Multi-Stakeholder Quantitative Analysis of Sustainability for Value Delivery Systems

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"It must be remembered that there is nothing more difficult to plan, more doubtful of success nor more dangerous to manage than the creation of a new system.

For the initiator has the enmity of all who profit by the preservation of the old institution and merely lukewarm defenders in those who would gain by the new one."

Nicolo Machiavelli - 13^{th} century

"Not everything that is countable counts, and not everything that counts is countable."

Albert Einstein – 20^{th} century

To Antonella

Abstract

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This thesis presents a model to analyze multi-stakeholder decision-making and its application to Space Exploration strategy. The analysis of decision-making for Space Exploration is especially difficult because of the complexity of the value delivery process and the extended time frame to deliver value. In order to analyze the sustainability of Space Exploration, we use the hypothesis that only stakeholder groups that should be considered are those that control resources needed for the survival and growth of the initiative. Consequently, the key to sustainability lays in a tiered multi-attribute decision- making process, where the top layer is populated by the needs of Space Exploration as a Value Creating System (VCS), its second layer is the stakeholders who control the resources that satisfy those needs, and its third layer is the stakeholders' needs. Our model tries to measure the ability of different architectures to increase stakeholder needs satisfaction, thus increasing the likelihood that those stakeholders will provide resources back to the VCS, which is the key to the VCS's survival. The model uses a numerical extension of the Kano model of quality to weight the criticality of the needs. The feedback loop of value to and from the VCS is modeled as a flow of vectorial elements. The model uses the divergence in the data captured to generate a stochastic process, thus providing a probabilistic mapping of the characteristics of each architecture option. The main output is a graphic with the trade between the architecture option capability of increasing the feedback of resources to the VCS in one axis and its capability of gathering consensus across the different stakeholder groups in the other axis. This diagram shows that there is an efficient frontier which trades value and stability, showing some architectures as less stable because of the alienation of some stakeholders, and thus with reduced consensus, but at the same time a higher feedback of resources to the VCS. Other architectures are shown to be more stable by creating a consensus opinion among stakeholders; but in order to do so, they might sacrifice some amount of resource feedback to the VCS.

Keywords

Stakeholder analysis, space exploration, space systems architecture, value delivery, feedback, stochastic model, organization strategy, Kano model of quality, multi-attribute utility, system dynamics, decision making, system architecture

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Foreword and Thanks

It has been an enormous challenge to write this work.

The problem of multi-stakeholder analysis is present in our life everyday. Every one, personally, has to balance opposite interests, trying not to alienate powerful forces around us, but at the same time managing to best satisfy our needs. More complex, and at the same time with the higher impact is the balancing process performed by Governments, their Agencies, Corporations, and large Organizations in general, dealing with parties that are not willing, or even forbidden to negotiate

It is our intent to present a methodology that would allow taking decisions based on the best interest of the large organization of interest.

As any new idea, this one needs further development, yet we have tried to present the essential concepts, and to propose an approach for each of the steps of the framework. These ideas aspire to provide some guidance on this balancing act between the exercise of power and the need for consensus.

We hope the errors are few, and those found encourage the readers to improve this work.

The author would like to thank his wife, Gisella, whose support in so many different ways made this work possible, and his daughter Antonella, whose laughter gave him the strength to finish. We also want to thank our family in Peru: Claudio, Susana, thanks so much for your constant encouragement.

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To the author fellow researchers and friends, from whom he has learned so much: Dr. Geilson Loureiro, Dr. Eric Rebentisch, Julien Lamamy, David Broniatowski, Ryan Boas, Tom Speller, Paul Wooster, Wilfried Hofstetter, Willard Simmons, Bruce Cameron.

Y al Señor de los Milagros, pronto seran 5 años desde aquel Octubre, gracias!.

And the warmest thanks to the MIT community at large. The author felt at home these wonderful years.

Sandro Catanzaro

1. The need for a framework to evaluate complex, multi-stakeholder value delivery systems

1.1. Analysis of value delivery for complex systems

The focus of our research is the sustainability of complex systems over time and the conditions lead to failure or success of those systems. Our research is based on the observation that a common characteristic of sustainable systems seems to be that they deliver value to parties that control resources, which the system needs for its survival and growth.

While it would be desirable to optimize the value delivery process described above, the optimization is not trivial because

- the path through which the value flows is not always direct
- there is not a single value recipient
- what constitutes value to one party might be damaging to another
- there is uncertainty on what actually is valuable

If we understand that the architecture defines the concept that links functions, forms and interfaces[1], then the architecture can be defined by the set of decisions that are taken in order to choose a specific form and function over its alternatives.

In our study of the value delivery system, we can identify a feedback loop that goes from the agent that implements the architecture, the Value Creating System (VCS), to the recipients of the architecture effects, the stakeholders. Stakeholders, in their turn, provide resources needed by the Value Creating System. It is necessary to clarify that the word “resources” needs to be understood in a liberal way, comprising every need that the Value Creating System might exhibit in order to implement the system.

If we can ensure that the prospective sustainable system will receive a generous and stable supply of resources, then it will be sustainable over time, and it will prosper through growth, which is this study’s goal.

Our research presents a quantitative tool that could help the architect to select those architecture elements that will increase the amount of resources, which the Value Creating System receives as result of the feedback, and reduce the political risk of the value delivery process.

While strategies that maximize value can be achieved through policies focused on short term results, these policies might alienate less powerful stakeholder groups, which in the longer term might affect the resources supply. Hence, there is a need to balance the requirements of powerful stakeholders and less powerful ones, which is achieved through the maximization of consensus among stakeholder groups.

We intend to measure the consensus by measuring the lack of dispersion of stakeholder satisfaction. Under this postulate, architectures that generate the same satisfaction in every stakeholder group (without taking into account whether the satisfaction is high or low) would be more stable than others that generate a different degree of satisfaction on the groups analyzed.

The tool we present generates a two dimensional graphic, where each architecture can be mapped.

- One axis indicates the expected amount of resources that the Value Creating System will receive as a result of the feedback

- The other axis indicates the expected stability of the architecture, represented by the stakeholder consensus about the architecture value.

We expect to find an efficient frontier, where the best architectures will oscillate between a higher amount of resources on the feedback loop and relatively lower stability, and a higher stability but with relatively lower amount of resources.

A particular instance of a complex system is the one that intends to develop the exploration of the Moon and Mars. For that objective to happen it would be needed to implement an architecture that delivers its final results after 30 years of effort and that has to be sustainable during that period of time.

This research uses the space exploration problem as a particular instance of a complex system, which involves multiple parties, a value articulation that is difficult to capture, and an extended period of time over which value would be delivered. By exploring this particular instance, we can better understand the characteristics and limitations of the proposed method, in order to improve and generalize it.

It is expected that this model could be applied to other complex systems, among which we initially have identified international policy systems, countries' development strategies, and corporate strategies.

1.2. Terminology

We will introduce several terms that seem useful to describe the value delivery system we are analyzing.

Value Creating System (VCS) - The system that creates value, and which includes an organization and a set of forms and functions. This system exhibits capabilities and needs for resources in order to deliver on those capabilities.

Architecture - The embodiment of concept, and the allocation of physical/informational function to elements of form, and definition of interfaces among the elements and with the surrounding context[1]. We think of Architecture as the set of decisions defining what the Value Creating System is.

<u>Stakeholders</u> - We will use in the following parts of this work the term "stakeholder" to refer to any party which controls resources of interest to our system. This definition is somehow different of the one used by some authors, but, as we will see, it was the original intention of the creators of the stakeholder theory. Nevertheless, with our liberal definition of the word "resources" we think that most important groups would be included.

<u>Resources</u> We will use the word "resources" liberally, to mean a broad set of needs that our Value Creating System exhibits. These needs include funds, political capital (credibility), and human resources, among others.

<u>Need</u> 'nEd, *noun*, 1: necessary duty: obligation 2 a: *a lack of something requisite, desirable, or useful* b: a physiological or psychological requirement for the well-being of an organism 3: *a condition requiring supply or relief* 4: *lack of the means of subsistence*: poverty [Merriam-Webster Online Dictionary]

1.3. Lack of concurrency on needs valuation

We postulate that our architecture delivers value when it satisfies a specific need of a particular party. Because resources are always a constraint for any Value Creating System, it seems natural that their use should be prioritized across the set of possible actions to be taken by the VCS.

The prioritization process is not simple, because we will not find alignment in the needs of different stakeholders. Moreover, it might be possible to identify needs exhibited by one stakeholder that, if satisfied, generate dissatisfaction for another. A direct consequence of this lack of alignment is that it is not possible to prioritize needs without implicitly prioritizing some stakeholders over others.

One alternative to avoid entering into the political field is to evaluate the satisfaction that each architecture generates for every stakeholder, and present the satisfaction per stakeholder group to a political decision maker. The political decision maker, will then balance the requirements of different parties in order to decide on a certain architecture[2]. We find this mechanism to be useful, but limited, because of the difficulty the political decision makers will face to integrate all the information they will receive.

Our goal is more ambitious. Since we postulate the highest goal to be the survival of the system, we are at the same time making the architect a top-level decision maker. As a result, the aggregation we propose happens in a natural way, giving priority to the stakeholders that possess a larger say over the VCS's ability to implement an architecture. Our analysis will provide to the decision maker a better understanding of the consequences of some architectural decisions.

1.4. Uncertainty in the value identification process

While our goals are ambitious, the model has to be anchored in the reality. It will be extremely difficult to assess with precision how value flows from the architecture to each stakeholder group, and the relationships between the different groups. At best, we could find some values and error ranges for these interactions, parameters that will help us understand the value delivery process.

The fact that human and organizational actions generate reactions on the affected parties has been known since the first interactions between humans, however the study of those interactions through numerical modeling has a history of no more than 50 years, being pioneered by the field of System Dynamics at MIT. These methods are highly valuable, but require a detailed understanding of the nature of the interactions involved. Our proposal intends to extend the reach of the System Dynamics paradigm to areas in which our understanding of the world is limited.

The model presented uses a very simple adaptation of a System Dynamics feedback loop which does not use any accumulation. The use of an accumulation on the measure of stakeholder satisfaction would make this model closer to reality and add an additional time dimension, but is out of the scope of this work. Nevertheless, we find of interest for System Dynamics the use of uncertainty in defining parameters, and the use of a vectorial flow, as opposed to scalar.

The proposed model incorporates the lack of absolute certainty of what constitutes value, and uses a probabilistic propagation of value through the different interactions, which in turn will provide a profile of expected resources received back, and a range of uncertainty in the results.

We think that both the expectation and the variance of value are of interest. While the expectation of value provides us a measure of what is the most probable result, and its optimization will yield the most probably valuable architectures, the reduction of the variance is at least as important, since it will reduce our lack of understanding about the value delivery process, and will help us to focus our research efforts on areas that are more uncertain.

1.5. Multiple interacting parties involved

The stakeholder analysis was born from the understanding that not only the classic enterprise shareholders are impacted by the enterprise activity, but also other parties such as suppliers, employees, government, the community and other special interest groups. These other parties have direct or indirect ways to affect the enterprise.

The concept of stakeholders is therefore a superset of the shareholder concept, and includes the analysis of other parties that were usually not taken into account by the classic economic analysis. The enlargement of the group of interactions increases the complexity of the analysis, but provides additional insights into how the architecture affects the value delivered, and into the risk of being vetoed by one or several affected parties.

We are interested in providing a map that could represent on one axis the value expectation and variance of a specific architecture, as described in section 1.4 and on the other axis some measure of the stability of that same architecture.

An anticipated result, derived from the lack of concurrency of needs, is that it might be necessary to sacrifice some value expectancy in order to increase the consensus of the architecture.

1.6. Traditional consensus building approach might not be applicable

The traditional approach to decision making, when facing contradictory needs presented by multiple parties, has been to build consensus through structured meetings of expert representatives of those parties[3].

For the meetings to be successful in reaching a fair and binding agreement, two conditions should happen:

- The benefits that the represented groups would derive from the decision should be relatively simple and well understood by the representatives
- The representatives should have been invested with authority to impose the agreement inside the group they represent

These two conditions are not present in the case we explore.

Space Exploration benefits are not always direct, and in most cases are of low priority for the represented groups. The analysis of indirect benefits results in complexity, which is not studied in depth by stakeholders who use their time on matters more pressing to them.

The identification of adequate representatives is difficult, and sometimes impossible. Stakeholder groups, such as the US Congress, are inherently unable to present a unique representative, with a unique position, and with a delegated decision making power.

Even if those two conditions were met, it would be extremely difficult to achieve some kind of consensus through a dialogue or conference, which would be subject to a political dynamic, not necessarily guided by the need to increase the system sustainability

These reasons make the traditional approach to consensus building through dialog not applicable to the proposed example.

1.7. Proposed solution

In order to analyze how sustainability is achieved, this research proposes to use a model that shares with system dynamics the feedback paradigm, but that differs from it in the use of vectors flowing through the loops, instead of scalars.

This research postulates that any system's ultimate goal is its own survival and growth, chances of which would be improved through an increased and safe supply of resources needed for those ends. The space exploration enterprise is not different, and in order to survive over the years it will have to provide for itself a stable and increased resource flow.

This research intends to help the decision maker, faced with the task of architecting such a complex system, by providing a probabilistic map of value and consensus for each analyzed architecture.

The analysis will be made by assessing the alignment of each architecture with a set of objectives and the alignment of those objectives with each stakeholder's needs.

These assessments could be represented by matrices with a similar structure to the one used in the Quality Function Deployment method[4]. The elements of the QFD matrices to be used will not be specific numbers but parameters for probability density functions that will represent the likelihood of a certain answer. By working with these matrices, we could identify how much each architecture increases or decreases the different stakeholders' satisfaction level in a direct way.

Nevertheless, it is foreseen that some stakeholders might not be impacted in a direct way, and that the value they receive might travel through another group before reaching them. In order to capture this effect we will use an additional matrix to map the interactions between stakeholders.

After the effect of the stakeholder interaction matrix has been taken into account, a final satisfaction level for each stakeholder would be identified. The final satisfaction level will be compounded by the ability of each stakeholder to control resources of interest to the VCS, promoting the VCS's interest in satisfying stakeholders, which control resources critical to the VCS's survival.

An alternative measure of interest is the consensus on the value that the VCS delivers across stakeholders. This measure can be approximated by the inverse of the variance of the satisfaction level of the different stakeholders. A smaller variance (and thus a larger inverse) will signal that the stakeholder groups share a similar satisfaction level about the VCS (presence of higher consensus) and as a result, the VCS should have a lower volatility in the flow of resources it will receive.

In order to map each architecture on those two dimensions (expected resources supply, and expected stakeholder consensus), the model will run Monte Carlo simulations, generating random numbers for each element of the model where uncertainty is going to be incorporated.

Each Monte Carlo simulation will provide a density function of resource feedback and consensus per architecture, which could be represented in an XY diagram.

We think that this research will help to extract useful insights from a system that is inherently complex and uncertain, and thus impossible to analyze through traditional tools. We intend to use a stochastic model that would take into account our ignorance and lack of agreement about the different interactions.

The model presented is static in its nature; the formulation responds to what is happening in the present time and does not incorporate the accumulation of stocks that a system dynamics model would use. The extension of this model to a dynamic one poses interesting questions that could be explored in future work.

2. Literature Review

2.1. Literature Review on Information Integration

Anderson's book "A Functional Theory of Cognition"[5] presents a theoretical framework on Information Integration Theory written from the perspective of psychology. While Information Integration Theory was proven empirically, the use of an algebraic model helps to generalize its results.

The author states that the two basic characteristics of Information Integration are its focus on *purposiveness* and its use of cognitive algebra. These two characteristics are intertwined, with *purposiveness* providing a valuation that makes it possible to work in an algebraic way and cognitive algebra providing an analysis tool for value and thus *purposiveness*.

Purposiveness, proposes that behaviors are goal directed, and as a result that it is possible to draw a one dimensional approach-avoidance character for our thoughts and actions. This one dimensional representation encapsulates the concept of value.

The concept of value is useful as long as it becomes possible to measure; yet, this measure has been controversial in Psychology even for the most basic sensations. The field of cognitive algebra provides tools to solve this issue.

The measurement of value has to deal with the fact that actions and thoughts are dependent on *multiple determinants, which* affect them in a different degree. These determinants are personal, and vary not only across groups but also from individual to individual. Cognitive algebra studies the rules of integration for these different determinants, so that they convey a unitary response. While the values from individual to individual might be different, their rules of integration should be similar.

The problem of the three unobservables, shown in Figure 1 below, presents an overview of the IIT framework.

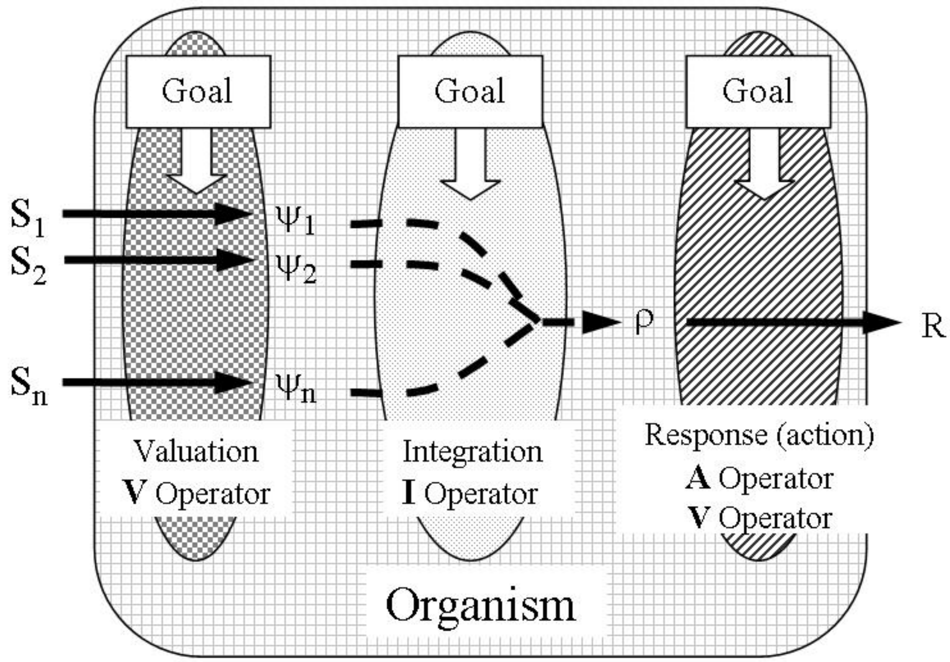

Figure 1. The three unobservables of Information Integration Theory.

In the first step, the valuation operator extracts information from exterior world stimuli S_1 ... S_n, and transforms them into their internal psychological representations $\psi_1 \dots \psi_n$, transformation that is influenced by the Goal. This first non-observable process is internal to the organism.

In the second step, there is an integration of the internal representations $\psi_1 \dots \psi_{n,}$ which are combined into a unitary internal response ρ. In practice, it has been noted that the operators the mind uses have simple algebraic forms, a situation that helps the tractability of the step.

Finally, the third step is the expression of a Response, generated by an operator which transforms the organism-internal response ρ into an observable response R, which is the one expressed by the organism to the exterior world.

This three operators act independently one from the other. Specifically, the independence between Valuation and Integration has been empirically verified.

An important issue is that all three operators, central to the problem discussed, are not directly observable: the internal stimuli are often non-conscious, the integration operator is beyond the reach of introspection, and even the R is a biased estimation for ρ.

In order to deal with this issue, cognitive algebra proposes the test of parallelism, which consists of analyzing the external response R when the organism is presented with a combination of stimuli levels, through a factorial approach. It is said that the patterns are parallel, if the line generated at analyzing the different levels of S_i at a certain combination of levels for the remaining $S_1 \ldots S_n$ is parallel to the line generated by S_i at every other combination of levels for the remaining $S_1 \ldots S_n$, as shown in

Figure 2 below.

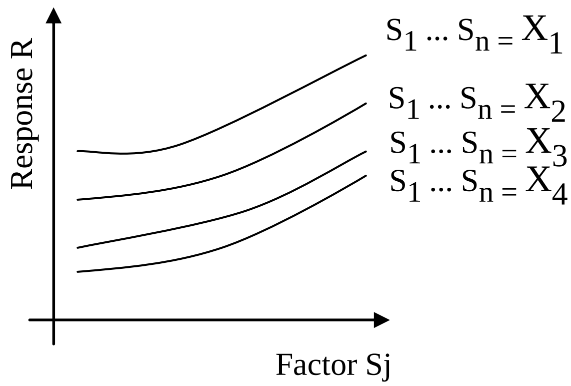

Figure 2. The figure shows the change on a Response R, when the Factor Sj varies.

While the observation of parallelism would support an additive rule to integrate stimuli, the fact that parallelism is not always exhibited would suggest an averaging rule as shown later. Parallelism also supports the invariance on the meaning of each stimulus S_i when it is observed under different combinations of the remaining $S_1 \ldots S_n$ stimuli.

It is using an algebraic system that is possible to unify the particularizing approach of psychology and the generalizing intent of the scientific method. While valuation will take into account different individuals' values, the integration rule should be applicable to a general population providing a means to generalize results.

The lack of parallelism suggests the use of an averaging rule, which is able to account for most of the cases studied in cognitive algebra. The main differences between the addition and averaging rules are the use of weights for each stimulus and the presence of an initial state:

$$\rho_{ij} = \frac{\omega_A \psi_{Ai} + \omega_B \psi_{Bi} + \omega_0 \psi_{0i}}{\omega_A + \omega_B + \omega_0}.$$

As a result, the addition rule is a particular case of the averaging rule, when the weights are equal.

As we observe in the formula, we could avoid the use of the denominator terms by using normalized weights. This will be further commented in section 4

The following three properties of conceptual analysis support the application of the averaging rule:

- Subadditivity, which implies that a second informer of the same value has a lower weight, could be explained through the use of averaging, and not through the use of the additivity rule.

- Neutral information, which refers to the case where a non-informative stimulus actually reduces the effect of the following ones; a fact that, again, is difficult to explain through additivity, but not with the averaging rule.

- The Opposite-effects Paradox points to the fact that the same stimuli can have different and opposite effects depending on what the previously analyzed values are. A medium value added to a sequence of low values will have a positive increase; that same medium value will have a negative effect if it follows a sequence of negative values. While this fact cannot be explained by the use of the additive rule, without changing the sign of the value, the averaging rule is able to explain this behavior.

The mechanisms of learning could be explained through an integration rule, but expressed in sequential way, where the past value of a certain ρ generated by the accumulation of stimuli over time is affected by new ideas in a way proportional to the difference of the previous experience from the new one. In other words, the results that are farther away from the organism expectation will yield a higher correction to the internal ρ, as shown in the following formula:

$$\rho_n = \rho_{n-1} + \omega_n(\psi_n - \rho_{n-1}).$$

Conceptual analysis sometimes depends on background assumptions that are taken for granted, without realizing the fact of the assumptions being made.

Conclusions

The book is a psychological analysis of how knowledge-based decisions are taken.

It proposes, and shows empirical proof, that the *averaging model* has been found to be the most adequate to explain Information Integration

$$\rho_{ij} = \frac{\omega_A \psi_{Ai} + \omega_B \psi_{Bi} + \omega_0 \psi_{0i}}{\omega_A + \omega_B + \omega_0}.$$

This formula is closely linked to the one used in multi-attribute decision making.

Learning mechanisms can be modeled also through an integration model which is sequential. The correction to introduce at each iteration is higher if the weight ω_n is higher and if the difference between the new stimuli and the old value is larger.

$$\rho_n = \rho_{n-1} + \omega_n(\psi_n - \rho_{n-1}) .$$

2.2. Literature review on Stakeholder Theory and Integration of objectives

Freeman's classic book "Strategic Management, A Stakeholder Approach"[6] on Stakeholder analysis is framed from the perspective of a manager, a position that an architect shares when trying to define a strategy. The study, written in 1984, might be one of the first comprehensive treaties on stakeholder analysis.

The author states that stakeholders are groups that have a stake in the organization, so they have means to influence it. Freeman's work not only tries to *understand* stakeholders but also proposes ways to *manage* or affect them, making his work very relevant to our research.

Freeman proposes four perspectives to analyze stakeholders:

- A corporate planning view, where stakeholders' objectives must be balanced for the survival of the firm. In this perspective there are two categories of stakeholders, the primary ones, expressing economic objectives, and secondary ones, which present social objectives.

- A systems theory view, which observes that the stakeholder groups interact in a system, and thus, the goal, is to optimize global objectives, through a collective strategy.

- A corporate social responsibility view, which states that because of the influence of businesses in society, they should take into account not only the owners of the organization but also its employees and the community.

- An organization theory view, which looks to the impact on individuals that the organization might have, and how those individuals that have an impact on the organization's results could be considered the organization's "clientele"

Freeman proposes that a firm can have 5 different types of strategies related to stakeholders:

- Specific Stakeholder Strategy, when the firm chooses to favor a subset of stakeholders, concentrating its efforts on satisfying their needs.

- Stockholder Strategy, when the firm favors the ownership over every other stakeholder group. A closer variant is the financial stakeholder strategy, which favors stakeholders with financial stakes in the firm; these stakeholders are not only the owners but also banks, investors and analysts.

- Utilitarian Strategy, when the firm looks for benefits to society as a whole, trying to "provide the greater good for the greater number of people".

- Rawlsian Strategy, when the firm sees itself as an agent of social change, and tries to favor the less favored groups of society, raising the level of their least well off stakeholders.

