’s costs are driven largely by technical and organizational parameters, Congressional budgeting behavior is driven largely by salience and political compromise. In the absence of a salient interest, NASA can expect to receive an incremental funding baseline – approximately equal between years but for minor stochastic perturbations. On the other hand, periods of non-incremental behavior arise when outside factors conspire to divert funding to or from NASA’s budget. This upset in the status quo can occur for many, often unpredictable reasons. Congressional testimony links salience of NASA’s agenda to national security in the specific context of returning astronauts to LEO after the loss of the Space Shuttle *Columbia*. In addition to the motivations of national pride and prestige associated with having an American presence in LEO, many members of Congress derive distributive benefits from NASA’s human spaceflight programs. The threat inherent in the prospect of the loss of these values and associated distributive benefits is sufficient to gain Congressional attention and, if the testimony of certain members of Congress serves as any indication, additional funding. Nevertheless, the conditions of Congressional salience cannot be expected to last forever. If history is any indication, NASA's budget can be expected to return to an incremental steady-state following the fulfillment of Congress' desire to return humans to LEO. If NASA is to fulfill the President's directive to affordably and sustainably explore beyond LEO, funding must be present to enable a successful CEV upgrade. Given this environmental context, design for ease of upgradeability becomes a salient concern for NASA. Political sustainability within this context suggests that NASA should build a CEV that may be easily upgraded later in the future. In the specific example provided by the TPS, NASA should begin development of the Block 2 TPS now while there is funding available. For example, if it is at all possible to minimize future funding by including a lunar-capable TPS in a Block 1 CEV, it should be done.

Delaying lunar expenditures until after LEO deployment is not politically sustainable from a lifecycle perspective. Indeed, if the costs of upgrade from Block 1 to Block 2 are too high, the deployment of a lunar-capable CEV will be delayed, and possibly cancelled, in the face of more pressing national priorities. Thus, acceleration of the CEV should be undertaken with utmost care to ensure that the means by which this acceleration is implemented do not undermine the Vision for Space Exploration. This dynamic illustrates the differing preferences of Congress and the President. To the extent that Presidential and Congressional goals are in alignment, one may expect definite action accompanied by the funding required to carry it out. It is therefore unlikely that the Block 1 CEV will be cancelled or significantly delayed. Nevertheless, if the Presidential goal of lunar exploration is to be carried out, NASA must take advantage of the current political environment to design a CEV that does not inspire Congressional ambivalence by exceeding future funding expectations. This will more easily enable a sustainable lunar exploration by helping to keep future development costs for the CEV under the incremental level enforced by Congress-NASA power dynamics.

Political sustainability on the part of NASA requires a constant attention to the details of technical design and political choice. Although it might also seem to require a prescience that extends over several years, general principles can apply to how systems are developed in a politically sustainable fashion. In particular, the presence of events that raise an agency's national salience allows that agency an opportunity to briefly increase expenditures for the purposes of reducing future costs. So as to maintain credibility, these expenditures must be associated with the goals of Congress. Nevertheless, NASA's ability to control design implementation allows for the selection of a design that can simultaneously satisfy Congressional directives while enabling ease of future execution of the President's VSE.

## VIII. Conclusion

This paper is largely concerned with political sustainability. In the broadest sense, political sustainability requires an active process of cooperation and coordination between system architects, political experts and technically-trained engineers. Most importantly, the interdependence of those in the technical and political realms must be realized. This requires that the concerns of Congress and other stakeholders in the political process be explicitly taken into account during the technical design process. Likewise, political actors must be informed of the consequences of their decisions upon the technical architectures. Communications between representatives of the President and members of Congress must be structured so as to clearly reflect the core values of our elected representatives. These communications must focus on enabling forward thinking both among agencies and Congress. The role of the system architect in this regard is therefore one of translator – the architect must be able link the technical parameters of the engineering system under consideration to the salient values of the policy-makers who are supporting it. For this support to be sustained, the architect must be able to translate the long-term considerations of system design into short-term, frequently-delivered benefits for the system's stakeholders. To paraphrase [2], the concept of political sustainability does imply limits – not absolute limits but limits imposed by existing technological capabilities and political organization on budgetary resources and by the ability of the taxpayer, through Congress, to fund the human expansion into space. But technology and political organization can be both managed and improved to make way for a new era of space exploration.