- Harmony Strategy, when the firm's strategy is aligned as closely as possible with its community, and yearns to solve any divergence of interests with it through dialog and mutual understanding.

Freeman also proposes that by extending the classic competitive strategy framework proposed by Porter[7], it would be possible to engage with stakeholders in four different ways, depending on their capabilities for threat and cooperation. These possible engagements are shown in Figure 3

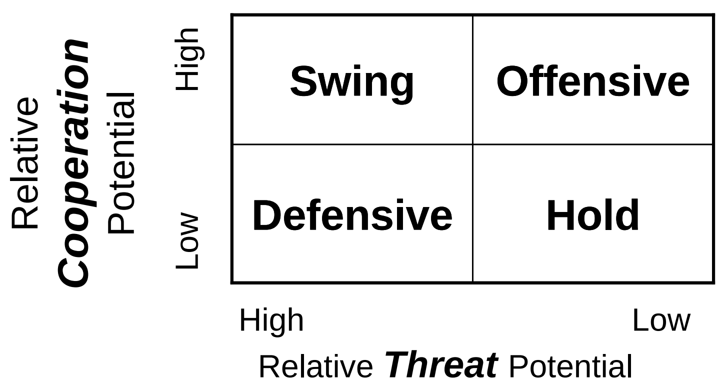

Figure 3. Generic Stakeholder Strategies.

Stakeholders that should be dealt through the Swing strategy will be influenced towards

- Formal rules change through law
- Change in the decision forum
- Change in the kind of decisions to take
- Change in the transaction process

Offensive strategies will consist of

- Change in beliefs about the Value Creating System
- An innovative approach
- Change in the stakeholders' objectives
- Adoption of the stakeholder strategy
- Linkage of the program to others that the stakeholder views favorable
- Change in the transaction process

Defensive strategies are based on

- Reinforcing current beliefs about the Value Creating System
- Maintenance of the current programs
- Linking issues to others that the stakeholder sees favorably
- Letting the stakeholder drive the transaction process

Holding strategies will

- Do nothing and monitor existing programs
- Reinforce current beliefs about the Value Creating System
- Guard against changes in the transaction process

Nwankwo and Richardson[8] present the analysis of force fields of critical stakeholders as a way to harness the contributions of powerful allies, and thus improve the rationality of strategic decision making.

They also introduce the idea of two opposing visions of organizations. One is called pluralist, in which there is a zero sum game, where the winnings of one group are balanced by losses of another. The other tendency is called unitarist, in which there are common interests and cooperation. This idea of opposite interests, one linked to power, and the other to cooperation, is also a central point of the work we present. Our diagram of resources feedback and stakeholders' consensus shows the tension between those opposite goals.

Nwankwo and Richardson also mention the importance of the control of resources that are critical to the Value Creating System operation. Stakeholders that control critical resources gain power, and if they monopolize the access to such a resource, they gain absolute power. Our research borrows this concept of criticality of resources as a way to weight stakeholders.

Sternberg[9] argues that the recent change in the meaning of the term "Stakeholder" has rendered the Stakeholder Theory ineffective as a result of the lack of tools to balance the objectives of numerous groups.

She argues that while initially the term "stakeholder" was used to name groups without which the organization would cease to exist, it has now been extended to any group that could be affected by the organization. This extension makes the Value Creating System accountable to everyone, and thus, actually accountable to no one.

Our proposal is aligned with the original meaning of “Stakeholder”, and we would disregard stakeholder groups that do not have controlling power over critical resources.

Sternberg also argues that the key to successful stakeholder policy is to optimize long term value to the owner of the organization. Our model takes into account the temporal dimension through the interactions between stakeholders; the model allows doing a shorter or longer term analysis by increasing or decreasing the intensity of those interactions.

In his analysis of who actually appropriates the benefits of the competitive advantage of an organization, Coff[10] argues that it is not necessarily the owners of the organization, but instead those groups that possess bargaining power. In his analysis, he proposes that the group’s bargaining power will increase with the concurrence of four factors:

- Stakeholders’ capability of a unified action
- Stakeholder access to information
- High replacement cost to the Value Creating System
- Low exiting cost to the Stakeholder group

While bargaining power will provide resources to any stakeholder, it is to be noted that Coff’s analysis is centered in the ability of employees (agents) to appropriate rent generated by a firm’s competitive advantage. While not a central point of our interest in the paper, we are also aware of the special power that employees possess on the results of an organization, because of the last three factors.

Jensen[11], in his paper on value maximization and stakeholder theory also argues that is impossible to maximize in more than one dimension at the same time and proposes that maximization of the long term value of the Value Creating System is the most adequate criterion for making the required trade-offs between opposite interests. He proposes that the only way to discern between different positions is to have a unique measure along the axis better / worse. This is a concept that we have already identified in Anderson’s work.

Jensen also mentions the tension between balancing short and long term benefits, and also neighboring and collective interests. In this respect he argues that the market is able to balance those interests in the most efficient way. We would suggest that this happens when it is possible to ascertain that the market has few imperfections, situation that would not be so in every case.

Finally, Jensen also analyzes the Balanced Scorecard theory, which he identifies as a concept similar to Stakeholder Analysis; as a consequence, his critiques come from the same direction, underlining the impossibility of the Scorecard to provide a number that would signal if one strategy is better or worse than another.

An interesting section of Jensen's paper is dedicated to argue Senge's ideas on Stakeholder theory, presented in chapter 2 of the book "Breaking the Code of Change"[12]. While in general, Jensen's positions are different to the broader (and sometimes softer) analysis that Senge proposes, Jensen captures a metaphor of Dr. Senge's, the analogy of the organization as a living system. Jensen states that any living system needs resources to survive and faces a continuous threat of death and extinction if it fails to provide for itself. In the course of our research we devised a similar metaphor.

Senge does not fully support a long term value perspective as the authors we have reviewed. Senge agrees with Jensen that more than one only objective is not an effective criterion for taking decisions, since managers can bend the though decisions to their will, and also agrees that long term value of the firm should guide the decisions of managers. Then, he makes the caveat that those managers are often times more interested in preserving power quotas, than in the long term value of the firm.

The section of the book written by Senge presents a living organism as example of the need for a broader perspective, when preparing strategy for corporations. We have also used this argument during the presentations of our research, yet our conclusions have been the opposite.

The book states that the capabilities of a living system arise from the interplay of design and emergence. While design is specified, emergence happens as a result of the interplay of the elements: living organisms need to breath in order to maintain adequate oxygen levels, but, their interactions with other organisms are result of emergence.

Jensen uses the example to illustrate corporations' functions and purpose, stating that profits are to a corporation what oxygen to an organism: needed for survival. As a contrast purpose is emergent, and result of the interactions of the corporation in the society.

We believe this argument does not take into account that in the daily fight for survival, some organisms will fail, and evolution will preserve the fittest for survival. Since there is a thin line between which part of its resources the organism, or the corporation, can give to external parties, and which part they have to secure for themselves, purpose can exist as long as there is an extra reserve to spend in its creation. Organisms that live in extremely harsh environments have as their only purpose survival; hence, it will depend on the environment where the organism or corporation develops, their capacity to create a broader purpose beyond survival. In the case of the corporation, the manager will have to decide which kind of environment the organization faces.

2.3. Literature review on Decision Making and Utility

We were interested in the analysis of how an increase in the amount of benefit received, would increase the satisfaction of the benefit's recipient. This transformation from benefit to satisfaction is done through a utility function, which was a starting point for our research.

The first results of our review on utility theory showed the prominent results by Morgenstern, Von Neumann and Nash, on Decision Making under Uncertainty. This was not the intention of our research, but to understand, once the benefit is delivered, what drives satisfaction of a party.

We then began to look upon Marginal Utility, and our first guide was chapter 6 of an overview book, written by Soderlind, who comments on the classic early XIX century work by Bentham and Mill.

Bentham and Mill created the term utility, and used it to deal with decision making under certainty conditions, which is what of interest for our work. Their work was done from the perspective of a consumer, doing a commodities' routine shopping.

They started with 2 assumptions on consumer behavior:

- Individuals have a predictable satisfaction driven by their acquisitions

- Individuals will seek to maximize their satisfaction through an adequate mix of acquisitions

From that point, they proposed two postulates:

- The Assumption of Positive Marginal Utility, or principle of non-satiation, which translates as "more utility is the better than less utility", and "there is no limit to the increment of utility"

- The Assumption of Declining Marginal Utility, which states that the additional utility acquired for the (n-1)th amount of commodity increment is higher than the additional utility acquired by the (n)th amount of commodity increment. In other words, the more you have the less you care about getting more.

From these positive and diminishing marginal returns, they drew their major conclusion: for a given basket of commodities and a set of prices; a consumer that maximizes his or her utility will choose to consume in levels such that, the marginal utility for each commodity is equal.

We can understand this conclusion easily if we think that the marginal utility of each commodity is the additional satisfaction achieved by the last infinitesimal of that commodity added to the consumer chest.

If the consumers have only one “dollar” to spend, they will be able to increment their satisfaction in a higher amount by spending that dollar in the commodity with the highest marginal utility. Furthermore, in order to increase satisfaction, it will make sense to them to reduce consumption of those commodities with a lower marginal utility, and spend the saved money in commodities with higher marginal utility. This redistribution of resources will end when the consumers spend their resources in commodities, such that, the marginal return on every one is the same.

After the ideas on marginal utility spending, Soderlind presents some results on the concept of price sensitivity. Price sensitivity answers to the question of how much will change the demand for a specific commodity when the commodity’s price changes. When doing this analysis, individuals are comparing their priorities across all the commodities in the commodities basket.

Three results on price sensitivity are presented

- The sensitivity to price increases as the price of the item relative to the individual’s budget raises

- The sensitivity to price of a commodity increases with the number of substitutes to that specific commodity

- The sensitivity will rise with time, since higher prices encourage individuals to look for alternatives.

As we see, ideas on declining marginal return trace their origins to classic economics theory. Additionally, the concept it is presented the concept that the marginal utility of each good should be the same to maximize the utility of the consumer chest. Finally, it is hinted the idea that sensitivity to price of a good is a function of the good itself, and of the chest of which the good is an element, as a whole.

We also reviewed the classic book on decision making written by Keeney and Raiffa[13], authors who extensively deal with several issues of our research. The book, in fact is a throughout review of decision making for multiple objectives, for the case of one only stakeholder. Our research is based on several of these results and intends to extend them to the case of multiple stakeholders.

The authors present some terminology useful to differentiate between objectives, attributes and goals, and proximate attributes.

- An *Objective* is an action that in general indicates direction in which the VCS should strive to do better. An example will be "to minimize total transit time for a given category of mail".

- An *Attribute* is used to measure an objective, in the mail example; the attribute would be the number of days for transit time. They state that attributes are a measure for degree of achievement of objectives. In this respect they refer that attributes can be scalar, when the attribute is described entirely by just one attribute or vectorial, when it is needed more than one attribute to fully describe the objective.

- A *Goal* is a specific number of days for an objective; continuing with our mail example the goal will be "to deliver at least 90% of the parcels and letters in less than 2 days". Also mentioned in the book is the classic Kennedy statement about "placing a man on the surface of the moon by the end of the decade"

- A *Proximate Attribut*e is the one that measures how much the objective has been achieved without really measuring the objective. Throughout our research we would call this type of attributes *proxies*; they will be discussed extensively in section 4. 4. 5

The authors then propose that attributes should be

- Comprehensive, which implies that knowing the level of a certain attribute or combination of them, the decision maker will have a clear understanding of the fulfillment of the associated objective

- Measurable, which means that it is possible to both,

  - obtain a probability distribution for each alternative over the possible levels of the attribute

  - assess the decision maker's preference over the levels of the attribute, possibly through an utility function

They distinguish between objective and subjective attributes, mentioning that the second kind is not possible to measure objectively through a commonly understood scale, and, therefore, it is needed to create an constructed scale, leading to the use of psychometrics, about which we dealt through Anderson's work[14] on section 2.1.In addition they recommend the use of proximate attributes to avoid the issue of subjective measure of attributes.

The notion of hierarchy of objectives is presented. They mention that while there is a need to identify the highest level objective, which will be the ultimate goal for the VCS, and will consolidate every other objective under it; there should also be a list of second level objectives that are operative and help the decision maker to actually decide.

We are not sure if finding this overall objective is possible for a multi-stakeholder analysis. We think that because different stakeholders expect *different*, and some times *very different even opposite* results from a VCS, we might have a hard time finding an overall objective.

Some desirable properties for attributes are presented. These properties are similar than the ones we present in a list for objective properties in section 3. 2. 4; yet, the authors present their properties' list as intended for attributes not objectives. In every case we found similarity, we will comment so in our work in the mentioned section.

- Completeness: a set of attributes is complete if it is enough to indicate the degree to which an objective has been fulfilled. That is to say that the elements of an attribute vector that maps an objective has to include all the areas of concern for the said objective.

- Operational: the attributes must be useful in helping to take decisions, since the objective of this analysis is helping the decision maker. The decision maker should understand the meaning of the attributes, and should be adequate to explain them to others.

- Decomposable: The list of attributes should be possible to break into parts of smaller number of attributes, in order to reduce the dimensionality of the problem. A n-attribute utility function will be difficult to deal with for n larger than 5; thus, breaking the problem into 2 groups would make the problem more tractable.

- Non-redundant: The list of attributes should not have areas where there is overlap, in order to avoid double counting of consequences

- Minimum size: while subject to the previous 4 criteria, it will be desirable to keep the set as small as possible.

The authors present an interesting result on the mapping of attributes to objectives, which will be very important for the building of our model.

- There is a vector $\overline{X}$, each element of which is an effect of interest to study, but, not possible to measure directly

- There is a vector $\overline{Y}$ possible to measure, and with a not very well known link to $\overline{X}$

- It is possible to estimate the utility $U_x\left(\overline{X}\right)$ of the vector $\overline{X}$

- It possible to estimate the conditional probability $P_{X|Y}$

Then

- It is possible to calculate $U_y\left(\overline{Y}\right) = U_x\left(\overline{X}\right) \cdot P_{X|Y}$

In other words, the mapping of a proxy attribute is as strong as the strength of the conditional probability of the proxy attribute on the intended objective. While will use this result when mapping attributes into objectives, we can see that this effect can be generalized for every mapping we intend to do in section 4.

We will use this result in order to map architectures and objectives.

Since there might not be a formula to link high level objectives, as expressed by stakeholders to an architecture vector actionable by designers of the type described in section 4.4, then this link will be done through the use of this distribution, over a subjective index. This methodology will be described in section 4. 6. 1.

The authors, then, approach the problem of multi-attribute decision making, stating that, decision making, in the context of multiple objectives, implies always the existence of a tradeoff between the different objectives, for a constant satisfaction preference level; this generates as a consequence an efficient frontier shown in Figure 4. Any point along the efficient frontier, such as X', is preferred to X", which is consequently dominated by the efficient frontier.

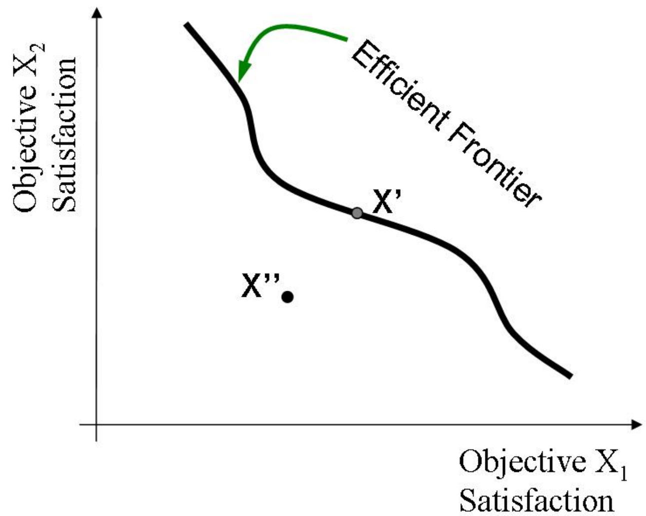

Figure 4. Diagram showing the objectives' tradeoff for the case of two objectives for one stakeholder.

The existence of an efficient frontier suggests that it is possible to have several of those lines, for varying levels of satisfaction preference. Furthermore it suggests that it is possible to travel along iso-satisfaction lines, trading one objective against the other. Keeney and Raiffa will name elements that lay on the same iso-satisfaction line as strategically equivalent, since they produce the same value to the *one* stakeholder, they analyze. This trading defines a marginal rate of substitution different than the classic one from Economics theory.

Whereas in Economics the lines of substitution were traced for equal wealth levels, and as a consequence, we read on Soderlind, that to maximize the utility the consumer will try to balance the marginal utilities of each objective; in this diagram the lines are iso-preference (regardless of the amount of resources used), thus their interpretation is different.

To reconcile both visions, we might say that while traveling along the iso-resources line (classic economics vision); we will reach a point where satisfaction is maximized. This point will be such that the marginal rate of substitution for each objective will be the same.

The authors then present a result that is central to our research; for an additive value function to exist, objectives should be *mutually preferentially independent* meaning that every subset of objectives should be preferentially independent of the remaining objectives. This definition is equivalent to state that the variation of some objectives does not influence the satisfaction received from the others.

These results based on Fishburn[15] and Pollak[16] theorems, and allow the assessment of utility of a system as a linear combination of its attributes. This formulation is the one commonly found on multi-attribute decision making methods, and it is a generalization of this method what bases our model. We will explore this perspective in section 4. 2. 2.

The model we propose relies heavily on linear combination of objectives to calculate values, thus, to fulfill this condition is critical. We believe this is achieved by avoiding overlaps between objectives, as presented in section 3. 2. 4. 2, and in general by avoiding overlaps between the different elements of the model.

Conclusion

It is the intention of this research to extend the classic results on decision making presented in the Keeney and Raiffa's book to the case of multiple stakeholders. We believe the most straightforward way to do this is to place a layer on top of the traditional decision making theory presented by those books, and to invest the architect with the power of supreme decision maker. Hence, as supreme decision maker, the Architect has the duty of optimizing on the benefit of his or her design, balancing the multiple needs the architecture presents.

While optimizing for the needs of the Value Creating System is a very important objective, we believe there is a need for balance between this self-centered perspective and a more outward looking one. This balance should be achieved through the diagram we present in section 3.10whose efficient frontier presents the balance between those two meta-objectives.

3. The systemic nature of the value delivery process

3.1. The need to study the reaction to different strategies

The process by which a certain Value Creating System creates value, delivers it, and acquires resources needed for its existence and prosperity is complex in its nature, due to the number of actors and interactions involved. While trying to understand this process, and inspired by ideas from the field of System Dynamics, we tried to identify whether there were any feedback loops whose analysis might provide some insight into the process.

Following these ideas, we determined that the nature of the value delivery system is such that the Value Creating System will, through its actions, generate reactions from the different groups with which it interacts, already introduced as Stakeholders.

From the definition of Stakeholders we are using, we know that these groups control resources needed by the VCS. A consequence, it seems most important to understand how these stakeholder reactions would be linked to the decisions taken while designing the system's architecture.

The reactions that stakeholders present to our design constitute the feedback loop we were looking for, and whose understanding will increase the sustainability of the Value Creating System. Our model intends to analyze the expected amount of resources this feedback will generate for each system architecture.

While System Dynamics were our initial reference point, we found a need to extend it, and as a consequence we are proposing some additions to the tool, by incorporating the use of vectors and uncertainty. Those extensions are discussed in section 4.1

3.2. Elements that interact in a value delivery process

3. 2. 1. Value Creating System

It is possible to identify a priori two main parts of the Value delivery process described in section 3.1, a part which uses resources and creates value, and whose design we are trying to help; and a part that receives the value created and in exchange provides resources, and whose design is outside our control. We will state that the section that provides value, and which is under our control, is the Value Creating System (VCS), since its intent is to create and deliver value.

The optimization of the design of the first part in order to secure its own existence and prosperity is the central objective of this research work.

We can distinguish different components in the interior of this Value Creating System (Figure 5):

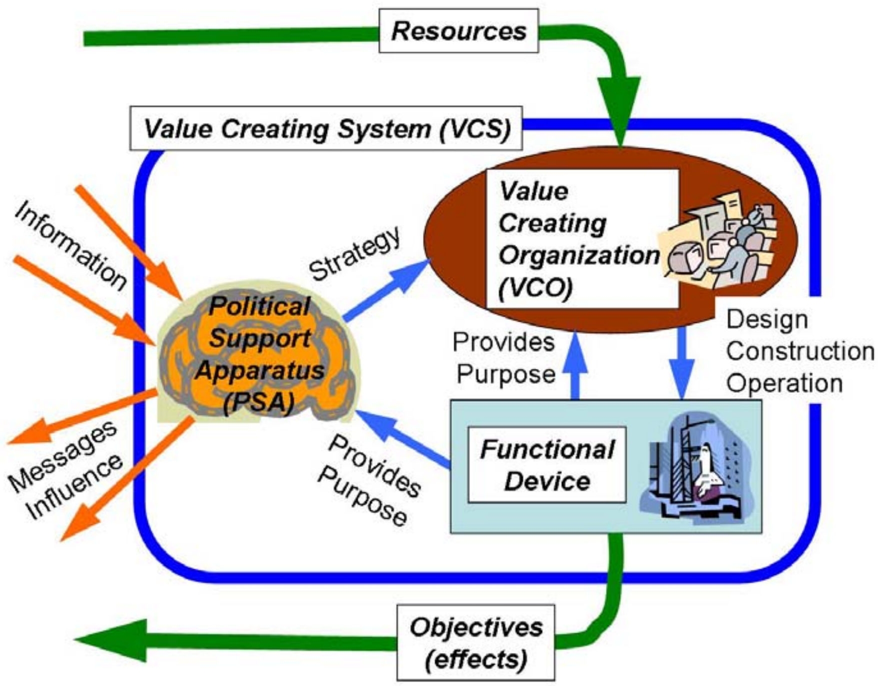

Figure 5. Diagram of the elements of the Value Creating System.

- A set of forms composed of hardware, software and knowledge elements. These forms, the processes they execute, and the interfaces between them are the main focus of architectural studies. We will call this set of elements the “Functional Device” (FD)

- An organization that operates the elements mentioned on the previous bullet. This organization presents also forms, hardware, software, processes and interfaces on its own, hence, requires an architecture too. We will call this organization the Value Creating Organization (VCO). The VCO is subject to constraints in the same way the Functional Device does, and many[17] would argue it is the VCO and not the FD the limiting factor for many macro-engineering endeavors, hence, the need for an increased interest on its design

- A set of information flows and information processing capabilities that aim to sustain and make prosper the Value Creating System, through adequate design and operation strategies. We will call this element the Political Support Apparatus (PSA), and we will postulate that the Architect works as a leader of this group. An analogy of the PSA would be the nervous system of an organism, which acquires information through senses, processes information through the brain, and instructs the different muscles to act again through the nervous system.

3. 2. 2. Architecture

As we stated above, taken from Crawley [1], our definition of architecture is "the embodiment of concept, and the allocation of physical/informational function to elements of form, and definition of interfaces among the elements and with the surrounding context".

Because our concept of Value Creating System includes not only the Functional Device, but also the Value Creating Organization and the Political Support Apparatus, in order to define the Architecture, the Architect needs to look into three different layers that are aligned with the previously described parts of the Value Creating System

- the layer of the political process, where a needs prioritization process occurs,
- the layer of design creation, where the architect acts as a technical individual selecting the optimum design to satisfy the decisions made in the previous layers, and
- the layer of the managerial process, where he should instrument the process of value creation.

In order to define how each of these sections should work, and what they should do, a set of decisions are be taken. The order in which the decisions are to be taken is roughly that of the layers mentioned above; yet it is expected that iterations and overlaps between layers might occur.

We conclude that architecting is the art of deciding, by choosing one form, function or interface among the feasible alternatives. If this is the case, then architectures can be represented by the answer to each of those design decisions.

Because the decision set is finite and discrete, it is possible to enumerate its elements and build a vector with them. We will call the set of all feasible architectures the design domain, and it will be possible to establish a one to one relationship between the elements of this design domain and the elements of the architectural vectors domain. These ideas will be shown in detail in section 4.4

The concept of vectorialization of the architecture is not new. While Suh's work[18] on Axiomatic Design has some elements in common with the model we propose, including the notion of vectors, we find his approach to be closer to the realm of engineering and hardware, shedding light on the Functional Device; we believe that a most useful analysis comes from looking towards the customers (stakeholders), and is more aligned with Christensen's analysis[19]. Hence, our interest in architecture vectors is a contingent on their usefulness while analyzing how customers react to architectures and how well those vectors are aligned with the objectives formulated in 3. 2. 4

While initially we observed that the Value Creating Organization's actual capabilities bounded the decisions that fell inside the Design Space, and separated them from the ones that do not, we now think that actual and potential capabilities are a better boundary. Nevertheless, included potential capabilities should fit inside the strategic intent or mandate of the Value Creating System.

There is, as a consequence, a set of decisions that are excluded, because they are considered part of the context in which the VCS operates.

If we use the example of NASA, the Design domain is included in the space of the capabilities that NASA *has* or *could develop*, including those related to all three layers: the device, the management and the political support.

The triad of organization, device and apparatus has a dynamic behavior. The device cannot exist if the political apparatus does not take strategic decisions and gather funds, and if the organization does not have the capability to build or operate it. The organization's essential purpose is to create, build and operate the device and to support adequately the clerical needs of the apparatus; finally the function of the apparatus is to decide for and provide funds to the device and the organization. Thus, without them, its existence is not needed.

An additional constraint of this decision process is that the case where the architect designs from a blank sheet is not common, especially with organizations that deserve an analysis such as the one we present. Usually the architect will face an existing VCS with a set of capabilities, and a group of stakeholders who exhibit a set of needs. It then becomes a challenge to realign the organization towards delivering the needs that the stakeholders exhibit, a realignment that adds complexity to the work of the architect.

While the design domain is the universe of every possible decision related to the system to be designed, and each decision needs to be taken eventually, there is a need to accomplish this study in a staged way, thus, using some type of hierarchy. Our analysis will assume such a staged implementation of the analysis, and a relatively short and synthetic list of decisions that can be studied at a time.

While in the case of Space Exploration, the higher level vector will include decisions about the device, the organization and the apparatus, it might prove most interesting to focus our attention on the functional device, which might be where the presence of stakeholders is felt less. Examples of functional device-related decisions are the duration of a mission, crew size, and vehicle configuration.

While sometimes it is possible to measure directly these parameters, on other occasions, it would be necessary to use indirect metrics to assess their value; an example of this is that the cost of the system will only be known some time after the mission is executed, but can be approximated by the system mass which constitutes an indirect measure for the system cost[2], or proxy.

3. 2. 3. Architect

The System Architect's role is to choose among the alternative forms, functions and interfaces, present at each decision point, in the three layers of the architecture concept as above described. While choosing among alternatives that fit inside the design domain constraints, the architect will try to maximize the performance and minimize the amount of resources consumed.

There is a further responsibility in his/her hands.

The architect should be aware that his/her actions will have consequences all along the value delivery process; by defining the elements of the three Value Creating System layers, the architect sets the general structure of the value delivery process and thus, the expected resource stream back to the Value Creating System.

As a consequence, in addition to the architect's goal of minimizing the amount of resources used, respecting the constraints imposed by the context, and maximizing the performance, the architect should design so that the value delivery process provides a constant stream of resources in the future, in order to keep the system operating, and thus ensure sustainability and prosperity.

Once again, the word "resources" should be thought of in a liberal way; in our research "resources" are the set of needs the value creating system exhibits in order to operate healthily and with prosperity.

3. 2. 4. Objectives

While the decisions concerning the architecture are meaningful at the interior of the Value Creating System, they might not be easy to communicate to parties that do not have a throughout knowledge of the Value Creating System details. There is a need to create a set of higher level goals that can serve as an interface between external groups and architectural decisions. In our research, Objectives is the name we have given to this set of goals.

The list of objectives should provide a common language to allow groups at the interior and exterior of the Value Creating System to enumerate needs in a precise way and prioritize them. A clear communication channel with the exterior world seems to be especially useful for groups that deal with technology, for such technology intensive groups sometimes confuse the means and the end.

By reaching out to external parties the VCS will be able to gather information on how important each objective is for each group, and prepare a prioritization of those needs, since the final intent of the formulation of the list of objectives is to acquire a ranking of the list, as assessed by each different stakeholder group. As we will explain in 0we propose to use an Importance – Performance analysis based on a survey of stakeholder representatives through a Kano questionnaire, in order to separate the needs into three main groups:

- Basic needs, which are expected tacitly and taken for granted, and whose absence will surprise the external group in a negative way

- Performance based, where the external party expects it to be delivered in some degree, and any increase of that degree increases the satisfaction level

- Delighter type, where the external party does not expect the need to be satisfied and creating surprise in a positive way when that happens.

If we think that this objectives' list is a communication channel, then each different objective is a word of the message to be transmitted, and the set of objectives, times the number of answers received, times the accuracy of the answers is the channel bandwidth. Because gaining more information about the exterior world will help to design a better Value Creating System, there is a need maximize the use of this channel.

Yet, because Stakeholders need to use their resources to answer inquiries from the VCS, such as our survey, an increase in the number of objectives, might yield a decrease, in either the number of answers, or the accuracy of them, due to surveyees fatigue, loss of interest or even perception of abuse. This ideas are also presented by Keeney and Raiffa[13].

As a consequence, there is a need to use a synthetic set of objectives, to reduce the strain over the communication channel, and thus increase the bandwidth of the communication channel.

This synthetic list requires that the analysis is done through a staged approach, where objectives are ordered through a hierarchy, and the analysis proceeds from a list that covers the whole objective domain, to more specialized lists that intend to probe detailed aspects. The research presented deals only with this higher level objective domain, yet the same methodology should be used for analysis focused on specific aspects.

The objectives list should cover the complete domain of potential goals of the VCS, defined as the intersection between the capabilities of the VCS, actual and potential, and the needs of the Stakeholders, present or future, under the constraints set by the VCS strategy.

The strategic use of constraints on the design domain deserves a special comment. The use of constraints should be limited as much as possible, since they artificially reduce the design domain. Because the impact of a strategic domain reduction reaches many stakeholders along the value delivery process, it is difficult to ascertain the consequences of it, without an analysis such as the one we propose in this work.

In order to cover the complete domain of potential goals, the objectives list to consider should be the result of an inductive process of the most extensive list of possible needs expressed by stakeholders, but which can also be satisfied by the VCS.

The concept of "jobs to be done" (JTBD) laid out in Christensen's book "The innovator's Solution"[19] has provided us important insights on the formulation of objectives for a technology oriented Value Creating System. Christensen argues that "customers" hire "products" to deliver certain benefits for them, and that those benefits might very well be different from the original intention of the designer of the "product". As a consequence, he states, it is critical to understand the circumstances in which the customer uses the product, and to segment customer markets across those benefits and not across an arbitrary demography.

If we translate this concept to our Space Exploration example, Christensen's customers are different space exploration stakeholders, who "buy" the product by providing resources; in the case of our example, the product is the whole Value Creating System (and not only its functional device). Following his template, the analysis should be focused on the benefits that each different stakeholder group gets from the Value Creating System, and not on what the Value Creating System intends to provide, hence there is a need to *phrase objectives in the voice of the stakeholder, not in the language of engineering*.

In this respect, the differentiation between objectives and requirements is crucial. Whereas Stakeholder benefits are less solid, less engineer-friendly, and thus perceived as fuzzy, engineering oriented objectives are usually stated in the form of *requirements*, a numeric amount, with units, and margins. Previous attempts to bridge the gap for the case of one only stakeholder have been done by Hauser and Claussing[4]. Our reasoning behind preferring a stakeholder-oriented list of objectives is shown in 3. 2. 4. 3

From our experience, the preparation of the objectives list seems to be more an art than a science; nevertheless, it is possible to provide some guidelines, about attributes that the list should possess. While reviewing the literature, we found a similar list at Keeney and Raiffa's book[13]. We have added comments from their work to each of the guidelines we are proposing below.

3. 2. 4. 1. Collectively exhaustive

A collectively exhaustive list will guarantee that the whole universe of intended objectives is represented in our model. If it were the case that some objectives are left out of the list if will not be possible for stakeholders to express their interest in those, effectively introducing a potentially damaging bias in our analysis, as mentioned in 3. 2. 4

In order to identify the broadest possible set of objectives, it is necessary to enumerate every possible need that the stakeholders would present and that the Value Creating System could solve, within the boundaries of the architecture domain, as was described in 3. 2. 2

For the case of the Space Exploration example, this exercise was done by the Value Evaluation sub-group of the MIT-Draper Concept Evaluation and Refinement research team[20], of which the author was a member. An extract of some of the columns of the needs database prepared by the group has been included in the Appendix 8.1.

Keeney and Raiffa refer to this as attribute completeness.

3. 2. 4. 2. Mutually exclusive

Objectives should be mutually exclusive for the model to provide clear differentiation between architectures to the designers, to provide clear alternatives to Stakeholders while answering the survey and to reduce the needed bandwidth for the survey; by fulfilling the condition of *mutually preferentially independent* statements as formulated by Keeney and Raiffa (see section 2.3)

Since one of the functions of the objectives list is to serve as an interface between those groups, the list will not be as useful if it does not address clearly what each objective includes and what it does not.

Some arguments could be made about the fact that if the objective set is collectively exhaustive, overlaps between objectives are harmless, since the whole universe of pertinent objectives has been covered. The problem with objectives overlap does not lay in the lack of completeness, but in the reduction of the communication channel resolution.

We can illustrate this with an example. Let us assume two objectives

- The ball will have red, blue and/or yellow spots

- The ball will have red, green and/or orange spots

The reduction in resolution will come from two directions:

- A stakeholder who wants a ball with red spots could answer either A or B, rendering the question irrelevant to some of the surveyees, and thus effectively reducing the bandwidth efficiency. The most efficient use of the communication channel will occur by using words with unique meanings.

- Furthermore, we might confuse and stress this red spot seeking surveyee, since they will feel confused about not understanding the difference between option A and B.

- Finally, an architect receiving results of mixed preference between A and B might understand that the red spots satisfy both options, while it might be the case that no representative preferred this option.

Keeney and Raiffa state that the list should have no redundancy.

3. 2. 4. 3. Stakeholder oriented

From the work done by Christensen, and our own research, we conclude the following are the most important reasons for which objectives have to be formulated by looking to the system from the perspective of the Stakeholder:

- The VCS is the interested party, for this analysis is done from the perspective of an architect trying to improve the VCS sustainability. It then makes sense for the VCS to try to pay as much attention as possible to the customer, this will be achieved by speaking in the customer's language

- Because some stakeholder groups do not consider the benefits the VCS provides a high priority for them, a list of objectives that is difficult to understand might not only yield error, but also may result in a refusal to participate in any communication effort.

- Because stakeholder representatives are not specialists in the mechanics of providing the benefits they expect, they might not be able to answer in an adequate way questions about priorities, if these questions are asked in a language they don't understand.

- Value Creating Organizations are sometimes too inwardly focused, and might forget why the Functional Device is being built. This is especially true for technically oriented and advanced organizations, where due to the difficulty of the tasks performed, the personnel might lose touch with the exterior world.

- Objectives stated from the perspective of the Value Creating Organization might suggest tacitly or explicitly a determinate design which is already a favorite in the interior of the VCS.

This property is tangentially touched in the comments about being operational in Keeney and Raiffa's book. Yet Keeney and Raiffa do not state clearly that the extra effort in bridging the gap between the VCS and stakeholders lies on the side of the VCS.

3. 2. 4. 4. Expressed in a language understandable by stakeholders and architects

Because the list is used as a communication channel from the stakeholders group to the architects, the language to be used should bridge the separation between both groups. By stating objectives in a language that is excessively close to one of the groups, the other might feel alienated.

This requirement intends to balance the previous one, which refers to being closer to stakeholders. While the effort should be made by the architect to understand stakeholders, the objective list should be actionable for the architect. A list that expresses objectives of interest to stakeholders but which does not provide clear signals to architects is not effective as a communication channel.

This is closer to the intent of Keeney and Raiffa's requirement of operational attributes.

3. 2. 4. 5. Implementation neutral

The objectives should be formulated in such a way as to satisfy the needs presented by stakeholders, yet not selecting specific forms to do so, hence avoiding a premature reduction of the solution space, except the so-called strategic ones. These form-independent objectives are said to be a "solution neutral translation from the Customer Needs domain to the Objectives domain"[18].

In order to prepare solution neutral objectives, their formulation should be written paying as much attention as possible to stakeholders' needs, yet taking the time to understand what the stakeholders *really* intend to solve, since stakeholders might also be prone to recommend forms that are best known to them.

In order to understand what stakeholders *really* want we do find useful the already mentioned chapter from Christensen's book[19].

As an example, a Stakeholder objective expressing interest in science data, the statement

- "the system will collect science data" is as general as possible,
- "the system will be able to collect rocks, or X object" would be too specialized,
- "the system should provide data", will be too general

We have not seen any comment on this aspect on Keeney and Raiffa's work.

3. 2. 4. 6. Aligned with the capabilities and strategy of the VCS

Finally, while the demands stakeholders might pose are multiple, it is a fact that some of them will fall outside the domain of feasible architectures. The Value Creating System will be able to satisfy a subset of those needs, areas in which the Value Creating Organization possesses expertise, mandate, differential advantage or strategic interest.

As a consequence, an additional constraint over which are valid objectives is the capabilities the VCS exhibits or has the potential to develop. This constraint is congruent with our definition of architecture boundaries, as stated in 3. 2. 2.

Our model's intention is to provide some help to the Political Support Apparatus preparing the strategy of the VCS, thus, it is recommended that no capabilities (real or potential) are left out. Nevertheless, as mentioned in 3. 2. 4, it might be of interest to use constraints strategically; if that is the case, the situation should be clearly stated in the model. Y Company's board decision to enter into market W, or the Congress' mandate for Government Agency Z, are examples of these strategic constraints.

This requirement is tacitly implicit in Keeney and Raiffa's list, because they state there is an overall objective, which we believe should naturally fall into the capabilities of the VCS. While that might be the case most of the times, a general enough objective, which covers the whole space of stakeholder requirements, will also cover functions that are outside the possibilities of the VCS. We believe that is important to make explicit the lack of efficiency of stating functions that are outside present or potential capabilities of the VCS.

3. 2. 5. Stakeholders

As proposed by Freeman[6], we will think of stakeholders as groups that have a stake in the Value Creating System we are analyzing, a stake that consists of the resources the stakeholder provides to the VCS. This stake ownership in turn provides the stakeholder with some leverage to influence the VCS behavior by controlling the resource supply.

We think this perspective is not only correct, but also leads to useful results, by providing a way to prioritize non-concurrent preferences across stakeholder groups.

As Freeman states, the term Stakeholder was created as a generalization of the term shareholder, which is central to the analysis of private corporations. Private corporations' explicit goal is the optimization of profits, which are the return to the corporation owners or shareholders. This concept was useful when analyzing corporations that operated in a less complex environment where it was possible to alienate some groups, without facing risks.

In the complex world of today, that is not true anymore.

The concept of stakeholder allows doing an analysis that includes a larger portion of the interactions to which the Value Creating System is exposed. Our interest in the intersection of the study of whole systems and corporate strategy is what disposed us towards the analysis of stakeholders' strategy and the elaboration of this research.

Today's private corporations not only answer to their owners, but also to groups that include their employees, suppliers, regulators, unions, customers, and universities (through research partnerships). The involvement of those groups is not necessarily because of an ethic imperative, but because those groups control resources of interest to the corporation.

Corporations receive from their employees work, which can be of greater or lesser quality depending on the employees' motivation; corporations also receive supplies and expertise from suppliers, which might be more or less helpful; corporations also need approval from regulators, which could shut down operations or products; and so on.

In the case of a public entity, the case for stakeholders is even stronger. Publicly owned organizations, such as government agencies, state-run programs, or non-profit groups, do provide benefits to a wide range of constituencies, and receive their resources also from a diverse group. Because there is no owner (or there are too many, if it is preferred), it was extremely difficult to take decisions that will optimize the value to be delivered to the many different groups, a situation that becomes more complicated when we think of the effect of intermediaries such as Congress' representatives.

We will not use the definition that a stakeholder is every group that *is affected* by the VCS, since this leads to non-effective models, as commented in Nwankwo[8], Sternberg[9] and Jensen[11]. These models provide large amounts of information to the decision maker but do not guide him/her in order to take a decision over the information.

The analysis proposed will be especially useful to prioritize non-concurrent needs presented by a diversity of groups, since it will allow prioritizing some stakeholder groups over others. This prioritization will be achieved by using the criticality of our resources need in order to prioritize stakeholders, an idea that was present in our research for some time, but we found was already presented by Nwankwo[8].

Our method intends to extend Nwankwo's[8] concepts to a quantitative analysis, where we intend to propagate numerically the criticality from resources to stakeholders and from stakeholders to objectives, which will finally translate into architectural decisions.

A result of this postulate of ours is that stakeholders controlling a larger amount of more critical resources will have a larger say in the design of the architecture, and as a result a higher satisfaction of their expectations.

Finally, another interesting concept that Christensen presents is that the segmentation of stakeholder groups should be done according to the benefits they will receive from the Value Creating System, and not across an artificial segmentation such as age or geographic location. Our classification of the customer in stakeholder groups partially achieves this goal, by profiling the groups according to functions they fulfill.

Our understanding of this concept of Christensen's is that he proposes that each objective in our list of objectives constitutes a virtual stakeholder group. To constitute stakeholder groups around what they expect to receive seems an interesting idea, and the analysis might eventually lead in that direction, nevertheless, in a first iteration we prefer to keep our original conception of stakeholder groups.

Once again, and in the purpose of pragmatism, we will try to arrive at a synthetic list of stakeholders. An excessively detailed list will increase the time invested by the researchers, and decrease the number of potential surveyees per group. We estimate that between 5 and 15 stakeholders are a good rule of thumb.

3. 2. 6. Resources

In the previous sections we have described the parts of the value delivery process, by which a Value Creating System provides benefits by satisfying needs of some groups with which it interacts. In order to perform those functions, the system will consume resources of different types, whose availability through time are critical to the system's survival.

The sustainability of a system is based on its ability to provide for its own needs. As a consequence, the VCS will survive and prosper as long as the amount of resources it receives as a result of implementing a specific architecture exceeds the needs for implementing the mentioned architecture.

At the same time, neither every VCS need is equally critical, nor is every resource needed in the same amount; this results in a need to prioritize needs by their criticality, in order to improve the sustainability of the system, a situation that mirrors the stakeholder prioritization of objectives already described in 3. 2. 4.

This apparent symmetry prompted us to think that the VCS relationship with the Stakeholders is actually symmetrical. The VCS is a stakeholder for them, as much as they are stakeholders to the VCS. While the VCS creates value and that value is delivered to stakeholder groups in order to satisfy their needs, at the same time those groups provide value to the VCS, satisfying the VCS's own need for resources.

As a consequence, it seems natural to formulate the list of VCS resources taking into account the comments made in section 3. 2. 4, and also use the suggested method to rank stakeholder objectives, that is the Kano method of quality.

Because the end goal is to ensure sustainability of the architecture, we will place the architect as supreme decision maker, and use the criticality of the resources needed by the VCS to rank the stakeholders that provide those resources, and their preferred objectives.

An interesting observation is that as a contrast with energy or mass systems where there is a balance between inputs and outputs; the case of a Value Creating System, does not balance inputs and outputs. Due to the phenomenon of *emergence*[21], value is actually created (hopefully) at interior of the VCS, through an adequate combination of resources.

The word "resources" has been used throughout this work, yet there are two caveats to its definition

- Wide meaning

  The VCS will present many different needs, and not all of them will be in the form of resources as traditionally understood. As a consequence, in the context of this research we extend the meaning of the word "resources" to represent every need the VCS exhibits in order to survive and prosper.

  Examples of traditional resources are funds, materials, technology, knowledge, and workforce.

  Examples of non-traditional resources are political capital, credibility, public support, international credibility, and motivation

- Resources embargo, negative resources, and veto

  While the usual perspective is that resources are provided in order to increase satisfaction, and reduce needs the Value Creating System might present, there might be cases where some stakeholder chooses to not provide or even provide a negative amount of some resource. This situation will be a consequence of the lack of alignment of the stakeholders' objectives, potentially leading to groups with a very low satisfaction level for some specific architecture.

  We will understand that a resource embargo will occur when a stakeholder ceases to deliver a specific resource, and supply of negative resources when the stakeholder is able to not only not deliver, but also decrease the stock already in possession of the VCS. A typical example of this latter case is a disgruntled stakeholder acting proactively through the press to damage the VCS's political support or credibility.

It is in the best interest of the VCS to avoid a negative supply of resources if at all possible, or to be sure this negative perspective is held by groups that neither possess direct or indirect control over resources of critical interest, nor will possess such a control in the future. Where this cannot be done, and in fact groups with resources control will oppose the architecture, a careful analysis of the situation is due.

3.3. Flow diagram

The central intent of this work is to analyze sustainability for an architecture or strategy, and the conditions for its growth and success. Our analysis starting point was to look to the system that creates value, and understand where it thrives and where it languishes. While studying this Value Creating System, we identified that its main intent was to provide value to external groups, and in order to do so, the VCS needed to consume resources.

The reception of those resources in enough quantity was a critical factor to the subsistence, thus, ensuring its supply was the key to our solution. While trying to understand how that supply could be ensured, we identified that several groups controlled the mentioned supply, and that their satisfaction was central to a successful strategy.

On the other hand, the main tool of the VCS to influence the external world is the delivery of the benefits for which it was designed, benefits that are delivered to parties who might exert control over the previously mentioned resources.

A central point of our work is based on the ancient Latin principle of "*do ut des*" (I give so that you may give); we propose that if a VCS increases the satisfaction level of a stakeholder, then the stakeholder will increase the supply of resources to the VCS.

Our acquaintance with System Dynamics suggested the idea that the existence of some type of feedback loop from the benefits provided to the resources needed might exist, and that the reinforcement of that loop will deliver the goal of sustainability.

We think that the fundamental role of the architect is to reinforce this loop in a positive way, by selecting an architecture that causes the stakeholders to provide more resources than the ones consumed by the VCS to implement that same architecture.

While a strategy to provide a resource's surplus is to implement an architecture that consumes less resources by delivering less benefits; this reduction on benefits points to a reduction on the Value Creating System, opposite to the intended growth, indicator of prosperity.

Nevertheless, there are a small number of cases where recognizing the Value Creating System has outgrown its optimal size might prove correct. In these cases, the reduction of benefits should be planned in order to avoid a vicious circle, where the lesser benefits drive even fewer resources.

A better strategy might be one that provides a resource surplus, through an increased stakeholders' satisfaction, which prompts them to increase their delivery of resources. This increased stakeholder satisfaction should be achieved through an efficient use of the resources the VCS has available already.

As mentioned in 3.1, inspired by the field of System Dynamics, we identified a feedback loop, from the VCS to the stakeholder groups, and back from the stakeholder groups to the VCS. This loop is shown in Figure 6.

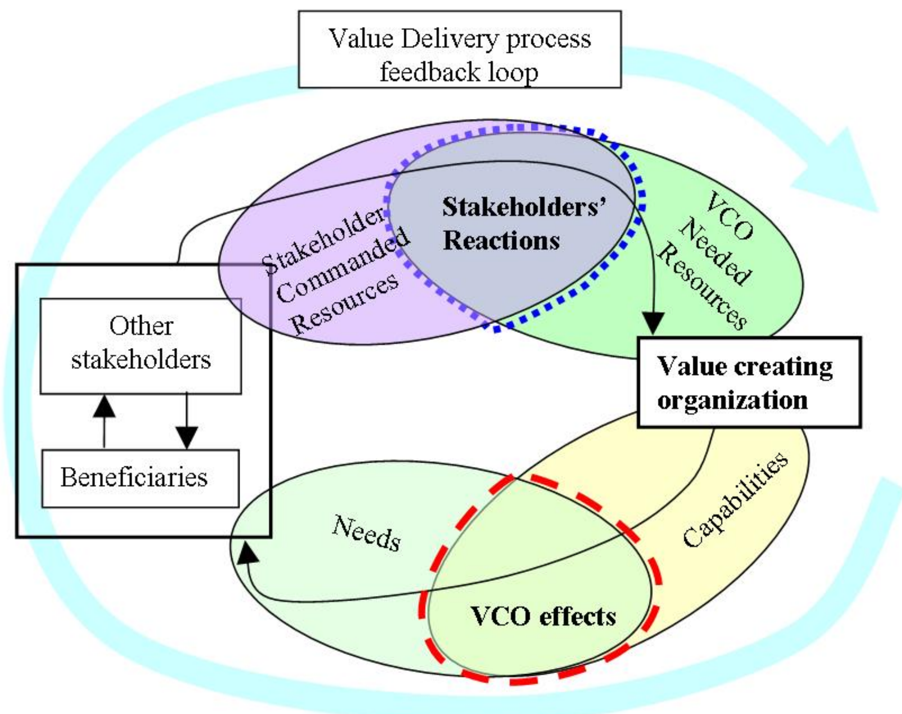

Figure 6. The Feedback Loop of the Value Delivery Process.

3.4.

3.5. Value is delivered through a stream from Value Creating System to stakeholders

The VCS intent is to fulfill the needs presented by groups of stakeholders, in concordance with the VCS strategy and capabilities. Because the supply of resources to every VCS is limited, we observe that no Value Creating System, in normal circumstances, is able to deliver every need of every stakeholder with a performance that is superior to every other VCS, and we conclude that VCSs will tend to focus and specialize in areas where they possess competitive advantage if private or a mandate if public.

Because of the imperative of the VCS to focus on a sub-set of needs, it is most likely that stakeholders will have to deal with other VCSs in order to satisfy their remaining needs. Stakeholders, as a result, also act as if they were VCSs on their own, looking for resources, and delivering value under their control.

The limited amount of resources available to the VCS, combined with the different competing needs at the interior of each stakeholder, prompts the VCS to optimize its ability to deliver on the pressing needs of critical stakeholders. This optimization implies that the VCS should choose to not develop some capabilities, and align itself around the ones that help fulfill its mission.

While this discussion was introduced stating that the needs are prior to the existence of a VCS, as stated in 3. 2. 2, this is rarely the case. Most likely the Architect will have as a starting point a “status quo”, with an existing value delivery process and a VCS. We will take advantage of the existence of this “status quo” point for our analysis, since it will provide a reference point to compare with every other architecture.

It seems that a matrix would be the most adequate way to map the relationship of an objectives satisfaction list, ordered as a vector, to a stakeholder satisfaction list, also ordered as a vector. This matrix is related to the one used for the Quality Function Deployment[4]; while the QFD matrix maps engineering requirements to higher level objectives, the matrix we propose in this case is one level above in hierarchy, mapping objectives to stakeholders’ satisfaction.