## Acknowledgements

The authors would kindly like to thank the following people and organizations for their input and constructive comments: Mr. G. Ryan Faith, Prof. Ed Crawley and the MIT Space Architects Research Group, the MIT Center for Aerospace Systems Policy and Architecture Research, the MIT Space Systems Policy and Architecture Research

Consortium and Dr. Karen Marais. This research was generously supported by a grant from the NASA Office of Program Analysis and Evaluation.

## References

1. Bush, G.W., *The Vision for Space Exploration*, NASA, Editor. 2004.
2. Brundtland, G.H., et al., *Report of the World Commission on Environment and Development*. 1987, General Assembly of the United Nations. p. 1-374.
3. NASA. *NASA's Exploration Systems Architecture Study*. [PDF] 2005 [cited 2006 March 9]; Available from: http://www.nasa.gov/pdf/140649main_ESAS_full.pdf.
4. The Charles Stark Draper Laboratory Inc., *CONCEPT EXPLORATION & REFINEMENT STUDY FINAL REPORT*. 2005, NASA Exploration Systems Mission Directorate.
5. Weigel, A.L. and D.E. Hastings, *Interaction of policy choices and technical requirements for a space transportation infrastructure.* Acta Astronautica, 2003. **52**: p. 551-562.
6. Bush, G.W. *A Renewed Spirit of Discovery*. [html] 2004 [cited 2006 April 19]; Available from: http://www.whitehouse.gov/space/renewed_spirit.html.
7. Lindblom, C.E., *The Science of "Muddling Through".* Public Administration Review, 1959. **19**(2): p. 79-88.
8. Jasanoff, S.S., *Contested Boundaries in Policy-Relevant Science.* Social Studies of Science, 1987. **17**(2): p. 195-230.
9. Van Dyke, V., *Values and Interests.* The American Political Science Review, 1962. **56**(3): p. 567-576.
10. Simon, H.A., *On the Concept of Organizational Goal.* Administrative Science Quarterly, 1964. **9**(1): p. 1-22.
11. Davis, O.A., M.A.H. Dempster, and A. Wildavsky, *A Theory of the Budgetary Process.* The American Political Science Review, 1966. **60**(3): p. 529-547.
12. Davis, O.A., M.A.H. Dempster, and A. Wildavsky, *Towards a Predictive Theory of Government Expenditure: US Domestic Appropriations.* British Journal of Political Science, 1974. **4**(4): p. 419-452.
13. Wildavsky, A., *The Politics of the Budgetary Process*. 1964: Little, Brown & Co.
14. Johnson-Freese, J., *Congress and Space Policy*, in *Space Politics and Policy*, E. Sadeh, Editor. 2003, Kluwer Academic Publishers: Boston. p. 79-103.
15. Logsdon, J.M., *Choosing Big Technologies: Examples From the U.S. Space Program*, in *Choosing Big Technologies*, Krilg, Editor. 1992: Washington, D.C., USA. p. 139-150.
16. Logsdon, J.M., *The Space Shuttle Program: A Policy Failure?* Science, 1986. **232**(4754): p. 1099-1105.
17. McCurdy, H.E., *The decision to build the Space Station Too weak a commitment?* Space Policy, 1988: p. 297-306.
18. McCurdy, H.E., *The Space Station Decision: Incremental Politics and Technological Choice*. 1990: The Johns Hopkins University Press. 312.
19. Gehman, H.W., Jr., et al., in *The CAIB Report*. 2003, Columbia Accident Investigation Board.
20. Technology News. *New NASA Boss Pushes to Replace Shuttle*. Technology News [HTML] 2005 May 3 [cited 2005 July 4]; Available from: http://www.technewsworld.com/story/43090.html#.
21. Cohen, L.R. and R.G. Noll, *The Technology Pork Barrel*. 1st ed. 1991, Washington, DC: The Brookings Institution. 400.
22. Wooster, P., et al., *Accelerating the Development of the Crew Exploration Vehicle*. 2005, Massachusetts Institute of Technology

Draper Laboratory

Georgia Institute of Technology. p. 3.