3.6. Indirect satisfaction effects

An aspect of the stakeholders modeling that became evident while working in the MIT-Draper NASA Concept Evaluation and Refinement group is the networked effect of value delivery. Some stakeholders will not receive value directly from the VCS, and some stakeholders do not control directly resources of interest to the VCS.

In order to model this aspect, we devised a square matrix, not very different from a Design Structure Matrix[22], where the strength of the interaction of each stakeholder with every other is assessed. This matrix will help to map the interrelations between the different stakeholder groups, and whether the satisfaction of one of them increases the satisfaction of another through an indirect channel.

3.7. Resources are delivered back from Stakeholders

As previously stated, stakeholders are groups that *hold a stake in* the VCS; the stake is expressed through the supply of resources that the VCS needs.

The analysis done in this section of the model should provide an understanding of how much the supply of resources should change as a result of a determinate level of stakeholder's satisfaction.

Our approach to this issue is that this second half of the feedback loop is symmetrical to the first half; but, in this case, the VCS, instead of delivering benefits, is receiving them, thus becoming, a stakeholder to the stakeholder groups; hence, the VCS chooses what is best for its own, looking to satisfy its own most important needs.

On the other hand, each stakeholder, if seen as a VCS, has a limited amount of resources to use to produce benefits, as the ones needed by the VCS focal to our study. These stakeholders, when thinking as VCSs, will prioritize their own needs according to their criticality and doing what is required to satisfy the most important ones first, and then the ones that are optional. As a result, it is most important for any VCS to understand

- what are their own most pressing needs,
- what stakeholders are critical because of their control of resources that satisfy those most pressing needs, and
- what are the most pressing needs of those critical stakeholders

This is because satisfying those critical stakeholders' pressing needs is crucial to the VCS's subsistence as observed in 3. 2. 5

As a consequence, a VCS that provides benefits which are not critical to one group controlling resources that are critical to the VCS, is subdued to that group (Nwankwo and Richardson[8]). Such a VCS should try to either *migrate towards providing critical benefits to those critical groups*, or, *if that is not an option, the VCS should avoid less popular strategies, which might require a leverage the VCS does not possess.*

There are however two caveats for this paradigm; caveats which result from the dynamism of stakeholder relationships. While our analysis of resources criticality points towards satisfying the most powerful stakeholders, those who control the most critical resources, this strategy is not always the best, because the share of power that stakeholders wield is not static and will evolve as a result of

- Internal changes within stakeholders: these changes are out of the scope of this research, so we will think of them as an intrinsic uncertainty, dealt with through a probabilistic approach as we will see in later in section 4

- Interactions among stakeholders: the study of these interactions will be done using a matrix similar to the already mentioned DSM matrix to incorporate the effect of indirect satisfaction into the model. This matrix will provide information on how stakeholders interact among themselves.

It is foreseen that there might be a need to apply this indirect benefit mapping in an iterative way; while some stakeholders are affected in direct way by the VCS benefits, others might need several intermediaries to be reached, thus requiring an iteration of the mapping scheme. We think that the farther away the stakeholder is, the weaker the effect of the influence; thus, there will be a need for an dampening factor, of the type mentioned in 0

Different stakeholders control different type of resources; hence, the model should contemplate through some mapping how different levels of satisfaction increase or decrease the supply of each resource. The use of matrices, once more, seems adequate to map the relationship many to many, translating a stakeholder satisfaction vector into a resource supply vector.

In order to study the control of resources by stakeholders, it will be necessary to assess how much power each stakeholder has over the resources the VCS needs. This assessment might be done by asking the VCS about the supplier of those resources, and also by reasoning through the resources list who might be an alternative supplier for them.

In the case of historical resources' suppliers, we need to look into recent history to see how much power these groups really have. While nominally a group might control 100% of some resource, in practice, that group might only be able to affect the resource supply in a reduced amount.

The model should provide a more accurate result if fed with the control that the stakeholder has been able to effectively exercise in the past.

3.8. Valuation of architecture options based on resources feedback

This concept has been central to our discussion; the fact of valuing architectures by their ability to increase the supply of resources, back to the VCS. The steps of the feedback loop are as follows:

- Each architecture will cause a determinate level of objective satisfaction.

- The satisfaction of these objectives will result in stakeholder satisfaction, with a positive correlation with their interest in the fulfillment of each objective.

- Stakeholders, through interactions among themselves, will influence how each of them is satisfied as a result of the architecture. This will result in primary, secondary and eventually n-ary satisfaction levels.

- Stakeholders' satisfaction will drive an increase or decrease in the feedback of resources supply

- The supply of resources will affect the VCS, in a degree relative to the resources criticality.

While this mapping expresses the general flow of benefits and information through the system, it is expected that we will never be able to know with certainty the functions that translate each of these elements into the next one. We propose to use probability as a method to deal with this uncertainty, and instead of using definite functions, use probability distributions in order to translate one amount into the next one.

In order to do so, at each step, we will try to take advantage of the differences in opinion of the different sources of information to introduce the adequate level of uncertainty in the translation.

As a consequence, the analysis will yield probability density functions, of which we will take advantage not only of their expected value, as a measure of "goodness" of the parameter, but also of their dispersion as a measure of "completeness" of the data used for the analysis.

In this case, we will obtain a probability density function of the amount of resources ranked by their criticality. This probability density function will provide a measure of the likelihood that a determinate architecture would be able to provide more resources back to the VCS than another.

We will introduce the mathematical construct used to reach this measure in section 4

Examples of the statements that we should be able to present are:

- To state that "There is a probability of Q% that architecture W is more valuable than architecture V", see Figure 7

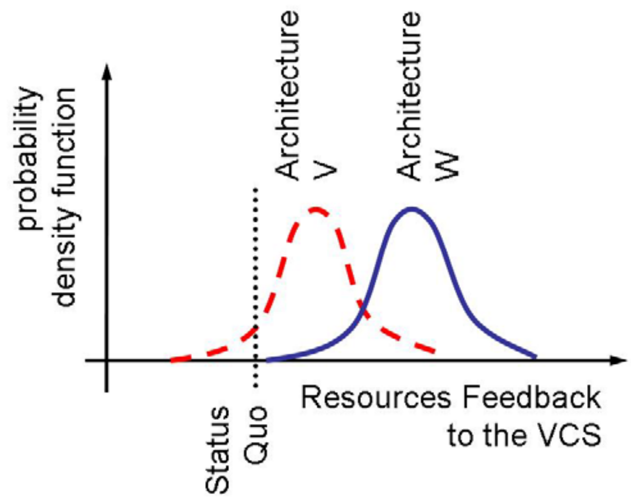

Figure 7. Probability density function (pdf) of the resources the VCS could expect as a result of implementing architectures V and W. In this respect architecture W is superior to V.

- To present a set of implications chained together so that we could see why architecture W is better than V.

    - **Architecture W** that satisfies objectives A, C, and D with a level of P%, which in turn satisfies stakeholders 1, 3, 5 and 6, which in turn control resources J, L, and M.

    - As a contrast, **architecture V** satisfies objectives A, and D with a level of R%, which in turn satisfies stakeholders 3, and 6, which in turn control resources J, and M.

The set of implications should show researchers where the strengths and weaknesses of their analysis are. Furthermore, this chain should provide a clear reasoning which could be followed by other people interested in the results.

A valuation based on resources feedback most likely will assign a higher value to architectures that are focused on satisfying a reduced set of powerful stakeholders. This is described by Freeman[6] as a Specific Stakeholder Strategy. A consequence of favoring a small number of stakeholders might be that architectures that rank well in this dimension might prove unpopular, requiring a strong leadership to be implemented. We will think of them as *leadership-oriented*.

On the other hand, leadership-oriented architectures, because they optimize the amount of resources received by the VCS, might favor a faster growth of the VCS. This faster growth will result in a VCS increased capacity to generate value, which might eventually deliver an increased return to every stakeholder group. Leadership-oriented architectures, while unpopular on the short term, might provide an increased value over the long term, if they survive.

3.9. Alternative valuations of architecture

As stated in 3.8 the use of a resources feedback valuation might alienate some groups that in the short term have less power. This policy might result in less stability and increased risk, due to the activism of the relegated groups. We felt that there was a need to establish a balance through alternative measures that would increase the long term sustainability of the strategy.

In this context we thought of several ways to measure stability, some of which are detailed below.

3. 9. 1. Valuation of architecture options based on stakeholder consensus

One alternative way to measure architectures is to assess how much agreement stakeholders have about the value of each architecture. This measure favors architectures which provide the same level of satisfaction to every stakeholder, no matter whether that level is high or low.

We name this measure "stakeholder consensus", since the higher the stakeholders' agreement, the higher the measure's value. This agreement translates into stability, because changes in power share between stakeholders will not result in changes in support of the architecture. An architecture regarded as having low value by every group in the present time, will be of low value in the future even if some stakeholders lose control of resources to other groups.

In order to measure consensus, we first observed that the opposite of consensus, that is disagreement, was easier to measure. Disagreement can be gauged by the dispersion across stakeholders' satisfaction, using the *same weight* for each stakeholder. A high dispersion in stakeholders' satisfaction will imply a high level of disagreement between them about the value of the architecture, and as a consequence a low consensus.

Hence, consensus could be thought as the opposite of the disagreement or dispersion in satisfaction, and be evaluated by taking the inverse of the dispersion of stakeholders' satisfaction.

If we have arranged all n stakeholders' satisfaction in a vector $\mathbf{S}$ it would be possible to calculate the dispersion by the known formula

$$\sigma_S = \sqrt{\sum_i^n \left[S_i - \overline{S}\right]^2}$$

And the proposed measure for consensus **U** would be

$$U_S = \frac{1}{\sqrt{\sum_i^n \left[S_i - \overline{S}\right]^2}}$$

Since the dispersion will be different than 0, except in the case of unanimity (which is the ideal case), then the consensus **U** is finite for all practical cases.

Once again, the result of this analysis will be a probability density function of the consensus measure as seen on Figure 8. The diagram on the left presents the satisfaction of the different stakeholders for two different architectures (V and W), calculated by adding the probability density functions of each one, with an equal weight. The diagram on the right, presents the probability density function of the dispersion of the diagram of the left.

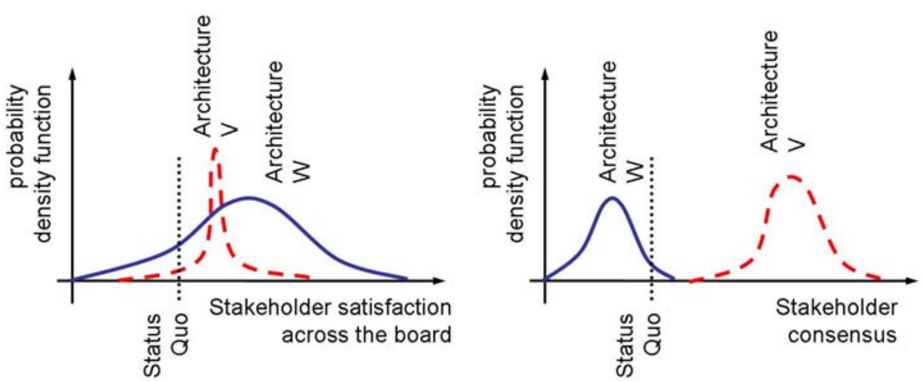

Figure 8. Diagram showing two architectures' stakeholder satisfaction and their resultant consensus. Note that the higher dispersion of Architecture W on the left meant a lower consensus of the architecture on the diagram to the right.

This measure favors consensus above the intrinsic architecture value, and thus will favor architectures whose support (or lack thereof) is evenly present. It is expected that the most consensual architectures might not be optimal in the amount of resources feedback they deliver, as measured in 3.8Decisions to implement consensual architectures, although not satisfying completely any stakeholder, will possess a broader support base, and thus would be more stable over time.

We expect that consensus-based architectures will have a lower political risk, because their support base does not rely on few but on many groups; thus, its resources supply is "hedged". This hedging strategy reduces the impact of political changes in specific isolated groups, over the VCS's resources supply.

Consensus driven architectures, because of giving a larger say over decision-making to a multiplicity of stakeholders, could be perceived as more "democratic". These architectures follow what Freeman described as a Harmony Stakeholder Strategy.

Consensus-driven architectures will do better in the case of VCSs with a lower share of power, and which do not provide critical resources to every stakeholder that provides critical resources back to the VCS, as commented in 3.7

3. 9. 2. Valuation of architectures based on risk of change

The intent of this measure is to map the probability that the feedback of resources identified in section 3.8 will change. The change could come as a result of the change of any of the factors in the chain that links the architecture and the resources the VCS receives back.

Since each link of the chain might affect how many resources are provided, the probability density function of resources feedback to the VCS, presented in section 3.8 could provide the information we are looking for. Once again we will look for the dispersion, as we did in the previous section, but, this time, we will weight each stakeholder satisfaction by their ability to control resources, and the criticality of those resources. This contrasts with the previous section where each stakeholder satisfaction was equally weighted.

In the diagram in (Figure 9), the probability density function on the left shows the probability of different amounts of resources feedback for two different architectures. This is the same diagram as the one shown in Figure 7. The figure to the right shows the probability density function for different dispersions of the diagram of the left.

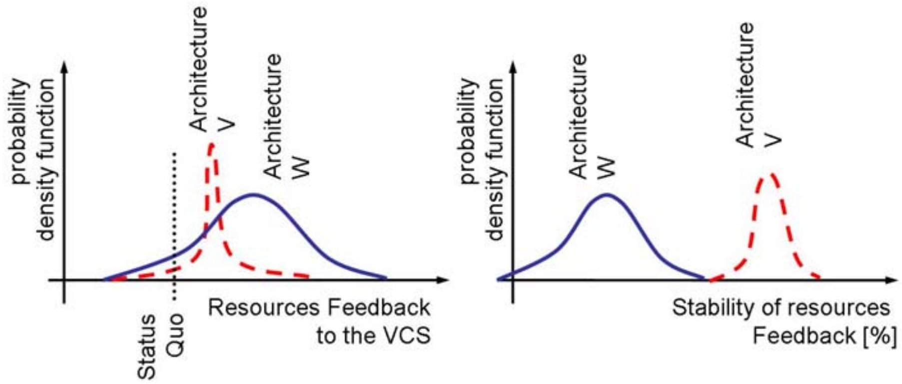

Figure 9. The diagram shows how two architectures could have different values for the risk of changing the amount of resources they deliver.

A low dispersion will imply a lower risk of change, and thus a more stable architecture. We can see in the example of the figure below, that even where Architecture W promises a higher amount of resources return, the supply of resources is less stable, because of a higher dispersion.

Furthermore, it should be noticed in Figure 9, that not only the probability of change is higher in architecture W, but also the probability of delivering value below the "status quo", or the present situation.

3. 9. 3. Valuation of architectures based on long term benefit

A third perspective on value stability is to analyze short term against long term benefits. This analysis is supported by the previously mentioned work of Sternberg [9], but it extends ownership, on the case of complex systems, to every group that possess a stake in the VCS.

While a time-phased analysis could potentially take into account infinite time horizons, we identify as most interesting two time horizons, one in the short term and one in the long term. We will choose the separation between both by using the most critical stakeholders' change rhythm as a metronome.

In order to implement the measurement of benefits or value delivered on the different time frames, there might be several approaches:

- We might analyze the value delivery process using stocks and flows as done through System Dynamics' tools. While this is the most general approach, this solution is beyond the scope of this work.

- We might identify manually which benefits are delivered over different timeframes, and use this criterion to build different probability density functions.

- We might use the identified stakeholder interaction matrix, with different dampening factors (also presented in this work as success discount rates, see 0). While an increased dampening factor will weight heavier the effect of actions that occur in the close time horizon, thus measuring short term effects, on the other hand, a lower dampening will make actions in the future equally valuable to those in the present, thus providing a measure for long term benefit.

In the case of United States Space Exploration strategy, the most important stakeholders are political, thus, the electoral calendar is the one providing the rhythm of the system interactions. As a consequence, a time horizon of 2 to 4 years, which is the electoral process in the United States, might be the most natural separation between short and long term.

The discount rate mentioned in the last bullet above should be understood as the chances of failure, which in this case are the chances of cancellation of the policy or program being analyzed, over the timeframe proposed. For the case of space exploration, the dampening factor should be the risk of program cancellation over a time horizon of 2 to 4 years. In order to scale adequately the dampening factor, it would be necessary to assess how fast the interactions between stakeholders are, when compared with the time horizon boundary.

3.10. XY graph of leadership vs. consensus

While the vision of choosing architectures by their ability to provide resources to the VCS seems interesting, it could prove also riskier, because in order to increase the satisfaction of powerful stakeholders, the VCS might alienate others, which might eventually affect the VCS.

Because of having fewer members, the coalition that supports a leadership-oriented architecture is prone to support swings; changes with any of the few members of the coalition have a higher impact on the VCS.

Nevertheless, if a leadership-oriented architecture survives, it might prove correct over the long term, because, by winning resources to the VCS, they might be able to eventually increase the satisfaction to every stakeholder.

In order to analyze this tension we propose to use a two dimensional graphic, where we could represent each architecture, to compare them,

- On the horizontal axis, the amount of resources that a specific architecture presents as a result of the stakeholders satisfaction feedback.

- On the vertical axis, the measure for stakeholders' consensus as introduced in
  3. 9. 1, for that same architecture.

Since both measures are probability density functions, the resulting diagram is a three dimensional probability density function, whose projection in two dimensions can be seen in the notional graphic of Figure 10.

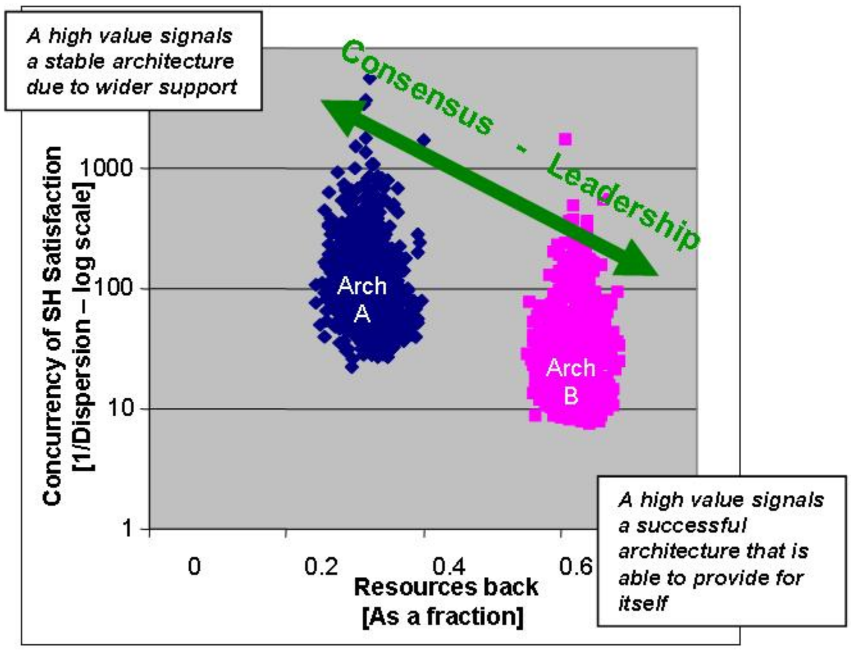

Figure 10. This diagram shows the mapping across two dimensions of competing architectures.

In this graphic, we can see that architecture A has its expected value around (0.3, 100) and architecture B is centered around (0.62, 50).

An additional benefit of using probability density functions is showing the certainty and completeness of the data fed to the model. The excessive dispersion of the results of a given architecture, or the overlap of results between two different architectures, will signal that the model does not possess enough information to provide an accurate recommendation.

It is previewed that some kind of efficient frontier will be found, traveling between

* Architectures that provide an increased feedback of resources combined with low consensus (Leadership-oriented)

* Architectures with feedback of resources to the VCS, but combined with a higher consensus.

In the notional graphic of Figure 10 we can observe the efficient frontier location as a two pointed arrow.

The negative slope of the efficient frontier could easily be seen through the following explanation:

In a case with just one stakeholder, say Stakeholder #1, there exists an Architecture B, which optimizes the objectives presented by that stakeholder, for a given amount K of resources invested.

If a second stakeholder is added, Stakeholder #2, with the condition that there exists at least one non-concurrent objective between both stakeholders, then, Architecture B, which was optimized for Stakeholder #1, will not be optimized for Stakeholder #2, because of the non-concurrent objective, for the same amount K of resources invested.

There exists, then, an Architecture C, different from Architecture B; Architecture C is optimized for Stakeholder #2 for an investment K. Symmetrically, Architecture C, because of the non-concurrency of objectives, is not optimal for Stakeholder #1. We can see these architectures represented in Figure 11.

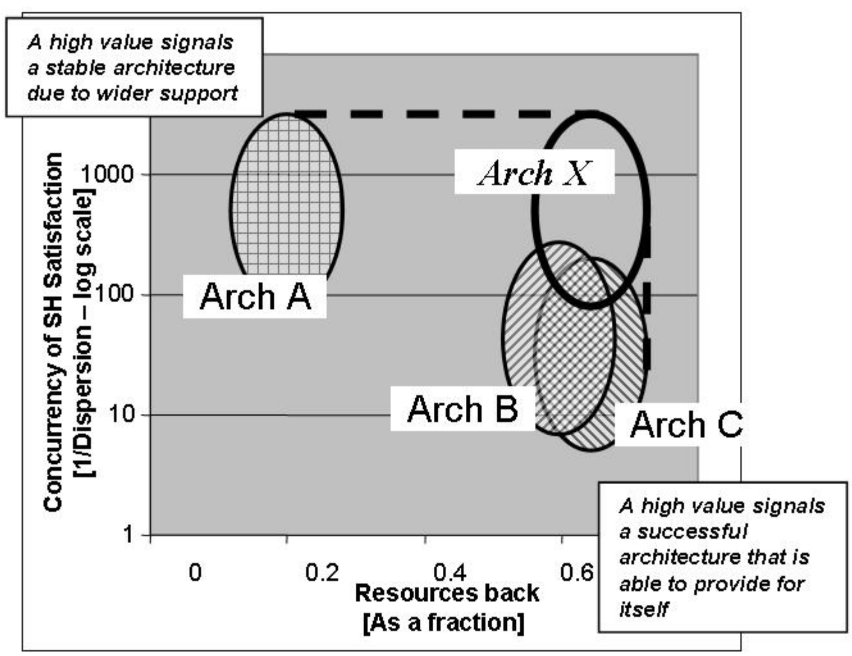

Figure 11. Illustration of the proof for the efficient frontier slope.

Because neither Architecture B nor C is optimal for, respectively, Stakeholders 2 or 1, there will be a non-zero value on the stakeholders' satisfaction dispersion, and thus a finite value of stakeholders' consensus. These two architectures will be located on the lower right side of the diagram of Figure 10.

Now, by extracting constraints from Architectures B and C, it will be possible to produce an Architecture A, which will be sub-optimal for both Stakeholder 1 and Stakeholder 2 yet, causes both Stakeholders to be *equally* "un-satisfied", and does not use resources above the amount K. This Architecture A, with a lower but equal amount of benefit to either Stakeholder, has a lower dispersion of stakeholders' satisfaction, and thus a higher consensus. This architecture will be located in the top left side of Figure 10.

Were it to exist an Architecture X that at the same time increases satisfaction of Stakeholders 1 and 2 to the level of Architecture A, and delivers a similar value than Architectures B or C without an increase over the investment level K, such architecture should satisfy simultaneously the non-concurrent objectives presented by the stakeholders. This fact is an absurd, as we will see.

If we see this Architecture X from the perspective of Stakeholder #1, this architecture is using resources on the optimization of an unwanted objective asked by Stakeholder #2. Were that objective not present, resources would be freed, and an increase on satisfaction of the objective asked by Stakeholder #1 would be possible. Yet, if Architecture X already provides the same value as the Architecture B, optimal for Stakeholder #1, further increase is not possible; then it is absurd to think that exists an Architecture X that fulfill the hypothesis conditions.

We are proving then, that the efficient frontier, for a given investment level has a negative slope.

4. Implementation Algorithm

4.1. System Vectorial Dynamics Probability Model (SVDPM)

In Section 3.1 we stated that System Dynamics guided our initial exploration on the value delivery process; yet, we also expressed we felt a need to extend the System Dynamics tool to incorporate the use of vectors and uncertainty. What follows is a presentation of these extensions.

Feedbacks and flows have been studied through System Dynamics for over 40 years[23]. From its origins, on the Control theory, System dynamics has evolved achieving acceptance as a mainstream model that allows understanding the interaction of competing forces in complex organizational systems. We can say that System Dynamics has changed the way we understand the world.

While System Dynamics models have produced stellar results on areas ranging from project management to enterprise growth, it is our impression that the problem of analyzing multiple stakeholders is opaque to its analysis. The difficulties we found lay basically in two areas:

- System Dynamics models become difficult to understand and model when more than a few factors are taken into account; to organize the factors into categories of factors, through a vectorial arrangement has been useful for our research.

  System Dynamics requires an *a priori* and intuitive understanding of which of the many factors of the model drive its behavior. Without this understanding it is not possible to discard enough variables to make tractable a problem as the one we analyze.

- System Dynamics models require certainty on the modeling data; to be able to use uncertain data, and even take advantage of it has been needed for our research.

  There is a need to assign a specific function to the relationship between each factor to the one that follows. In the case of the value delivery process, while the specific function structure might be inferred, the function's coefficients are not only difficult to assess, but will be always surrounded with uncertainty.

System Dynamics might be asking for a complete understanding of the problem of interest, before the process of modeling has begun; yet it is exactly that understanding which we expect the tool to provide and not require.

As a consequence, we propose that an extension of System Dynamics to deal with these two problems could prove useful. This extension is not the central object of our research yet; we need to introduce it in order to apply it later.

4. 1. 1. System Dynamics extension to vectors

The first bullet states that there is a need to select some factors and segregate them from the analysis. Complex problems, with multiple factors and uncertainty regarding their importance, like multi-stakeholder analysis, make especially difficult this assessment. Besides, the researcher's own bias at selecting factors will influence the outcome of the analysis.

Furthermore, not only many flows were traveling from one element to the next, but, it required an even larger number of equations, linking each incoming factor to the array of outcomes. The situation and its proposed solution can be observed in Figure 12.

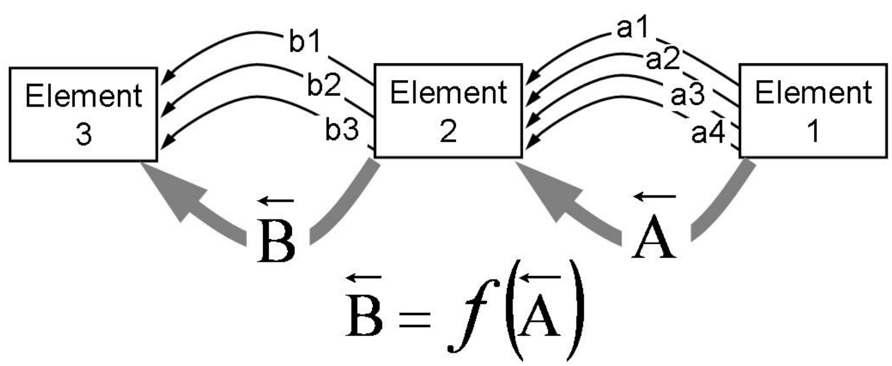

Figure 12. Linkage of element to element through multiple parameters or through vectors.

In order to deal with this complexity, initially we thought it made sense to simplify our System Dynamics diagram by using vectors instead of scalars flowing through the model. This makes the diagram easier to understand. As we see, the vector B becomes a function of the vector A.

It was only a natural extension to think that in order to connect a set of vectors entering an element with a set of elements leaving that element we could use a matrix, and apply matrix algebra to operate the tool.

$$\overleftarrow{\mathrm{B}} = [\mathrm{M}] \times \overleftarrow{\mathrm{A}}$$

Matrix multiplications, which we know operate through the formula that follows, assign linear combinations of the elements of A to every element of B

$$\mathrm{B}_j = \sum_i \mathrm{M}_{ji} \cdot \mathrm{A}_i$$

The linear combinations presented in the expression above assigns to the first element of the vector B, a linear combination of all elements of vector A, weighted by the elements of the first row of matrix M; assigns to the second element of vector B, a linear combination of all elements of vector A, weighted by the elements of the second row of matrix M, and so on.

As it can be seen, this makes a matrix multiplication an obvious choice for a repeated application of multi-attribute decision making based on linear combination of factors, based on the adequate selection of coefficients for the matrix M.

It would be useful to normalize the weights of these linear combinations to one. The reason for this is to keep each element at every vector to a comparable size; which we chose to be one. If each element of vector A is $A_i \leq 1$, then a linear combination of them will also be less than one.

$$
\begin{aligned}
&\textit{Being}\ \ \mathrm{B}_j = \sum_i \mathrm{M}_{ji} \cdot \mathrm{A}_i \\
&\textit{if}\ \ A_i \leq 1 \quad \forall i \quad \wedge \quad \sum_i \mathrm{M}_{ji} = 1 \quad \forall j \\
&\Rightarrow \quad B_j \leq 1 \quad \forall j
\end{aligned}
$$

Furthermore, this conforms with the averaging rule described by Anderson[14] as seen in section 2.1.

While this might be an interesting extension to System Dynamics, we think that the main strength of System Dynamics is actually to provide an intuitive way to operate numerically and graphically with a system of differential equations. In this respect, our rough initial formulation of a vectorial system dynamics tool, through linear combinations is not delivering on System Dynamic’s full potential, and just proposing a starting point in a rather simplistic way. As we stated, we believe that our proposal on this aspect is still not mature, and that the formulation of a full fledged vectorial system dynamics model, with its underlying differential equations foundation might be an interesting problem to attack in the future.

In the model we propose now, the researcher will have to identify *categories of factors* that link one element to the next one, such as, objectives, stakeholders’ satisfaction or proxies, and assign these categories to vectors.

After this is done, the researcher should identify what elements each of these vectors should contain. As an example, at the vector that contains stakeholders’ satisfaction, each element of the vector will represent the satisfaction of a specific stakeholder group.

Then, the researcher should attempt to link categories through a cause and effect process using a similar methodology to the one used to build System Dynamics models. This work should lead to closed causal loops, where causes and consequences generate a ring.

Anderson's[14], Fishburn's[15] and Pollak's[16] work propose the use of linear combinations to link precedents to consequences. We propose to use the same mechanic, and calculate the elements of each vector as a linear combination of the elements of the previous one; hence, linking one category to the next one through a multiplication of matrices.

4. 1. 2. System Dynamics extension to uncertainty

The second limitation we found in System Dynamics is the need for certainty at formulating the relationships between the different factors. In our short experience with System Dynamics this requirement was partly addressed through repeated sensitivity analysis; however those analyses add an additional dimension to the already complex issue of many inputs and outputs at each element. If we have 10 inputs, and 10 outputs flowing between 4 elements, we have already 10,000 combinations; measuring sensitivity to 5 levels at every factor over that many combinations, will lead to 50,000 sensitivity analyses. A system as simple as this one escapes the human capacity of analysis.

Our proposal not only operates with uncertain data, but takes advantage of it. Insights will come in two levels; the first one is a probability density function as answer to the question posed. By doing so, we will take advantage of the divergence of opinions of the different surveyees, and use the dispersion of their answers to provide the uncertainty we already identified as important. The coefficients of the matrices mentioned in section 4. 1. 1., will be parameters that describe determinate probability density function distributions.

The use of a Monte Carlo simulation allows for a random choosing of the value of each element for the different matrices following a defined probabilistic distribution. In this first iteration of the model we have chosen to use a normal distribution in every case. Hence, from the relevant data we will extract an expected value and the standard deviation for each matrix element; that means that each of the matrices we will present in section **Error! Reference source not found.** is actually a set of matrices that contain the parameters needed to generate the elements of the Monte Carlo experiment.

At each Monte Carlo experiment, the numerical simulator will generate a new matrix, whose elements follow the specified distributions. Then, using matrix algebra, it would be possible to operate and obtain the results we look for. A large number of experiment iterations will lead to results that are possible to analyze through standard statistical tools, deriving probabilities for the questions of interest.

While the answers the model will provide may not be definitive, they will be closer to the reality, where neither information nor methods are completely certain. To know that we don't know enough is already a valuable insight.

We propose the name of System Vectorial Dynamics Probability Model (SVDPM) for these two extensions, which provide a vectorial representation of the world, and a probability mapping of the results of System Dynamics model.

The lower difficulty and increased benefits of incorporating uncertainty to System Dynamics makes us believe it should be the first step to follow.

There is a higher complexity on incorporating vectors on System Dynamics. Since System Dynamics is a representation of a system of differential equations, and changing from scalar differential equations to vectorial ones would have quite important implications, we believe our proposal for vectorialization is less mature than our proposal for the incorporation of uncertainty.

We also think that the incorporation of uncertainty to System Dynamics is a more urgent need, since it will address what we believe that the key weakness of System Dynamics: its intent of providing *one answer* to complex problems without bounding it with probability.

Additionally, it should be relatively easy to implement a stochastic algorithm in a System Dynamics simulator, because of their numerical nature.

4.2. SVDPM application to Space Exploration

As presented in the preceding section, in order to build a SVDP model we will need to identify categories of factors that influence one another; not the factors themselves.

The diagram in Figure 13 shows the different categories that were identified in the value delivery process causal analysis. The categories are shown as solid line boxes, and are connected one to the next one through matrices, which are represented by dotted line boxes.

Table 1 presents the inputs and outputs of each step presented in Figure 13, as well as their dimensions and mathematical operations involved in their calculus.

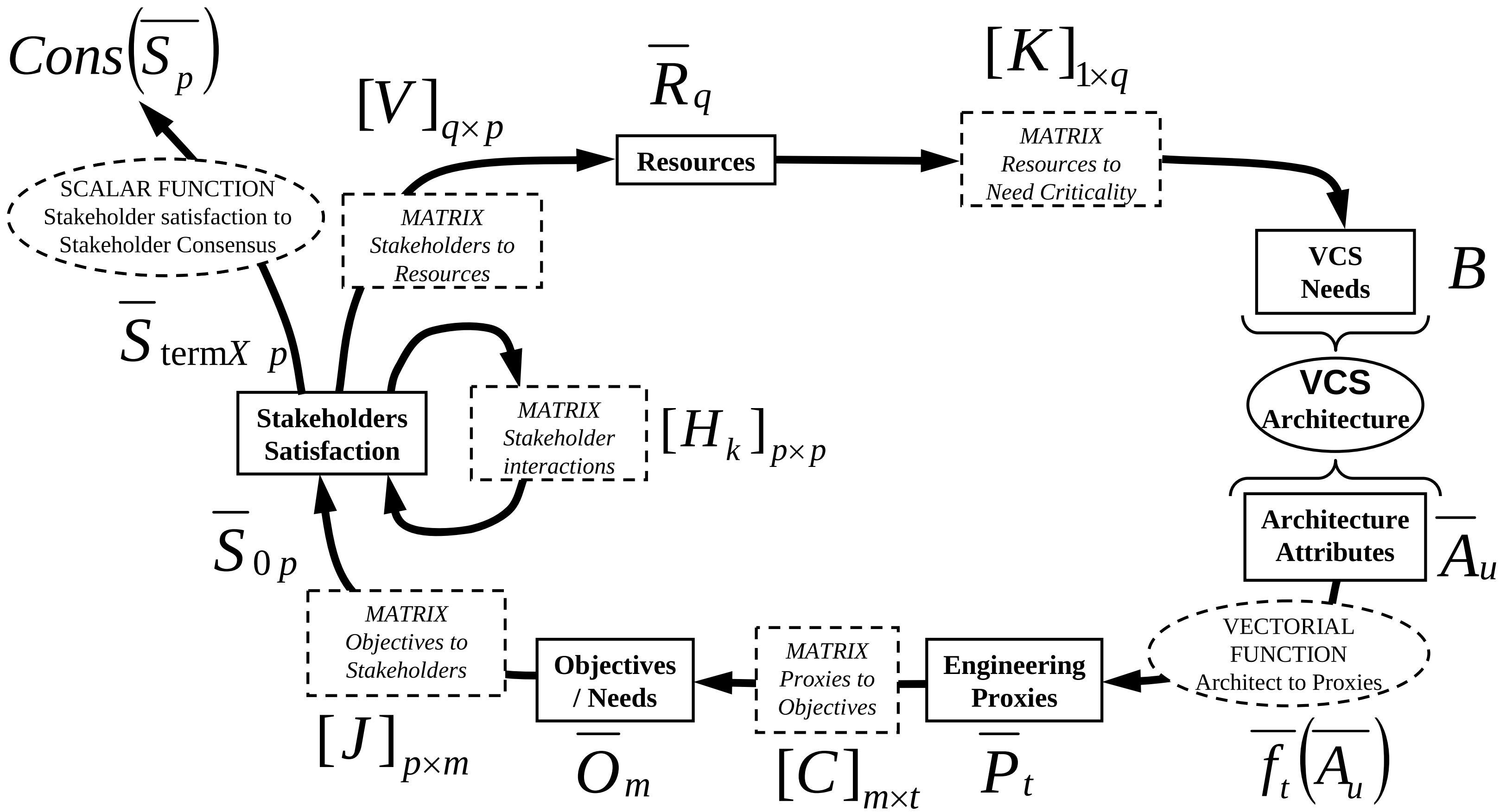

Figure 13. Operation of the model and data flows.

Step	**Input vector**	Input dimension	Input dimension for the case of space exploration	**Matrix**	**Output vector**	Output dimension	Mathematical operation
1	$\overline{A}_u$	u = number of architecture decisions	4	$\overline{f_t}\left(\overline{A_u}\right)$	$\overline{P}_t$	t = number of engineering proxies	Vectorial function evaluates input vector
2	$\overline{P}_t$	t = number of engineering proxies	33	$[C]_{m\times t}$	$\overline{O}_m$	m = number of objectives	Matrix multiplication
3	$\overline{O}_m$	m = number of objectives	23	$[J]_{p\times m}$	$\overline{S}_{0\,p}$	p = number of stakeholders	Matrix multiplication
4	$\overline{S}_{0\,p}$	p = number of stakeholders	11	$[H_{0.5}]_{p\times p}$	$\overline{S}_{\text{term}0.5\ p}$	p = number of stakeholders	Matrix multiplication
5	$\overline{S}_{0\,p}$	p = number of stakeholders	11	$[H_{0.99}]_{p\times p}$	$\overline{S}_{\text{term}0.99\ p}$	p = number of stakeholders	Matrix multiplication
6	$\overline{S}_{\text{term}X\ p}$	p = number of stakeholders	11	$Cons\left(\overline{S_p}\right)$	$Cons$	1 (scalar)	Vectorial function evaluates input vector
7	$\overline{S}_{\text{term}X\ p}$	p = number of stakeholders	11	$[V]_{q\times p}$	$\overline{R}_q$	q = number of resources	Matrix multiplication
8	$\overline{R}_q$	q = number of resources	23	$[K]_{1\times q}$	B	1 (scalar)	Matrix multiplication

Table 1. Presents the model steps, inputs, outputs and involved operations. Shows the dimension of the vectors for the case of the space exploration initiative.

The nomenclature of the matrices and vectors we will use is shown near the respective category. The sub-index shows the dimensions of each vector or matrix.

This diagram shows that, in order to calculate the vector P, we will apply the function f to the vector A; in order to calculate the vector O, we will do a vectorial multiplication of the matrix C by the vector P.

The formula to calculate the Stakeholder consensus presented below as "cons" is based on the formula for standard deviation, as shown on section 3. 9. 1.

$$\overline{O} = [C] \times \overline{P}$$

$$\overline{S_0} = [J] \times \overline{O}$$

$$S_{term} \text{ is function of } k \text{ and } [H]$$

$$\overline{S}_{term} = \sum_{i=1}^{\infty} k^i . \left(\prod_{j=1}^{i} [H] \right) \times \overline{S}_0 + \overline{S}_0$$

$$\overline{R}_{short} = [V] \times S_{term-short} \qquad \overline{R}_{long} = [V] \times S_{term-long}$$

$$Cons = \frac{1}{\sqrt{\sum \left(\overline{S}_{term} - \underline{\overline{S}_{term}} \right)^2}}$$

$$B = [K] \times \overline{R}$$

4. 2. 1. Delays and accumulation in the Value Delivery Process

The first iteration of the model uses a static view of reality, without taking into account more advanced system dynamics concepts such as accumulation. A successive refinement should include those effects.

By excluding accumulation the issue of delayed effects needs an alternative treatment. The model presented in this research will use a "discount rate" to decrease the value of effects that have to go through intermediaries, or effects that are further away in time, as explained in section 4. 6. 4.

The discount rate we propose to use is not linked to the traditional financial discount rate, but is more closely linked to a "probability of success". In this respect, systems with highly likely success would not be punished for delivering values far in the future, or in an indirect way; on the contrary, there should be a higher discount for value streams with a less certain success chance.

4. 2. 2. Alternative vision of SVDP as a tiered multi-attribute decision making model

As we mentioned in section 2.3, our model could be understood as a tiered implementation of the known multi-attribute decision making model, based on additive utility functions. The additivity of utility functions studied by Fishburn[15] and Pollak[16] provides a theoretical framework to formulate utility of several attributes as a linear combination of the utilities of the attributes.

In the case of the traditional decision making, "the customer" is surveyed to gather data on how its different needs are prioritized; this data will be manipulated into a linear combination of those needs, which provides a measure of the customer satisfaction to different levels of them. This is shown in Figure 14.

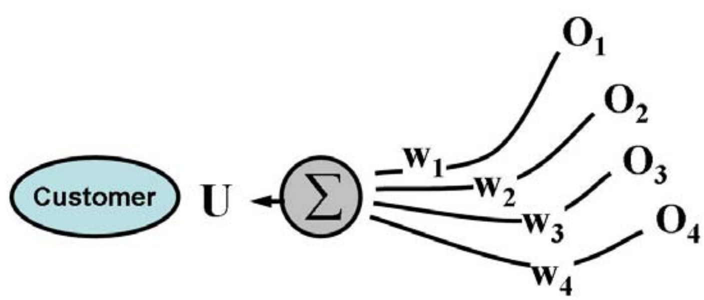

Figure 14. Traditional additive Utility function for decision making.

The model we propose also uses surveys but applies them to "the many customers" or stakeholders, and to the VCS too. The model analyzes the priority of VCS's own needs and looks for suppliers for those needs; it is then where the "the many customers" or stakeholders needs play, in a tiered process that we can see in Figure 15.

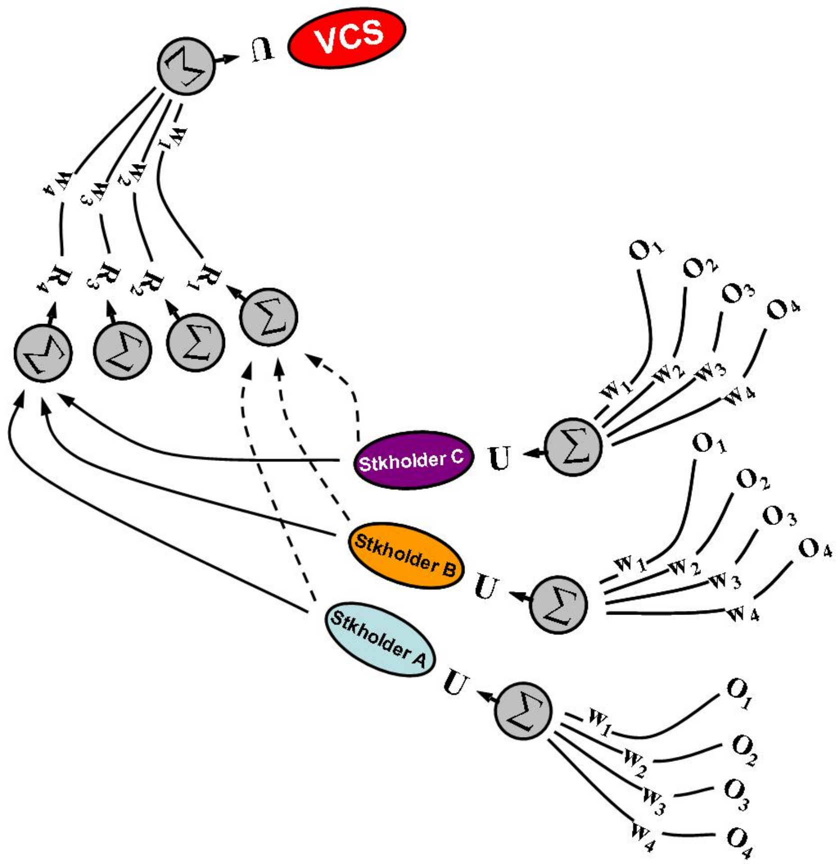

Figure 15. Proposed tiered additive Utility function for decision making.

The traditional model places "the customer" as dictator and its needs as most important; as a contrast, the model we propose, places the VCS's architect as dictator, and the VCS's own needs as critical criteria, subordinating the external "customers" to their ability to provide for the VCS's needs, building in fact a tiered multi-attribute model.

The use of matrices to perform this sequence of linear combinations is just a useful mathematical algorithm. The incorporation of probability allows providing useful insights even in cases where the weights are not possible to identify with absolute certainty.

Since multi-attribute decision making is a widely known and accepted technique for combining non-concurrent requirements, we believe that to see our model as a tiered decision making process, with sustainability of the VCS as the higher goal by providing the resources it needs, provides additional arguments in favor of the model.

4.3. Model limitations

There is no way to know if the answer the model provides is correct. There is never absolute certainty in the accuracy of a model but only increased or decreased probabilities of certainty; that is the inherent nature of the scientific method: to keep the doubt.

On the other hand, decisions are needed within certain timeframes, even if models and information are uncertain. The methodology used in engineering to deal with uncertainty is to add “safety factors”, which decrease the reliance on the answer accuracy to select one alternative. The use of these factors try to increase the success likelihood to “most” of the cases.

Knowing that there is never an absolute answer, but a most probable certain one, and borrowing from the concept of “safety factors” the idea that a lower accuracy would not allow to distinguish two options that are similar, we postulate that the model can support rough high level decisions at this moment and that further improvements will allow it to distinguish between closer alternatives.

Nevertheless is important to understand where the model could fail, so to avoid those loopholes when modeling. The following are reasons for which the model might not provide an accurate answer:

- The model framework is wrong

  This research is based on the hypothesis that value is created, and delivered from one party to another, that resources are needed to create value, and that the Value Creating Organizations’ actions influence their future supply of resources.

  Along this research we have tried to show what rules value follows while traveling from one group to another, and to use previously developed tools, such as multi-attribute decision making or the Kano model of quality to instrument those rules.

  Being a first iteration, we would not trust the model to decide between alternatives that have a similar valuation. While we hope further work will help to refine the model and increase its accuracy, the general framework proposed should be robust enough to structure the work that would follow.

- The implication strength between linked elements is weak

  Because the model involves many steps executed sequentially, we need just one of the steps to fail for the model to fail as a whole. Being each step modeled as an implication, of the type “if p is level X, then q must be level Y” the results might not be convincing if the hypothesis we present and the absence of the shown results can happen at the same time.

This event could happen for a number of reasons, including a wrong selection of categories or a wrong selection of elements for those categories.

Along this work we have tried to show what we believe are the most important properties that categories and elements of the model should possess. While a wrongful selection of categories might occur, after using the method to analyze the case of Space Exploration and the case of Resource Extraction (see section 4. 6. 9), we think that the general framework provides tools that allow analyzing problems of this kind in an orderly fashion.

Nevertheless, we think that at some point the model will produce results against common. These results will call for a throughout revision of the assumptions made, among which a very important one is whether the elements linked possess implication strength.

From mathematical logic we know that the fact that p implies q is equivalent to:

$$\sim p \vee q$$

That is, for the implication to be true, "if q is false then p must be false"; equivalently, the implication is false when at the same time, the antecedent p is true, and the consequence q is false.

The strength of an implication can be related to the probability of both events, "*antecedent true, and consequence false*", not happening at the same time.

Hence, in order to link one element to another in the category that follows in the model, we should strive to find elements where, the change of the element in the antecedent and the lack of predicted change on the element on the consequent have a low probability.

This low probability is equivalent to a high implication strength.

The model ability to handle uncertainty should not confuse us, by suggesting that a larger number of low implication strength antecedents would increase the certainty of the consequence. We should try to reduce the number antecedents and use only those that being present, cause necessarily the presence of the consequence.

The model chain of implications should be easy to follow, and each step links should be intuitively understood. Because the model final objective is not only to provide an answer, but, as we will show on section 7.2, to present a chain of implications that convince a less technical audience, the categories selected should be the basis for a credible case where the final decision can be followed and understood through the model. The model would be most valuable when it successfully convinces a larger audience about a result that is non-intuitive.

- The data acquired is not adequate

Unfortunately, not always the data acquired would be enough to reduce uncertainty to a level where the analysis provides some clear answer. This situation might obey to different factors including, lack of communication channel bandwidth with the individuals that possess the information the model requires and the lack of agreement between individuals of those groups.

This lack of clear answer should not be understood as a lack of answer, but as a sign that either, stakeholders do not have a strong preference for one alternative. This situation points towards a more technical and inward looking approach to select the alternative to use.

4.4. Vectorial representation of an architecture

4. 4. 1. Model of an Architecture as a decision tree

Because of the nature of the work of the architect is to decide on different aspects of an architecture, it should be possible to lay out in a time line the set of decisions he or she has to take, in the order they are taken. By walking through this timeline, it should be possible to build the architecture.

As a first approximation, we would not take into account the possibility that some decisions might require an iterative process; this restriction would be relaxed in 4. 4. 3. For the moment, we would assume that it is possible to define one decision after another in a sequential way, and without delay.

We have not found an evident classification for our architecture representation model under the nomenclature presented by Maier and Rechtin in their System Architecture book[24]; the closest match seems to be a *Model of Form*. The authors state that models of form represent physically identifiable elements of, and interfaces to, what will be constructed and integrated to meet client objectives.

A weakness of “models of form” is that they are linked to *specific forms* which could be dangerous, because it artificially restricts the solution space. On the other hand, being careful in generating the options in the decision tree, this danger could be avoided. Because the process is laid out as a tree, it lends itself, once some branches at a certain node are identified, to generate some more by analogy.

Let’s use a transportation system as an example to better present this model.

As architects, we should receive a set of requirements; these are from the perspective of architecture, constraints.

For a transportation system, these requirements might be a certain amount of freight to move, certain reliability, a required maximum travel time, and distance. Besides a tacit context requirement is the fact of *building a transportation system*, which falls under the category of a strategic use of constraints as explained in 3. 2. 4. and the last bullet of 4. 6. 9.

If we use for our example, the need to move 5MT from Boston to Los Angeles in 2 weeks, we might suggest different concepts to fulfill the objective. These concepts are answers to implied questions, which define the chosen architecture.