23. Putnam, Z.R., et al. *Entry System Options for Human Return from the Moon and Mars*. in *AIAA Guidance, Navigation and Control Conference*. 2005: Georgia Institute of Technology.
24. NASA Ames Research Center. *Request for Information: CEV Heatshield Materials for LEO Return*. [doc] 2006 [cited 2006 March 28]; Available from: http://prod.nais.nasa.gov/eps/eps_data/118831-OTHER-001-001.doc.
25. Guerra, L. and R. Shishko, *Estimating the Cost of Crewed Space Systems*, in *Human Spaceflight Mission Analysis and Design*, W.J. Larson and L.K. Pranke, Editors, McGraw Hill. p. 933-959.
26. *VA/HUD Subcommittee's report on HR 5041*. 2004.
27. Calvert, K. *Rep. Calvert Applauds House Passage of H.R. 3070 the NASA Authorization Act of 2005*. spaceref.com [html] 2005 July 22 [cited 2005 July 22]; Available from: http://www.spaceref.com/news/viewpr.html?pid=17474.
28. DeLay, T. *DeLay: NASA Funding Fulfills President's Space Vision; House Passes NASA Funding Bill by Vote of 418-7*. spaceref.com [html] 2005 June 17 [cited 2005 July 4]; Available from: http://www.spaceref.com/news/viewpr.html?pid=17159.
29. DeLay, T. *Delay: NASA Prepared to Make Next Giant Leap; House Passes NASA Authorization Bill by Vote of 385-15*. spaceref.com [html] 2005 July 22, 2005 [cited 2005 July 22]; Available from: http://www.spaceref.com/news/viewpr.html?pid=17478.
30. Gugliotta, G., *House to Back Bush on Moon, Mars Trips*, in *The Washington Post*. 2005: Washington, DC. p. A05.
31. House Science Committee. *House Overwhelmingly Passes NASA Authorization Bill*. spaceref.com [html] 2005 July 22, 2005 [cited 2005 July 22]; Available from: http://www.spaceref.com/news/viewpr.html?pid=17476.

32. House Science Committee. *In Testimony Before Appropriators, Rep. Boehlert Urges Funding for American Competitiveness Initiative*. [html] 2006 April 6, 2006 [cited 2006 April 7, 2006]; Available from: http://www.spaceref.com/news/viewpr.html?pid=19464.
33. House Science Committee Democratic Membership. *Bipartisan Compromise Yields Positive Results for NASA*. spaceref.com [html] 2005 July 22, 2005 [cited 2005 July 22]; Available from: http://www.spaceref.com/news/viewpr.html?pid=17475.
34. Hutchison, S. *Senators Hutchison, Nelson Urge Importance of Return to Flight*. spaceref.com [html] 2005 July 21, 2005 [cited 2005 July 22]; Available from: http://www.spaceref.com/new/viewpr.html?pid=17458.
35. United States Senate. *Floor Statements by Senators Huchison (sic) and Nelson Regarding "Sense of the Senate Regarding Manned Space Flight"*. spaceref.com [html] 2005 July 22, 2005 [cited 2005 July 22]; Available from: http://www.spaceref.com/news/viewsr.html?pid=17433.
36. *Congressional Record Excerpt: NASA Authorization Act of 2005 -- Senate -- September 28, 2005*, in *United States Senate*. 2005, Congressional Record: Washington, DC.
37. *Hearing on Fiscal Year 2006 NASA Appropriations*, in *Committee on Appropriations: Subcommittee on Commerce, Justice and Science*. 2005: Washington, DC. p. 33.
38. *Hearing on Human Spaceflight*, in *U.S. Senate Committee on Commerce, Science and Transportation: Subcommittee on Science and Space*. 2005: Washington, DC. p. 16.
39. *NASA Authorization FY 2006-2010*. 2005.