In a first level, we might choose between:

- Concept 1 – Railway
- Concept 2 – Truck
- Concept 3 – Airplane
- Concept 4 – Star Trek’s transporter
- Concept 5 – Rocket
- Concept 6 – Ship

In a similar way to a “20 questions” game, each of these concepts would be uniquely identified by using a finite number of answers that represent decisions taken; these decisions could be arranged using a tree like structure, from more generic to more specific, as shown in Figure 16.

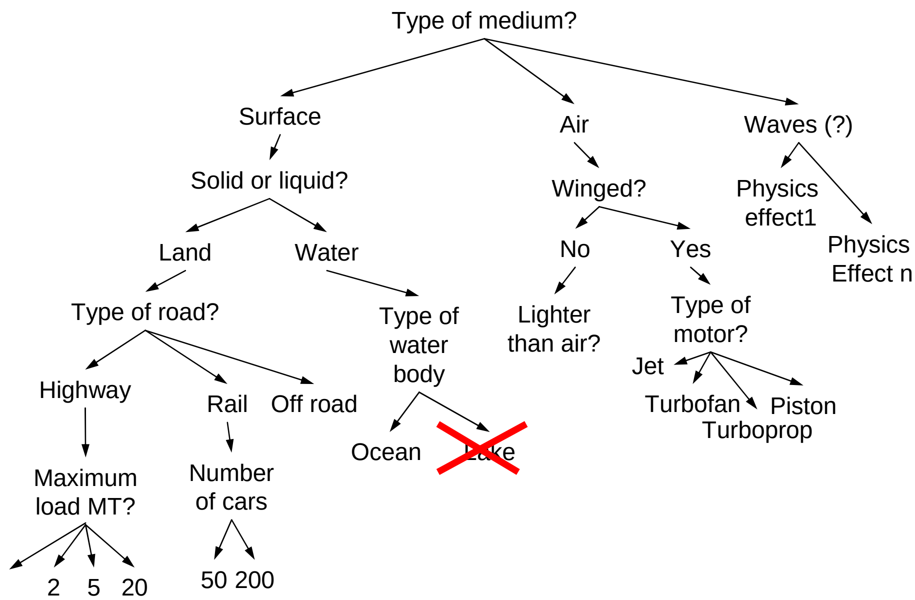

Figure 16. Representation of an Architecture as a Decision Tree.

If we follow the transportation system example, some details might not be of interest while choosing the architecture. For example, the question on whether the highway to use has 3 or 4 lanes might not be relevant, if no stakeholder is able to distinguish whether the freight was moved from Boston to Los Angeles through a highway with 3 or 4 lanes.

This aspect is extremely important: *if stakeholders are not able to distinguish between two alternatives*, or if they do see the difference, but do not care about the result, then, there is indifference between those alternatives, and *the decision should be taken by using a technical criterion*, internal to the VCS.

As such, the decision on the number of lanes might need to be taken at the stage of detailed design, independent from stakeholder bound constraints.

The architecture vector does not include decisions that are not feasible in the sense that they are contradictory. As an example, if we are designing a vehicle that will travel to the moon, a variable we will not include is the number of wheels, since it does not have any meaning in that context.

4. 4. 2. Decision tree representation as a vector

Because we have been able to arrange the design in a sequential manner, it is possible to assign a sequential number to each decision, and by using this sequential number assign the decision to an element of a vector. The numbering algorithm would start assigning numbers from the root of the previous decision tree.

In our example, the root or first node has the question “Type of Medium”. We would assign to this node the number 0.

Then, we can proceed on the second level, where from left to right, we can assign numbers 1, 2 and 3 to the questions on the nodes “Solid or liquid?”, “Winged?” and “Physics effect number?” respectively. For a particular architecture, some questions might not be relevant; those would receive a value of N/A.

On the third level of the tree, we would assign numbers 4, 5, 6 and 7, to the questions “Type of road?”, “Type of water body?”, “Lighter than air?” and “Type of motor?”

While some questions would call for a numeric value, from the perspective of who is getting the benefit there is a minimum “quanta” increment below which, the stakeholder is indifferent to one value or another. In our example, a car with an engine displacement of 2400 cm3 and 2401cm3 will not be differentiable. Hence, for the cases of numeric values it is advisable to assign “buckets” with numeric ranges, leaving the final number for a later technical decision. This simplification leads to a countable number of branches at each node, and thus preserves the validity of the postulate of a countable number of elements on the architecture vector.

Since there is a limitation on the available bandwidth to acquire information from stakeholders, and there is imperfection in such information, we should focus our analysis on a subset of the whole architecture vector, presumably closer to the root of the decision tree. These higher level nodes present the higher probability of impacting stakeholder objectives. We might add some elements that are farther away from the root, if there is merit in deciding among options at that node.

4. 4. 3. Releasing constraints

We opened this Architecture modeling proposal with the assumption that it was possible to lay out decisions along time, in an orderly way, without iterations. This is not always the case, and sometimes we will reach points were one decision needs information that will be acquired after the decision is taken, leading to what Suh names a coupled design[18]. In a representation using the Design Structure Matrix[22] this will mean some elements of the decision tree will be above the diagonal line of the matrix. This is shown in Figure 17.

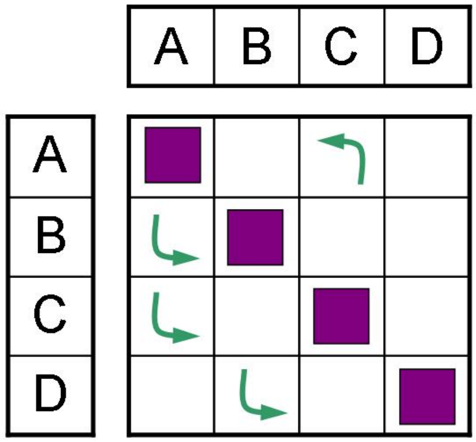

Figure 17. Design Structure Matrix showing precedent and consequent for decisions A, B, C and D.

In Figure 17, the first decision, A, is a needed to decide B and C, or A is a precedent for B and C; and B is needed to decide D. These precedents, located in the lower diagonal area of the matrix, follow the natural order of decision making.

On the other hand, in order to decide A there is a need for information from decision of C, this "out of order" requirement is shown by the arrow in the first row, third column. This means that there would be a need for iteration, where a later decision needs to be fed back to an earlier one.

In other words, decisions A and C are coupled. For this case, we should include every feasible combination of the possible answers to A, with possible answers to C, collapsing node A and node C into a single A-C node, using a full factorial.

While a coupled design will need a full factorial for coupled nodes, these nodes are possible to prune, by eliminating unfeasible decisions, simplifying the model. But even if the tree is not pruned, the vector will have a finite number of elements.

4. 4. 4. Value analysis as deviation from the Status Quo

The Status Quo Architecture (SQA) is the set of answers, and its associated vector, that are believed to be executed by the system, in its present state, previous to the analysis we are preparing.

It serves as a background and main point of comparison, providing an anchor point in reality.

As a consequence, it is assumed that there is an equilibrium situation where enough resources are available to implement the SQA, in exchange for the benefits the SQA provides.

For the cases where there is no official SQA, we could assign an arbitrary, most likely value, to the SQA vector.

Some of the values of certain elements of the architecture might not affect stakeholders, because of their indifference, or because the value is not pertinent to that architecture (assigned a N/A value). For those cases, the architecture preserves the SQA value.

4. 4. 5. Assigning numbers to decisions

The intent behind the model was to produce a set of matrices and vectors that through standard matrix operations would allow analyzing the value delivery process. In this context, the elements of an architecture vector should have been numbers, which operated through a linear combination, would provide the level of objective satisfaction.

This goal has been elusive, and as a result, we have reached the conclusion that an intermediate step, the assessment of engineering proxies, is needed between an architecture vector and an objectives vector. The link between the architecture vector and the engineering proxies' vector is done through a set of ad-hoc functions, and as a consequence, the assignment of numbers to the content of the elements of the architecture vector could be arbitrary or even unnecessary.

We distinguish two cases, in this assignment:

- Case where the architecture decision is a number, the architecture vector should contain the numeric answer to that decision.

- Case where the architecture decision is to choose among several options, and there is not a clear plus-minus axis. Some questions of Figure 16, such as type of road or if the vehicle is winged or not, are an example of this.

  We can choose either to arbitrarily assign a number to each option, keeping track of an index of the original answers, or to directly use text tags with the decision answers. In this implementation of the model, we have chosen the second option, and we will use text tags. Because an ad-hoc function will be used to analyze each architecture vector, the assignment does not matter.

4.5. Vectors

In this section we present the different vectors that are used in the model. We will start with the Architecture vector A, on the right section of the diagram in Figure 13, and proceed clockwise. We will leave the matrix that link one vector to the next one for section 4.6

4. 5. 1. Architecture – Vector A

The model we propose could be applied at several levels of abstraction, from high level systems to detailed design, as long as the decision has some impact on stakeholder groups. It seems that the best case would be to start at the root of the decision tree, yet, in order to present examples of the application at different abstraction points; we will use for the example four questions with different level of detail.

These four decisions are by no means the most important ones, they are just examples presented to illustrate how the model works. We believe a meaningful model would have 30 to 40 decisions, deemed important asking by the architecture group.

The number of questions to ask is only limited by the amount of information the architecture group wants to acquire. Since the stakeholders have already been surveyed, the model could potentially answer as many questions as needed without an increased stakeholder fatigue. Nevertheless, we believe that only a relatively small number of decisions would have a meaningful answer from stakeholders' perspective.

A. A high level architecture vector element with a question on the timeframe for a Lunar landing – with three possible answers
    - 2015
    - 2017
    - 2021

Since the answer is a number, we should apply the first valuation method for this architecture decision, using numbers. Hence, the first element of the architecture element would be chosen from the set

{2015, 2017, 2021}

B. A medium level architecture vector element with a question about whether the CEV should land on the moon or not – with three possible answers, one of which is a real option
    - CEV is designed for landing on the moon, and does land on the moon
    - CEV has the potential ability to land on the moon, but is not planned to do so

- CEV is not designed to land on the moon

The text tag selected for the second element of our vector would contain one element of the set

{Capability and Landing, Capability and no Landing, No Capability and no Landing}

C. A question on energy supply for a moon base – with 4 possible answers result of a coupled design
    - Energy supply for a moon base on the pole should be nuclear
    - Energy supply for a moon base on the pole should be solar
    - Energy supply for a moon base on the equator should be nuclear
    - Energy supply for a moon base on the equator should be solar
    - There will be no lunar base

The text tag selected for the third element of the vector will be chosen from the set

{Pole-nuclear, Pole-solar, Equator-nuclear, Equator-solar, no-base}

D. A question on the size of the launcher – with a continuous range for answer, but, bracketed in 5 options
    - Approx 8 metric tons
    - Approx 23 metric tons
    - Approx 40 metric tons
    - Approx 125 metric tons
    - Approx 300 metric tons

The possible values of the fourth element of the architecture vector would be elements of the set

{8, 23, 40, 125, 300}

4. 5. 2. Engineering Proxies – Vector P

We identified a difficulty at mapping directly architecture decisions to satisfaction of objectives, and as shown in section 4. 4. 5, an intermediate step between both categories is needed.

The intent of this intermediate category and its related vector is to present markers that could be linked to the satisfaction of the different objectives, in such a way that an increase of the marker implies an increase on the level of satisfaction of the objective and vice-versa. The need for these markers arises from the fact that we need to look into the architecture from the perspective of the stakeholders, and look into the architecture for signals that indicate that the needs of the stakeholders are covered.

A temptation is to use the measures suggested by the architecture, however, this sheds a poor light if the intent is to prioritize architectures based on stakeholders perspective. It should be *stakeholders* who look to the architecture, and use their *"rulers"* to measure it, and not the other way around.

As a consequence, the most important property for these markers is that their level should be strongly correlated with the level of their relevant objective satisfaction. Besides this property, these markers should have a real-world meaning; since this would help to build the previously mentioned ad-hoc functions.

Is in these markers where the handshake between the real and the model world occurs; they are the section of the model where the linkage between architecture meaningful decisions and sometimes abstract objectives happens.

An additional danger of using *architecture generated* engineering proxies is that the density of these proxies will be higher at areas where the architecture is better defined, stirring away the focus from the more difficult to define sections. The paradox is that in those difficult sections have a stronger need for the analysis.

For these two reasons (observation of the architecture from the stakeholders' perspective and preservation of the density of proxies across the different objectives), the proxies should be defined with a *stakeholder's mind frame*, and by looking to *the objectives* (and *not by looking to the architecture*). Otherwise, we might end up knowing exactly the state of the architect's favorite subsystem.

Keeney and Raiffa's book[13] present some guidelines for the selection of engineering proxies, which they call Attributes.

- Completeness – the selected engineering proxies should map the complete set of measures that can satisfy a given objective. It is to remember that when defining proxies, we are focused on just *one* objective and likely ad-hoc for that objective.

- Operational – the selected engineering proxies should be useful in order to analyze the architecture. Engineering proxies that do not shed light while choosing one architecture over another do not help to the analysis.

- Decomposable – the selected engineering proxies should be possible to order in a hierarchy in order to use a conjoint analysis of the engineering proxies' levels. We don't think this aspect is crucial, if the following two conditions are enforced. We do not use a conjoint analysis.

- Non-redundancy – the engineering proxies should not have overlap between them, to avoid duplicity in the mapping, so that some aspects of the architecture are not counted more than once.

- Minimum size – the engineering proxies should be as few as needed in order to provide completeness.

As presented in section 4.3., a high correlation between the elements of one category and the linked elements on the next one is of the highest importance. A high implication strength combined with the smallest size of attributes per objective seems to guarantee all five proposed properties.

A high implication strength implies completeness and operational qualities; and a small size implies non-redundancy, and size constraints.

The temptation to extend the number of engineering proxies in order to increase the accuracy of the mapping presents two challenges:

- If both engineering proxies are highly correlated, there is a wasted effort, because the level of one will imply the level of the other. But, because, it will always be the case that one of the engineering proxies has a higher correlation than the other, the lower correlation attribute will "contaminate" the information of the more adequate indicator. It is to remember that we proposed that the relationship between objectives and proxies is a "one-to-many" relationship (we could even say a "one-to-few").

  As a consequence, the number of engineering proxies should only be increased when a given attribute is not able to explore the whole objective, situation that might be present when engineering proxies are orthogonal one to the other. If we are looking to map the volume of an object, it will be needed not only the height, but also the depth and length.

  In order to know that we have mapped the *whole* objective, the question that we should be asking ourselves is whether the objective can change, while the proxies remain constant, case in which one or more additional proxies might be needed.

  An additional comment is that this mapping we propose is not perfect in its present form: while the above example for mapping a volume would suggest to use a multiplicative rule to combine them, we are proposing to use linear combinations, which might introduce error in some cases. We have chose the more robust "or" logical operator (through the use of linear combinations) over the more precise, but error prone "and" logical operator (on the form of a multiplicative rule).

- The use of additional engineering proxies in the belief that low implication strength can be reinforced by additional information. Adding more noisy information to an already noisy indicator does not increase the indicator prediction power. It will provide a false sense of safety, however, when the time comes to show to exterior parties how the results are linked together, the fuzziness of data at any step weakens the whole exercise.

The implication strength requirement is not a mapping of effect strength, instead is a valuation on how an increase or decrease in some variable's level, causes a change at another's variable level; this is related to a "width" of the diagonal cloud in a scatter graphic. As a contrast the effect strength, linked to the slope in a graphic linking both variables, can be changed by adequate scaling.

In Figure 18, we see on the left an XY diagram showing scatter plots for two relationships between variables, the one on top shows a better correlation, meaning a better implication strength than the one on the bottom; the one on the bottom is not going to be very useful for our purposes.

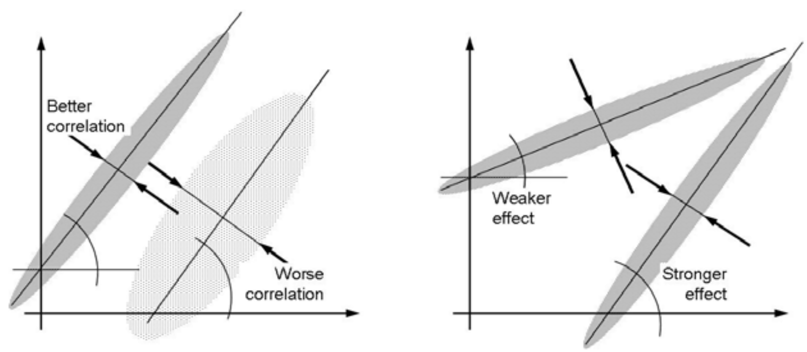

Figure 18. These figures compare the relationship between 2 variables. The one on top has a better correlation, but a weaker effect; the one closer to the bottom has a stronger effect but a weaker correlation.

On the same figure, the diagram of right shows scatter plots for two other relationships with different effect strength, but the same correlation; while the effect of the one on the bottom is stronger, both relationships present useful information for our analysis.

We should differentiate between correlation and implication. When we observe correlation between variables A and B, we cannot be sure whether A implies B or the other way around. An intuitive understanding of the underlying direction of the implication is needed to ascertain for sure that for example it is stakeholder W who become happy because of objective Z increase and not the reverse implication.

The comparison between implication strength and effect strength is illustrated by Table 2, through an example extracted from the world of computing.

	High implication strength	Low implication strength
Strong effect	**CPU clock frequency on computer performance** The increase directly affects the objective	**Computer temperature on computer performance** It has indirect link to the objective, but when true, will have a strong effect
Weak effect	**# of USB ports on computer performance** The increase should affect the objective, but in a mild way	**Area without useful information**

Table 2. The table shows examples of different implication and effect strengths.

Because engineering proxies are so closely related to objectives, we are presenting the list of selected engineering proxies in section 4. 6. 2, where we show the weights of the proxies to objectives mapping.

As mentioned in the introduction of this section, we tried to connect architecture and stakeholder objectives directly, without success. What follows are the different connection methods we explored, the last one being the Quality Function Deployment matrix chain, which hinted to us of the solution finally adopted.

- For the case where the architecture element was numeric, we thought of using a utility function with declining marginal value, and a superior bound of 1.0 An interesting candidate was the exponential utility function of the form

$$U(x) = 1 - e^{-kx}$$

$$where \qquad U(0) = 0$$

$$and \qquad \lim_{x \to \infty} U(x) = 1$$

  For a long time we considered this to be the solution of choice, yet we found some problems related to the determination of the constants k. It is not clear where should the SQA value be. We still believe that some work remains to be done in this area, and that there is a relationship between this curve and the Kano methodology (the Kano methodology is discussed extensively in section 4. 6. 3)

In Figure 19, we present three performance-satisfaction diagrams, all showing the same curve, a double exponential utility function, which is able to explain all three Kano responses, by changing the "good-enough" level of satisfaction for a given performance.

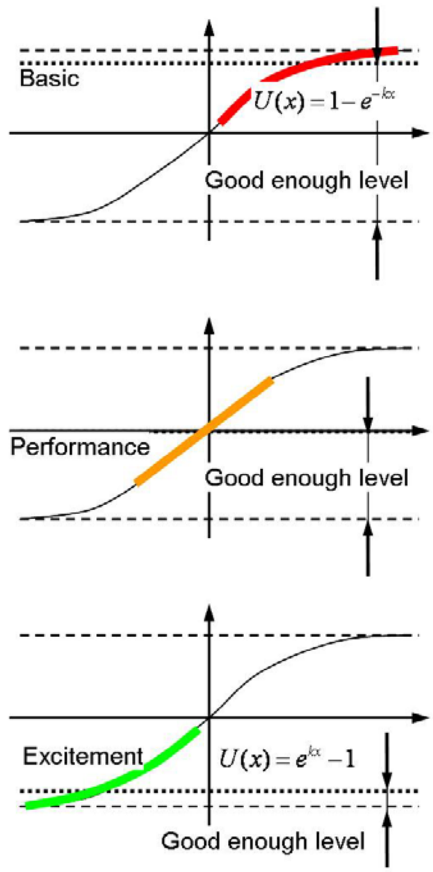

Figure 19. Double exponential utility function showing the different Kano responses by variation of the "good-enough" level.

A double exponential utility function has a limit of 1, for an ideal maximum performance, a limit of -1 for an ideal minimum negative performance, and presents a decreasing effect on satisfaction change, when subject to an increase in a positive performance, or a decrease in a negative performance.

Objectives with a very high level of "good enough" satisfaction, become basic objectives, as we see in the top satisfaction-performance graphic on top of Figure 19. Objectives whose satisfaction level is in the middle area, have a linear response to an increase in performance, and are classified as performance objectives. Finally, objectives that have a low good enough satisfaction level behave as excitement objectives, as can be seen in the diagram of the bottom. This should be theme for further exploration.

While promising, we did not found a clear solution for the problem of identifying a constant k. Nevertheless, we are using some of these concepts to translate proxies to objectives, as shown in section 4. 6. 2.

- The use of a tiered Kano methodology

  Under this methodology, a second layer of Kano questions would be modeled to be answered by each objective, however, it also was not clear who would be the surveyees for the questionnaire.

- The direct mapping of architecture values to stakeholder satisfaction

  This methodology's suggested to ask the stakeholders directly about architecture relevant questions. As an example, in the context of space exploration would have been to ask stakeholders about the size of the payload of the launcher.

  We discarded this option for the same reasons presented when explaining the use for objectives, in section 3. 2. 4. Technical objectives are difficult to assess by non-technical stakeholders who might not fully understand the consequences of their decisions. Besides, the available bandwidth with stakeholders will be strained, since objectives act as aggregators of architectural decisions.

- The use of a Quality Function deployment matrix

  This idea was a hint to us of the solution finally used.

  The Quality Function Deployment (QFD), a tool that has been used extensively in industry to translate high level objectives into architecture requirements. The tool proposes a matrix that links a set of high level objectives, which are closer to the customer, to a lower level set of objectives, closer to the engineering realm. The tool was invented in Japan around 1972, yet the first paper in North America was written in 1984 by Hauser and Claussing[4].

  The methodology asks to build a matrix arrangement, where each row corresponds to a high level customer objective (in this case the stakeholder's objectives list already presented), and each column to a certain lower level engineering objective.

  The steps to prepare a traditional QFD matrix (Figure 20 shows an example for the case of an automotive door) are:

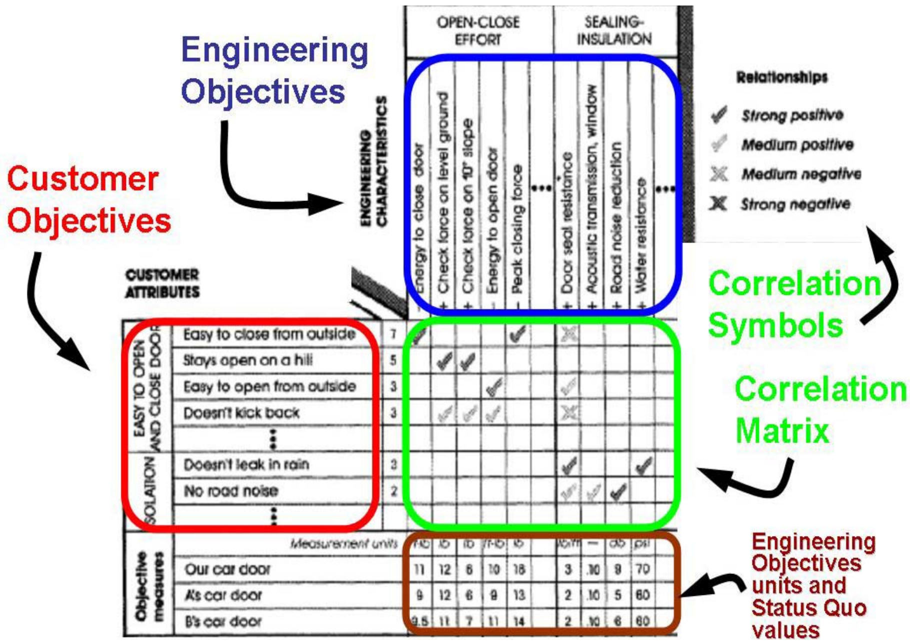

Figure 20. Diagram showing some elements of a QFD matrix, extracted from Hauser and Clausing's paper. Only the relevant sections of the QFD matrix are shown for clarity. The non relevant elements have been erased in this image.

- Assignment of weights to the customer objectives (we will not use this step, since the weights in our case will be assigned by the criticality of resources as explained in section 3.7 and section 4. 6. 3.

- Identification of the relevant lower level engineering objectives, in order to place them as headings of the different columns.

  Our initial intent was to have architecture actionable items as lower level engineering objectives. That was not possible, and it led to incorporate engineering proxies.

- Identifications of units, ranges, and present level (Status Quo Architecture) for the lower level engineering objectives.

- Assignment of a correlation marker at each element of the matrix defined. These markers would signal how strong is the correlation between a specific customer objective and a specific engineering objective

The QFD method asked for a staged approach due to the distance between the high level strategies and low level actionable architecture decisions we were trying to link. The intermediate step would introduce a set of engineering proxies, which indicate how well the objective is fulfilled.

The architecture decisions will be evaluated by these proxies, which will reveal how well they fulfill the stakeholders' objectives. This waterfall process of linking one QFD matrix to a second one is described in the work of Hauser and Clausing, as seen in Figure 21.

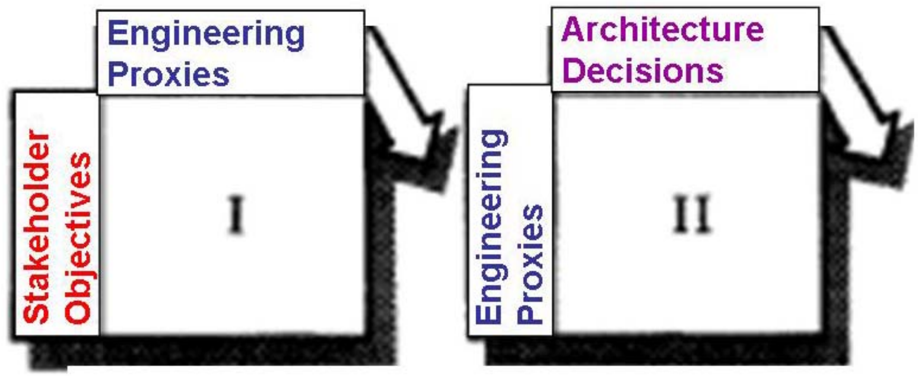

Figure 21. Diagram extracted from the Hauser and Clausing paper, showing two QFD matrices linked. The structure is similar to our tiered multiattribute process. .

Because the QFD matrices are more a communication tool than a mathematical entity, the matrices are filled with symbols that should be translated into numbers as required by the model. The translated matrix should be operable with the traditional matrix multiplication, as described in section 4.1.

Our first attempt was to look for what in Figure 21 is shown as matrix II. This matrix, given a vector of architecture decisions, could yield the value of the engineering proxy as a linear combination of elements of the architecture vector. That would have allowed us to use matrix algebra as in the rest of the model. We found this matrix not trivial, as we will see on section 4. 6. 1.

The matrix multiplication will be used for the second step, in matrix I of Figure 21, as we will see on section 4. 6. 2.

4. 5. 3. Objectives – Vector O

For the case of Space Exploration value delivery, the identification the different elements for the objectives and stakeholder categories was done through the analysis of policy papers for each stakeholder. The analysis done by the members of the Value Identification sub-team of the MIT-Draper Concept Evaluation and Refinement Research group[20], including the author, allowed enumeration of the stakeholder groups, and building an extensive mapping of their needs, which is included in Appendix 8.1. We used the needs list to synthesize a set of objectives using the methodology described in section 3. 2. 4.

The list of identified objectives is presented in Table 3.

1	1.1	Develop strategic long term planning for the Space Exploration System
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)
4	2.2	Increase positive perception about NASA (political capital)
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups
6	2.4	Motivate-recognize technical workforce
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues
8	2.6	Increase foreign citizens positive perception about their governments by promoting their participation in the Space Exploration
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership
11	3.3	Align NASA funding priorities towards space exploration
12	4.1	Create interesting and inspiring content for educational use
13	4.2	Create entertaining and inspiring content for media
14	5.1	Provide easily and quickly accessible data for use on science knowledge
15	6.11	Create security related dual use technologies
16	6.12	Improve security qualified space access and infrastructure (US independent and clearance protected)
17	6.13	Provide space presence and freedom of action
18	6.14	Provide space acquired earth relevant security data
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction
21	6.4	Promote commercial acquisition of space good & service (includes COTS and entrepreneurial except space tourism)
22	6.5	Develop space infrastructure development and operational knowledge
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)

Table 3. List of objectives used to build the vector O. The list shows the order in which the vector elements are assigned to objectives' satisfaction level.

In order to ensure that the objectives are non-overlapping and complete at the same time, we arranged the objectives using a tree-like structure. This diagram is presented in the Appendix 8.1

4. 5. 4. Stakeholders – Vector S

The list of stakeholders we identified are shown in Table 4.

1	United States Congress
2	Executive Branch of the United States
3	Space Exploration International partners
4	Security related interests, including defense forces, and homeland defense
5	Economic Interests, including large aerospace corporations, and space entrepreneurs
6	Scientific interests, both space and non-space related
7	Technologists community, including space and non-space related
8	NASA legacy, not linked to space exploration
9	Media
10	Educators, students and administrative staff for education
11	United States voters-Taxpayers

Table 4. List of stakeholders used to build the vector S. The list shows the order in which the vector elements are assigned to stakeholders' satisfaction level.

Explorers, included in a previous version of the stakeholders' list, are actually the VCS of our example. We will use a Kano methodology to evaluate their needs, since those are the resources we need to ensure are provided. This analysis is done in the next section.

4. 5. 5. Resources

One insight we shown before is the realization of the symmetry of the relationship between the VCS and stakeholder groups. This symmetry implies that what the VCS sees as resources received, are at the same time benefits delivered from the perspective of the stakeholder groups, who were covering needs presented by the VCS; this happens in a similar way as the VCS benefit delivery towards stakeholders.

This symmetry prompted us to separate "Explorers" as stakeholders, and use their needs as the list of resources needed for the VCS.

4.6. Matrices

4. 6. 1. Architecture to Engineering proxies – Vectorial Function $f(\overline{A})$

The input to this step is the architecture vector A that contains the specific decisions taken to select a specific architecture, and a vector stating which the Status Quo Architecture is. The output will be will be a vector P containing the percentage change of the engineering proxies for that specific architecture vector, when compared with the Status Quo Architecture.

In section 2.3. we presented Keeney and Raiffa's concepts on the translation from the architecture domain to the objectives' domain through the use of attributes, which are no more than the engineering proxies presented on section 4. 5. 2.

While the list of engineering proxies is derived from the stakeholders' list of objectives, and, thus comes from an upstream to downstream process, on the other hand, the list of decisions that constitute the architecture vector is driven by the need to describe the architecture, hence, it is generated and evaluated in a downstream to upstream direction, which is opposite. This leads to a difficulty in formulating tools to link one to the other, which is presented in section 4. 6. 9.

Furthermore, while the architecture is influenced by the stakeholders' objectives, it is mainly the result of a chaotic creativity process, rendering the link more difficult.

Besides, because many of the functions the system will present are the result of *emergence,* meaning that it is not possible to identify the function as derived from a specific element in a lower level decomposition of the system, the system design decisions will not be able to signal the presence or absence of all the traits of interest for stakeholders.

These two aspects convinced us that it was impossible to find a linear combination of elements of the architecture decision vector that could yield a value for the level of satisfaction of the objectives. The solution we propose is to use ad-hoc functions that would map the architecture decisions to the engineering proxies change.

Emergent properties can increase the complexity of these ad-hoc functions, yet their conceptual definition is simple.

Given an architecture vector, which is result of combination of feasible values of each element of the vector, each engineering proxy's ad-hoc function will assign the value of the percentage *change* of the proxy between the architecture being analyzed and the SQA.

Metaphorically, it is as if we have been asked to acquire some information about different models of cars shown to us. Our client's request is that we measure the engine power, the diameter of the tires, the color, and the height of the vehicle, and present them in a nicely organized table, indicating how much of an increase or decrease are those values compared with a certain standard car.

While the car's height could show in the architecture vector, it could be result of the combination of several other elements, such as tires' inflation pressure, wheel diameter, and chassis and body properties. The relationship between those elements and an engineering proxy might not follow an easy to derive rule, much less be linear.

We might receive the objection that this step asks for a subjective judgment of the architecture, hence weakening the objectivity of our model. While there is some level of subjectivity, we believe that the lower complexity of the required judgment reduces the possibility of error.

This assessment should be rather technical, and engineering proxies should be fact based if possible.

Unfortunately, it will not be always possible to select fact based engineering proxies, which map completely the objectives of the analysis. There will be a tension to represent adequately high level requirements as dictated by stakeholders and at the same time to have objectively valuable measures that can be assessed with the information of an architecture description.

This tension might lead to choosing subjective engineering proxies in some cases. Even in this case, we believe that evaluating proxies will be easier and more compelling than evaluating objectives directly, because

- The evaluation will occur over a one dimensional variable, which is narrowly specified, leaving the trades of conflicting objectives, and stakeholders, and the subjectivity of high level goals outside this assessment.

- We could introduce a stochastic methodology to this section of the analysis too, by acquiring assessments of the engineering proxies by a large number of experts. Their agreement (or lack thereof) would be reflected in the answers the model provides, by a larger or smaller dispersion.

- The evaluation is done through a differential comparison with a Status Quo Architecture, which provides a background to compare the options.

Using our vehicle metaphor, it is not needed to know the exact height of the car, but "how much % taller" than a standard model.

The list of proxies for Space Exploration we are presenting is prone to improvement, but it provides an example to show the model functioning.

The potential elements of the vector were extracted from the list that follows:

{2015, 2017, 2021}

{Capability and Landing, Capability and no Landing, No Capability and no Landing}

{Pole-nuclear, Pole-solar, Equator-nuclear, Equator-solar, no-base }

{8, 23, 40, 125, 300}

Our identified SQA has the following values for the architecture vector:

[2017, No Capability and no Landing, no-base, 125]

For the proposed example case, with 4 elements in the decision vector, we will assume the decisions have disjoint effects. That is, we will assume that each of the decisions is possible to implement independently of the others, and that there is no increased effect over the engineering proxies because of specific decisions combinations, besides the accumulative effect of each decision on its own.

The following three tables, Table 5, Table 6 and Table 7 show an assessment of the different architectures, when measuring the engineering proxies. This evaluation could be improved by experts in each architecture decision. The intent of the tables is to show an example of the mechanic to follow; further improvement of the initial data will increment the accuracy of the model's predictions.

Engineering Proxies Expected Values $f\left(\overline{A}\right)$

		Dec 01 1st Lunar Landing	Opt1 2014	SQA 2018	Opt3 2022	Dec 02 moon land	Opt1 cap-land	SQA nocap	Opt3 cap-noland	Dec 03 Energy Supply	Opt1 Pole-nuc	Opt2 Pole-sol	Opt3 Eq-nuc	Opt4 Eq-solar	SQA No-Base	Dec 04 Larger launcher size	Opt1 8 MT	Opt2 23MT	Opt3 40MT	SQA 125MT	Opt4 300MT
Number of years of planning in advance	[yrs]	16	-4	0	4	16	2	0	1	16	6	2	6	4	0	16	-4	-4	-1	0	2
Savings to first result	[billion usd]	300	90	0	-30	300	9	0	5	300	-10	-2	-10	-5	0	300	-5	-7	-2	-1	3
Reduction in Time to first result	[yrs]	4	2	0	-3	4	-2	0	-2	4	-1	1	0	-1	0	4	-2	2	0	0	0
High Visibility Events (**HVE**) linked to the **Executive Branch** Vision for Space Exploration, and **Congress**' bills	[HVE/yr]	3	3	0	-2	3	-1	0	-1	3	2	2	1	1	0	3	-2	-1	-0.5	0	4
Popular acceptance of space policy and high level space exploration goals	%	65%	20%	0	-10%	0.65	0	0	-5%	0.65	-0.1	15%	-5%	10%	0	65%	-10%	-5%	-5%	0	10%
HVE linked to NASA technical implementation of Space Exploration	[HVE/yr]	3	1	0	-1	3	0	0	-1	3	3	2	3	2	0	3	0.5	2	0	0	0
Positive perception about NASA as a whole	%	60%	-5%	0	5%	0.6	5%	0	-5%	0.6	10%	15%	-5%	10%	0	0.6	1%	10%	0	0	0
Ability to show benefits to non-engaged groups	[subj scale]	10	-3	0	5	10	2	0	-2	10	-3	3	–4	3	0	10	2	5	2	0	-1
Hours of class dedicated to space exploration at middle school	[hrs/yr]	20	0	0	0	20	0	0	0	20	10	20	10	20	0	20	0	0	0	0	0
NASA technical workforce salary as a % of average tech salary	%	70%	5%	0	0	0.7	10%	0	5%	0.7	10%	5%	10%	5%	0	0.7	10%	10%	0	0	-10%
Fraction of the space budget paid by foreign partners	%	20%	5%	0	0%	0.2	0	0	0	0.2	-10%	10%	–10%	10%	0	0.2	20%	20%	0	0	0
Number of HVE that are first page on newspapers of non-allied countries	[HVE/yr]	3	2	0	-2	3	0	0	-1	3	-1	2	-1	2	0	3	0.5	1	0	0	2
Fraction of the space exploration activities involving public diffusion of foreign partners participation	%	10%	-3%	0	5%	0.1	0	0	0	0.1	-5%	5%	–5%	5%	0	0.1	5%	5%	0	0	0
Strategies leading funding lock-in from Congress and other fund sources	[subj scale]	10	2	0	-2	10	4	0	4	10	3	2	3	2	0	10	-6	-3	0	0	0
Fraction of the architecture that is possible to share	%	15%	-5%	0	5%	0.15	0	0	0	0.15	2%	2%	2%	2%	0	0.15	15%	15%	5%	0	0
Fraction of NASA's workforce realigned towards space exploration	%	35%	20%	0	-5%	0.35	5%	0	3%	0.35	10%	8%	8%	6%	0	0.35	-15%	-15%	5%	0	0
Opportunities to generate interesting material	%	100%	-5%	0	0%	1	0%	0	0%	1	10%	10%	10%	10%	0	1	0	0	0	0	0
HVE that make it to a TV newscast	HVE/yr	10	0	0	3	10	0	0	0	10	4	4	3	3	0	10	2	2	0	0	2
Amount of data available, measured on # researchers times # of years to analyze it (?)	%	100%	-20%	0	40%	1	0	0	-3%	1	40%	40%	20%	20%	0	1	0	0	0	0	-20%
Amount spent on research related to space exploration	%	100%	-40%	0	40%	1	-5%	0	-5%	1	40%	40%	20%	20%	0	1	5%	5%	0	0	-20%
Science time while exploring other bodies	%	100%	-40%	0	40%	1	0	0	0	1	500%	500%	500%	500%	0	1	0	0	0	0	0
Fraction of architecture investment that can be used for security purposes	%	100%	-30%	0	15%	1	0	0	0	1	5%	0%	5%	0%	0	1	30%	30%	15%	0	0
Delay from launch need identification to execution	[days]	30	-5	0	0	30	0	0	0	30	0	0	0	0	0	30	-25	-25	0	0	100
Fraction of architecture launched on security qualified vehicles	%	100%	0	0	0	1	0	0	0	1	-5%	-15%	-5%	-15%	0	1	-30%	-30%	0	0	0
Reduction in time for the first outpost	[yrs]	30	2	0	0	30	-5	0	-5	30	-15	-15	-18	-18	0	30	-5	-5	-2	0	2
Fraction of time the farthest outpost is populated	%	50%	0	0	50%	0.5	5%	0	5%	0.5	30%	30%	30%	30%	0	50%	5%	5%	0	0	-15%
Fraction of data infrastructure that has dual security related use	%	30%	0	0	20%	0.3	0	0	0	0.3	0	0	0	0	0	0.3	20%	20%	0	0	0
Red Cost of sending material to LEO	[USDx1000/kg]	10	0	0	0	10	0	0	0	10	-2	-2	-2	-2	0	10	6	6	0	0	-2
Red Launch failure rate	%	2%	0	0	0.50%	0.02	0	0	0	0.02	0	0	0	0		0.02	1.5%	1.5%	0.70%	0	-0.50%
commercial space related business by year 2018	[billion usd]	4	1	0	-1	4	1	0	0	4	1	1	1	1	0	4	4	4	2	0	0
Fraction of Space Exploration budget spent outside NASA	%	90%	-5%	0	5%	0.9	-1%	0	-1%	0.9	-1%	1%	-1%	1%	0	0.9	2%	2%	1%	0	0
Time of accumulated development and operation knowledge	%	100%	15%	0	0%	1	10%	0	5%	1	40%	40%	20%	20%	0	1	10%	10%	0	0	0
Fraction of space related investment that has application besides space	%	100%	-25%	0	25%	1	0	0	0	1	2%	5%	2%	5%	0	1	30%	30%	0	0	0

Table 5. Table showing the expected values for different architecture decisions. This is not a matrix, but a table showing points of the vectorial function that assigns values to the architectural decision vector. On each row of this table are the real world measures for each engineering proxies, when a determinate architecture decision is taken, based on experts answers (values are conceptual). Architecture decisions are represented in the by the columns.

Engineering Proxies Standard Deviation $f\left(\overline{A}\right)$		Dec 01 1st Lunar Landir	Opt1 2014	**SQA** 2018	Opt3 2022	Dec 02 moon land	Opt1 cap-land	**SQA** nocap	Opt3 cap-noland	Dec 03 Energy Supply	Opt1 Pole-nuc	Opt2 Pole-sol	Opt3 Eq-nuc	Opt4 Eq-solar	**SQA** No-Base	Dec 04 Larger launcher	Opt1 8 MT	Opt2 23MT	Opt3 40MT	**SQA** 125MT	**Opt4** 300MT
Number of years of planning in advance	[yrs]	16	1.163	0.456	0.314	16	0.905	0.267	0.522	16	0.616	0.58	0.4678	0.06	0.376	16	0.676	0.807	0.549	0.449	0.438
Savings to first result	[billion usd]	300	11.82	5.493	4.021	300	7.718	14.92	6.092	300	7.253	9.841	6.9688	9.357	8.508	300	4.925	9.688	9.517	10.97	5.146
Reduction in Time to first result	[yrs]	4	0.261	0.127	0.019	4	0.015	0.122	0.192	4	0.177	0.096	0.254	0.179	0.165	4	0.19	0.075	0.236	0.205	0.168
High Visibility Events (HVE) linked to the Executive Branch Vision for Space Exploration, and Congress' bills	[HVE/yr]	3	0.06	0.082	0.12	3	0.063	0.075	0.117	3	0.101	0.09	0.1067	0.038	0.066	3	0.103	0.076	0.116	0.058	0.118
Popular acceptance of space policy and high level space exploration goals	%	65%	2%	0.015	1%	0.65	0.006	0.034	2%	0.65	0.011	0%	2%	1%	0.029	0.65	1%	2%	2%	0.024	0.021
HVE linked to NASA technical implementation of Space Exploration	[HVE/yr]	3	0.111	0.118	0.042	3	0.119	0.065	0.1	3	0.124	0.128	0.1197	0.098	0.066	3	0.155	0.143	0.106	0.057	0.136
Positive perception about NASA as a whole	%	60%	2%	0.016	2%	0.6	1%	0.027	1%	0.6	0%	1%	1%	2%	0.009	0.6	2%	0%	0.017	0.024	0.035
Ability to show benefits to non-engaged groups	[subj scale]	10	0.199	0.465	0.483	10	0.346	0.444	0.19	10	0.266	0.258	0.5405	0.386	0.188	10	0.311	0.317	0.063	0.23	0.206
Hours of class dedicated to space exploration at middle school	[hrs/yr]	20	0.699	0.175	0.243	20	0.58	0.337	0.781	20	0.716	0.075	0.8501	0.767	0.694	20	0.583	0.793	0.365	0.272	0.684
NASA technical workforce salary as a % of average tech salary	%	70%	4%	0.034	0.014	0.7	2%	0.033	2%	0.7	4%	3%	3%	2%	0.013	0.7	2%	4%	0.014	0.03	0.003
Fraction of the space budget paid by foreign partners	%	20%	1%	0.004	1%	0.2	0.011	0.011	0.006	0.2	1%	1%	1%	1%	0.005	0.2	1%	1%	0.01	0.01	0.004
Number of HVE that are first page on newspapers of non-allied countries	[HVE/yr]	3	0.132	0.018	0.069	3	0.099	0.116	0.062	3	0.066	0.057	0.181	0.151	0.087	3	0.119	0.116	0.111	0.082	0.061
Fraction of the space exploration activities involving public diffusion of foreign partners participation	%	10%	0%	0.003	0%	0.1	0.004	0.004	0.002	0.1	0%	0%	0%	0%	0.001	0.1	0%	0%	0.006	1E-04	0.002
Strategies leading funding lock-in from Congress and other fund sources	[subj scale]	10	0.402	0.249	0.168	10	0.446	0.346	0.312	10	0.381	0.514	0.0705	0.273	0.154	10	0.163	0.585	0.443	0.148	0.178
Fraction of the architecture that is possible to share	%	15%	0%	0.002	1%	0.15	0.001	0.007	0.005	0.15	0%	0%	0%	0%	0.005	0.15	1%	1%	0.006	0.006	0.005
Fraction of NASA's workforce realigned towards space exploration	%	35%	1%	0.018	1%	0.35	1%	0.014	1%	0.35	0%	0%	2%	1%	0.008	0.35	0%	0%	1%	0.015	0.017
Opportunities to generate interesting material	%	100%	2%	0.025	3%	1	3%	0.052	3%	1	2%	2%	5%	2%	0.033	1	0.032	0.011	0.029	0.037	0.035
HVE that make it to a TV newscast	HVE/yr	10	0.134	0.286	0.006	10	0.591	0.017	0.1	10	0.435	0.15	0.389	0.329	0.321	10	0.3	0.398	0.207	0.192	0.28
Amount of data available, measured on # researchers times # of years to analyze it (?)	%	100%	2%	0.031	0.011	1	0.031	0.018	3%	1	2%	2%	2%	0%	0.029	1	0.027	0.042	0.015	0.022	0.013
Amount spent on research related to space exploration	%	100%	3%	0.021	0.04	1	1%	0.033	1%	1	6%	3%	2%	2%	0.055	1	2%	1%	0.019	0.035	0.006
Science time while exploring other bodies	%	100%	3%	0.027	5%	1	0.042	0.065	0.029	1	3%	6%	3%	2%	0.021	1	0.025	0.043	0.038	0.068	0.021
Fraction of architecture investment that can be used for security purposes	%	100%	0.006	0.033	0.032	1	0.041	0.048	0.015	1	2%	1%	1%	4%	0.035	1	0%	3%	4%	0.019	0.033
Delay from launch need identification to execution	[days]	30	0.195	0.362	1.199	30	1.482	0.05	1.473	30	0.365	0.068	0.293	1.104	0.479	30	0.961	1.12	0.678	0.717	0.368
Fraction of architecture launched on security qualified vehicles	%	100%	0.044	0.056	0.041	1	0.053	0.03	0.03	1	1%	5%	4%	2%	0.019	1	5%	1%	0.034	0.043	0.039
Reduction in time for the first outpost	[yrs]	30	0.183	0.982	1.02	30	1.198	1.371	0.819	30	1.393	0.449	0.723	2.247	1.11	30	1.346	1.235	0.884	0.987	0.677
Fraction of time the farthest outpost is populated	%	50%	0.021	0.015	0.022	0.5	0%	0.012	1%	0.5	3%	2%	1%	3%	0.017	0.5	2%	2%	0.016	0.013	0.016
Fraction of data infrastructure that has dual security related use	%	30%	0.004	0.003	0.012	0.3	0.004	0.014	0.011	0.3	0.013	0.007	0.009	0.014	0.012	0.3	1%	1%	0.011	0.011	0.005
Red Cost of sending material to LEO	[USDx1000/kg]	10	0.403	0.336	0.287	10	0.415	0.277	0.342	10	0.647	0.729	0.163	0.348	0.202	10	0.427	0.03	0.557	0.177	0.275
Red Launch failure rate	%	2%	8E-04	4E-04	1E-04	0.02	7E-04	0.001	7E-04	0.02	8E-04	8E-04	0.001	6E-05	5E-04	0.02	0.1%	0.0%	6E-04	6E-04	8E-04
commercial space related business by year 2018	[billion usd]	4	0.125	0.03	0.137	4	0.137	0.106	0.168	4	0.081	0.103	0.059	0.058	0.104	4	0.017	0.124	0.058	0.102	0.058
Fraction of Space Exploration budget spent outside NASA	%	90%	0.06	0.019	0.039	0.9	4%	0.015	2%	0.9	1%	4%	4%	5%	0.037	0.9	5%	2%	0.018	0.017	0.012
Time of accumulated development and operation knowledge	%	100%	4%	0.034	4%	1	1%	0.021	6%	1	5%	2%	2%	2%	0.02	1	4%	5%	0.017	0.012	0.049
Fraction of space related investment that has application besides space	%	100%	0.006	0.04	0.02	1	0.034	0.004	0.044	1	0%	5%	4%	1%	0.052	1	2%	1%	0.05	0.019	0.008

Table 6. Table showing the standard deviation for different architecture decisions. This is not a matrix, but a table showing points of the vectorial function that assigns values to the architectural decision vector, as assesed by experts (values are simulated). This table presents the standard deviation used for the Monte Carlo simulation.

Engineering Proxies
Expected Values
as percentage of SQA

$$f\left(\overline{A}\right)$$

Engineering Proxy		Dec 01 1st Lunar Landing	Opt1 2014	SQA 2018	Opt3 2022	Dec 02 moon land	Opt1 cap-land	SQA nocap	Opt3 cap-noland	Dec 03 Energy Supply	Opt1 Pole-nuc	Opt2 Pole-sol	Opt3 Eq-nuc	Opt4 Eq-solar	SQA No-Base	Dec 04 Larger launcher size	Opt1 8 MT	Opt2 23MT	Opt3 40MT	SQA 125MT	Opt4 300MT
Number of years of planning in advance	[yrs]	16	-25%	0%	25%	16	13%	0%	6%	16	38%	13%	38%	25%	0%	16	-25%	-25%	-6%	0%	13%
Savings to first result	[billion usd]	300	30%	0%	-10%	300	3%	0%	2%	300	-3%	-1%	-3%	-2%	0%	300	-2%	-2%	-1%	0%	1%
Reduction in Time to first result	[yrs]	4	50%	0%	-75%	4	-50%	0%	-50%	4	-25%	25%	0%	-25%	0%	4	-50%	50%	0%	0%	0%
High Visibility Events (HVE) linked to the Executive Branch Vision for Space Exploration, and Congress' bills	[HVE/yr]	3	100%	0%	-67%	3	-33%	0%	-33%	3	67%	67%	33%	33%	0%	3	-67%	-33%	-17%	0%	133%
Popular acceptance of space policy and high level space exploration goals	%	65%	31%	0%	-15%	65%	0%	0%	-8%	65%	-15%	23%	-8%	15%	0%	65%	-15%	-8%	-8%	0%	15%
HVE linked to NASA technical implementation of Space Exploration	[HVE/yr]	3	33%	0%	-33%	3	0%	0%	-33%	3	100%	67%	100%	67%	0%	3	17%	67%	0%	0%	0%
Positive perception about NASA as a whole	%	60%	-8%	0%	8%	60%	8%	0%	-8%	60%	17%	25%	-8%	17%	0%	60%	2%	17%	0%	0%	0%
Ability to show benefits to non-engaged groups	[subj scale]	10	-30%	0%	50%	10	20%	0%	-20%	10	-30%	30%	−40%	30%	0%	10	20%	50%	20%	0%	-10%
Hours of class dedicated to space exploration at middle school	[hrs/yr]	20	0%	0%	0%	20	0%	0%	0%	20	50%	100%	50%	100%	0%	20	0%	0%	0%	0%	0%
NASA technical workforce salary as a % of average tech salary	%	70%	7%	0%	0%	70%	14%	0%	7%	70%	14%	7%	14%	7%	0%	70%	14%	14%	0%	0%	-14%
Fraction of the space budget paid by foreign partners	%	20%	25%	0%	0%	20%	0%	0%	0%	20%	-50%	50%	−50%	50%	0%	20%	100%	100%	0%	0%	0%
Number of HVE that are first page on newspapers of non-allied countries	[HVE/yr]	3	67%	0%	-67%	3	0%	0%	-33%	3	-33%	67%	-33%	67%	0%	3	17%	33%	0%	0%	67%
Fraction of the space exploration activities involving public diffusion of foreign partners participation	%	10%	-30%	0%	50%	10%	0%	0%	0%	10%	-50%	50%	−50%	50%	0%	10%	50%	50%	0%	0%	0%
Strategies leading funding lock-in from Congress and other fund sources	[subj scale]	10	20%	0%	-20%	10	40%	0%	40%	10	30%	20%	30%	20%	0%	10	-60%	-30%	0%	0%	0%
Fraction of the architecture that is possible to share	%	15%	-33%	0%	33%	15%	0%	0%	0%	15%	13%	13%	13%	13%	0%	15%	100%	100%	33%	0%	0%
Fraction of NASA's workforce realigned towards space exploration	%	35%	57%	0%	-14%	35%	14%	0%	9%	35%	29%	23%	23%	17%	0%	35%	-43%	-43%	14%	0%	0%
Opportunities to generate interesting material	%	100%	-5%	0%	0%	100%	0%	0%	0%	100%	10%	10%	10%	10%	0%	100%	0%	0%	0%	0%	0%
HVE that make it to a TV newscast	HVE/yr	10	0%	0%	30%	10	0%	0%	0%	10	40%	40%	30%	30%	0%	10	20%	20%	0%	0%	20%
Amount of data available, measured on # researchers times # of years to analyze it (?)	%	100%	-20%	0%	40%	100%	0%	0%	-3%	100%	40%	40%	20%	20%	0%	100%	0%	0%	0%	0%	-20%
Amount spent on research related to space exploration	%	100%	-40%	0%	40%	100%	-5%	0%	-5%	100%	40%	40%	20%	20%	0%	100%	5%	5%	0%	0%	-20%
Science time while exploring other bodies	%	100%	-40%	0%	40%	100%	0%	0%	0%	100%	500%	500%	500%	500%	0%	100%	0%	0%	0%	0%	0%
Fraction of architecture investment that can be used for security purposes	%	100%	-30%	0%	15%	100%	0%	0%	0%	100%	5%	0%	5%	0%	0%	100%	30%	30%	15%	0%	0%
Delay from launch need identification to execution	[days]	30	-17%	0%	0%	30	0%	0%	0%	30	0%	0%	0%	0%	0%	30	-83%	-83%	0%	0%	333%
Fraction of architecture launched on security qualified vehicles	%	100%	0%	0%	0%	100%	0%	0%	0%	100%	-5%	-15%	-5%	-15%	0%	100%	-30%	-30%	0%	0%	0%
Reduction in time for the first outpost	[yrs]	30	7%	0%	0%	30	-17%	0%	-17%	30	-50%	-50%	-60%	-60%	0%	30	-17%	-17%	-7%	0%	7%
Fraction of time the farthest outpost is populated	%	50%	0%	0%	100%	50%	10%	0%	10%	50%	60%	60%	60%	60%	0%	50%	10%	10%	0%	0%	-30%
Fraction of data infrastructure that has dual security related use	%	30%	0%	0%	67%	30%	0%	0%	0%	30%	0%	0%	0%	0%	0%	30%	67%	67%	0%	0%	0%
Red Cost of sending material to LEO	[USDx1000/kg]	10	0%	0%	0%	10	0%	0%	0%	10	-20%	-20%	-20%	-20%	0%	10	60%	60%	0%	0%	-20%
Red Launch failure rate	%	2%	0%	0%	25%	2%	0%	0%	0%	2%	0%	0%	0%	0%	0%	2%	75%	75%	35%	0%	-25%
commercial space related business by year 2018	[billion usd]	4	25%	0%	-25%	4	25%	0%	0%	4	25%	25%	25%	25%	0%	4	100%	100%	50%	0%	0%
Fraction of Space Exploration budget spent outside NASA	%	90%	-6%	0%	6%	90%	-1%	0%	-1%	90%	-1%	1%	-1%	1%	0%	90%	2%	2%	1%	0%	0%
Time of accumulated development and operation knowledge	%	100%	15%	0%	0%	100%	10%	0%	5%	100%	40%	40%	20%	20%	0%	100%	10%	10%	0%	0%	0%
Fraction of space related investment that has application besides space	%	100%	-25%	0%	25%	100%	0%	0%	0%	100%	2%	5%	2%	5%	0%	100%	30%	30%	0%	0%	0%

Table 7. Table showing the expected values for different architecture decisions, expressed as a percentage of the Status Quo Architecture (SQA). Values are conceptual.

The first two columns of Table 5, Table 6 and Table 7 present the engineering proxies and their units; while some of them measure “real world” magnitudes, others refer subjective measures. The next columns are organized along the four decisions shown in the architecture vector: Lunar landing year, CEV moon landing option, Moon base energy supply, and size of the heavy lift launcher.

The decision “Y” is presented in a column labeled “Dec Y”; to the right of the decision column are the columns with the possible answers, labeled “Opt X” or as “SQA”, depending whether it shows answer “X” or the Status Quo Architecture answer.

Every element of the column of possible answer “X” shows the engineering proxy value difference between answer “X” and the SQA answer.

4. 6. 2. From Engineering proxies to Objectives satisfaction – Matrix C

The input to this step is the vector containing the measure of the percentage change of the engineering proxies for a specific architecture, when compared with the Status Quo Architecture. The output will be a vector that presents the change of the objectives satisfaction level, were that architecture to be implemented. The elements of the vector of objectives’ satisfaction level vary between -1 for an absolute (ideal) non fulfillment of the objective to +1 for an absolute (ideal) fulfillment of the objective, passing for a value of 0 that means that the satisfaction level has not changed.

As stated in section 4. 5. 2., the engineering proxies are derived from the objectives, and should be strongly correlated with them. Ideally a small number will be needed per each objective; and most likely, an engineering proxy will be useful to just one objective.

Because of the use of the Status Quo Architecture, the values of the engineering proxies are calculated as a difference to a baseline architecture. As a consequence, the objective satisfaction vector presents whether there is an increase or decrease in satisfaction from the present situation (SQA).

Since the engineering proxies are expressed as a percentage of the SQA value (potentially without limits), and the objectives satisfaction range is [-1,1], we need to find an adequate scale for this step.

We propose that an increase or decrease in a factor of 3 is the maximum practical change for a real world problem. This assumption enables us to write the following postulates:

- An engineering proxy value of 3 is implies an objective change of 1 (ideal)

- An engineering proxy value of 1 (no change) is implies an objective change of 0 (no change)

- An engineering proxy value of 1/3 implies an objective change of -1 (ideal negative)

The law of decreasing marginal utility[25] prompted us to use a logarithmic scale to reflect the objective change

$$ObjectiveChange = \frac{\log(EngineeringValue)}{\log(MaxEngineeringValue)} = \frac{\log(EngineeringValue)}{\log(3)}$$

Using these concepts we built this table showing percentage changes and objective value changes.

(Table 8)

Engineering Proxy Value	Engineering Proxy Change	Objective change
3	+200%	1.00
2	+100%	0.63
1.5	+50%	0.37
1	0%	0.00
2/3	-33%	-0.37
1/2	-50%	-0.63
1/3	-67%	-1.00

Table 8. Table showing some engineering proxy values, their changes in percentage, and their objective level change assigned through the proposed logarithmic function.

In order to combine 2 or more proxies we thought of using a weighted linear combination whose weights for the Space Exploration example are presented in Table 9.

		Objective	Weight	Engineering Proxy
1	1.1	Develop strategic long term planning for the Space Exploration System		Number of years of planning in advance
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	40%	Investment to first result
			60%	Time to first result
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	50%	High Visibility Events (HVE) linked to the Executive Branch Vision for Space Exploration, and Congress' bills
			50%	Popular acceptance of space policy and high level space exploration goals
4	2.2	Increase positive perception about NASA (political capital)	50%	HVE linked to NASA technical implementation of Space Exploration
			50%	Positive perception about NASA as a whole
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups		Ability to show benefits to non-engaged groups
6	2.4	Motivate-recognize technical workforce	30%	Hours of class dedicated to space exploration at middle school
			70%	NASA technical workforce salary as a % of average tech salary
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	40%	Fraction of the space budget paid by foreign partners
			60%	Number of HVE that are first page on newspapers of non-allied countries
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration		Fraction of the space exploration activities involving public diffusion of foreign partners participation
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention		Strategies leading funding lock-in from Congress and other fund sources
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership		Fraction of the architecture that is possible to share
11	3.3	Align NASA funding priorities towards space exploration		Fraction of NASA's workforce realigned towards space exploration
12	4.1	Create interesting and inspiring content for educational use		Opportunities to generate interesting material
13	4.2	Create entertaining and inspiring content for media		HVE that make it to a TV newscast
14	5.1	Provide easily and quickly accesible data for use on science knowledge	33%	Amount of data available, measured on # researchers times # of years to analyze it (?)
			33%	Amount spent on research related to space exploration
			33%	Science time while exploring other bodies
15	6.11	Create security related dual use technologies		Fraction of architecture investment that can be used for security purposes
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	70%	Delay from launch need identification to execution
			30%	Fraction of architecture launched on security qualified vehicles
17	6.13	Provide space presence and freedom of action	70%	Earliest time for the first outpost
			30%	Fraction of time the farthest outpost is populated
18	6.14	Provide space acquired earth relevant security data		Fraction of data infrastructure that has dual security related use
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	80%	Cost of sending material to LEO
			20%	Launch failure rate
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction		commercial space related business by year 2018
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)		Fraction of Space Exploration budget spent outside NASA
22	6.5	Develop space infrastucture development and operational knowledge		Time of accumulated development and operation knowledge
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)		Fraction of space related investment that has application besides space

Table 9. Table showing the assignment and weights of proxies to map each objective.

If we assume that engineering proxies are orthogonal one to the other, some arguments could be presented in favor of multiplying the proxies relevant to each objective, instead of adding or averaging them. We think multiplication is not the best option, because a zero value is likely to appear, rendering a multiplication ineffective at conveying information.

Because we are measuring deviations from a present level, a zero value is likely to appear, which would reduce to zero the whole product. While additional exploration of this point could be deserved, we feel comfortable presenting a linear combination as a valid map of objectives' level in this model.

The ability to evaluate the objective satisfaction level as a linear combination of engineering proxies allows for the use of matrix tools, as explained in section 4.1. Because of the focused nature of the engineering proxies, which were selected by their ability to map as well as possible a given objective, the translation matrix will be heavily banded. The linear combination of proxies that generates the value for each objective has coefficients proportional to the proxies' ability to justify the objective value.

For the case of Space Exploration, Table 9 shows the weights we identified in order to map the selected engineering proxies to objectives satisfaction level.

4. 6. 3. Objectives to Stakeholders Satisfaction – Matrix J

The input of this step is the vector O that contains the objectives satisfaction change, and the output is the vector S with the stakeholders' satisfaction change. This stakeholder satisfaction change is the one achieved by the direct effect of the VCS on stakeholders.

We propose to use the Kano method of quality for this step. This method allows classifying objectives according to their criticality to one customer (stakeholder) by surveying members of the customer group, using a questionnaire presented in Section 6.

While the objectives list should be assessed by every party which controls resources of interest to the VCS, some stakeholder groups have a closer relationship than others with the Value Creating System. Stakeholder groups such as VCS workforce and VCS contractors' intimate understanding of needs of the VCS might influence the strategy formulation, potentially generating imbalances in the ranking process.

These imbalances should be avoided since other groups that have a lesser opportunity to interact with the VCS might control resources vital to the VCS.

4. 6. 3. 1. The Kano Model of Quality

A tool to assign criticality to a set of objectives, as assessed by one customer group (or stakeholder, in our nomenclature) was presented in 1982 by the Professor Noriaki Kano of Tokyo Rika University, in Japan. The basic version of the tool allows separating objectives into four categories, yet, with some modifications, it is possible to prepare a continuous scale of priority and suggest a set of weights when balancing objectives.

Our work on Kano's methods is based on a special issue of the Center for Quality Management Journal[26] which presents the method, some criticisms and additional developments.

Kano's idea was that it was possible to classify objectives in 4 categories:

- Basic quality, for which, an increasing fulfillment does not increase the satisfaction of the customer, whereas a low fulfillment triggers disapproval. This category is represented by the curve on the bottom of Figure 22.

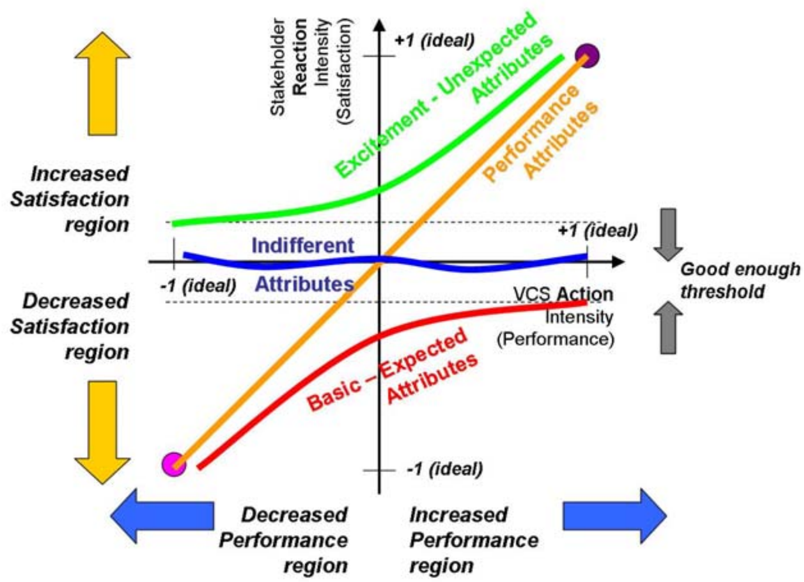

Figure 22. Performance-Satisfaction Diagram for the Kano Method.

- Performance quality, for which increments on objective fulfillment, cause a proportional satisfaction increment, and decrements cause a proportional satisfaction decrement. This category is observed in the diagonal on the center of Figure 22.

- The Excitement quality category, for which any increase triggers satisfaction, but decreases are not punished, since these objectives are surprising to the stakeholder. This category is shown on the top curve of Figure 22.

- The Indifferent quality category, a change in which does not affect the stakeholder satisfaction, or if it does, the effect is marginal. This type of quality would appear as a horizontal line on Figure 22.

In order to identify to which category each objective belongs, Kano proposed to survey the customers through two questions per objective, one “functional” for the case the objective was delivered, and one “dysfunctional” for the case when the objective was not. The first question aimed to understand the customer reaction to a high degree of achievement of the objective, that is to the right side of Figure 22, whereas the second question probes into the customer reaction to a low degree of performance of the objective, thus, to the left side of the diagram of Figure 22.

A typical pair of Kano questions is

- If the gas mileage of your car is good, how would you feel? (Functional Question, probing on an increase of performance)

- If the gas mileage of your car is poor, how would you feel? (Dysfunctional Question, probing on a decrease of performance)

The Center for Quality Management paper[26] states that one of the weaknesses of the method is the adequate understanding of the answers to the questions by the surveyees. As such, and after consultation with Prof. Crawley, Dr. Loureiro and Dr. Rebentisch, the following list of answers to the Kano questions was selected as the one that conveyed more clearly the intent behind the questions.

- I like it that way
- It must be that way
- I am neutral
- I can live with it that way
- I dislike it that way

The combination of answers to both Kano questions yields the classification, through a table shown Table 10.

		Dysfunctional				
		I like it that way	It must be that way	I am neutral	I can live with it that way	I dislike it that way
Functional	I like it that way	Questionable	Excitement	Excitement	Excitement	Performance
	It must be that way		Indifferent	Indifferent	Indifferent	Basic
	I am neutral		Indifferent	Indifferent	Indifferent	Basic
	I can live with it that way		Indifferent	Indifferent	Indifferent	Basic
	I dislike it that way					Questionable

Table 10. Table to evaluate the answers to a Kano questionnaire.

A Kano type questionnaire allows to prioritize among objectives for a given stakeholder group by separating them in four categories. The higher priority is given to the category with a higher damage potential.

That means that we should provide at least a good enough level of satisfaction at for the objectives in the Basic category, before trying to invest significant resources at increasing the degree of achievement of the objectives of the Performance category, and also that the Performance category takes precedence over the Excitement category. We could also infer that the level of investment on the indifferent category, for an optimized system, should be very low.

4. 6. 3. 2. Caveats on the use of the Kano method of quality

The Center for Quality Management paper[26] presents some caveats on the Kano method, that are important to mention:

- The person answering the questions needs to understand that the default answers shall reflect a classification and not a ranking.

  It is suggested to use letters instead of numbers for the answers, and to provide answer examples for surveyees to understand the mechanics.

- The phrasing of the questions is crucial, and should be done with great care, especially when dealing with an international environment.

  Surveyees are especially confused by the order of the answers, since the one states “it must be that way” is in the second position after “I like it that way”; this confuses surveyees who wrongly perceive that “it must be that way” is just a stronger version of “I like it that way”.

The improved wording of the answers that is suggested improves this aspect.

- It is suggested to complement the pair of answers with a third one asking for self stated importance of the objective

  This third question is important for our model, since, combined with the other two, it allows for a continuous function to assign priorities and weights as we will see in section 4. 6. 3. 3.

Additionally, the author of this research identified the following caveats for which some modifications are suggested:

- Classification of Reversed objectives
  While Kano's method is highly suspicious of receiving a reversed answer, our research would very likely have at least some objectives that are reversed since what constitutes a benefit for some group might decrease the satisfaction of another group.

  Contrary to what is advised in the Center for Quality Management paper[26], we will use these reversed answers as if they were equally valid, that will result in a Kano diagram that we show in Figure 23.

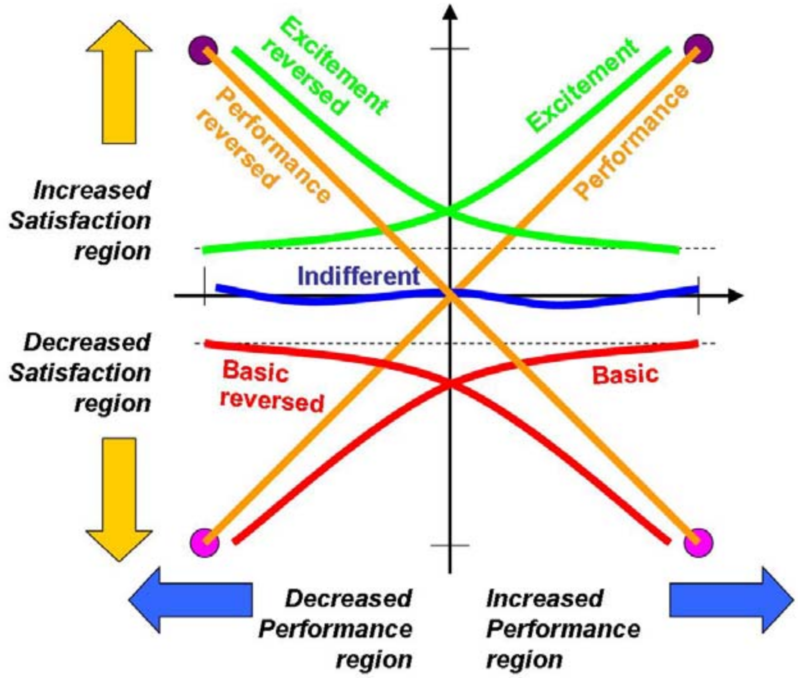

Figure 23. Performance-Satisfaction diagram, showing Kano's Method, including reversed objectives diagram.

A modification that we take from the Center for Quality Management paper[26] is to incorporate one additional questionable answer, when objectives are considered "It must be that way" for both the functional and dysfunctional questions

In order to assess adequately the answers, we will need to modify the evaluation table, as shown in Table 11.

		Dysfunctional				
		I like it that way	It must be that way	I am neutral	I can live with it that way	I dislike it that way
Functional	I like it that way	Questionable	Excitement	Excitement	Excitement	Performance
	It must be that way	Excitement reversed	Questionable	Indiferent	Indiferent	Basic
	I am neutral	Excitement reversed	Indiferent	Indiferent	Indiferent	Basic
	I can live with it that way	Excitement reversed	Indiferent	Indiferent	Indiferent	Basic
	I dislike it that way	Performance reversed	Basic reversed	Basic reversed	Basic reversed	Questionable

Table 11. Modified table to evaluate the answers to a Kano questionnaire, including reversed objectives, and additional questionable.

- Stakeholder fatigue and bandwidth

Research suggests that the maximum number of questions that surveyees are willing to answer is around 30 to 40. This issue is discussed in section 6.1.

Fatigue or just lack of interest take place and the quality of the information decays when more than 35 questions per questionnaire are asked.

- Dispersion use
  The information that is usually captured by a survey is the average or mode of the answers. We also are interested in taking advantage of difference between the answers of different representatives of a stakeholder group, to gain a measure of the differences of opinion inside the group. These differences will be measured through the dispersion of the survey answers.

4. 6. 3. 3. Adaptation of Kano's Method to a continuous analysis

Following the work presented by William DuMouchel at the Center for Quality Management Research Committee [27], we will use a points system on two axes to evaluate each objective. The proposed analysis locates each answer in a Functional-Dysfunctional XY diagram, which in the horizontal axis reflects the answer to the dysfunctional, with a reversed scale, and in the vertical axis the answer to the functional scale, with the axis in a direct scale.

While DuMouchel proposes that the reversed categories should be penalized, because of the comments presented in 4. 6. 3. 2, we will consider reversed results as valid as direct results. We will use a maximum value of 1.0, either negative or positive, in order to adapt the numerical scale to a -100% to +100% range.

DuMouchel also proposes that the quantitative equivalent of a "Live with" answer is half way of the equivalent of a "Dislike", and the same for the symmetric "Must be" and "Like". Were that to happen, the red line on the Kano Diagram in Figure 22 will not be as close to a neutral satisfaction as usually shown in literature.

We are not analyzing in detail this aspect. A deeper analysis should link the final asymptotic value of the basic quality to the concept of "good enough" quality that Christensen presents in his work[19]. The value of a "good enough" quality seems to be close, but above a neutral satisfaction, which is different to the classical Kano diagrams.

For the purpose of this research, we will propose a value of negative 0.2 or 20% of the ideal level for the threshold of good enough quality. Whether this value should be negative 20% or positive 20% should be further investigated.

Hence, the proposed modifications to the original DuMouchel's numerical scale system are as shown in Table 12.

	Functional		**Dysfunctional**	
	Original DuMouchel	Proposed	Original DuMouchel	Proposed
Dislike	Y = -2	Y = -1	X = 4	X = 1
Live with	Y = -1	Y = -0.2	X = 2	X = 0.2
Neutral	Y = 0	Y = 0	X = 0	X = 0
Must-Be	Y = 2	Y = 0.2	X = -1	X = -0.2
Like	Y = 4	Y = 1	X = -2	X = -1

Table 12. Table showing the assignment of coefficients to the answers of the the functional and dysfunctional questions of a Kano questionnaire. The methodology modifies previous work by Du Mouchel.

DuMouchel's model also takes into account a self-stated importance question, which is answered on a 1 to 9 scale, where 1 is “Not at all important” and 9 is “Extremely important”. This self stated importance will be used to compound the value provided by the Functional and Dysfunctional answers. As a consequence, surveyees that feel strongly about something will have a stronger voice than others that feel the objective is not a strong concern.

We propose to use here also a 0 to 1 domain for the answer; as such, our proposed scale system for self-stated importance is shown in Table 13

	Original DuMouchel	Proposed
Not at all important	W = 1	W = 0.00
Somewhat important	W = 3	W = 0.25
Important	W = 5	W = 0.50
Very important	W = 7	W = 0.75
Extremely important	W = 9	W = 1.00

Table 13. Table showing the assignment of coefficients to the answers of the the importance additional question in a Kano questionnaire. The methodology modifies previous work by Du Mouchel.

See below the graphical representation of the classification of answers in Figure 24.

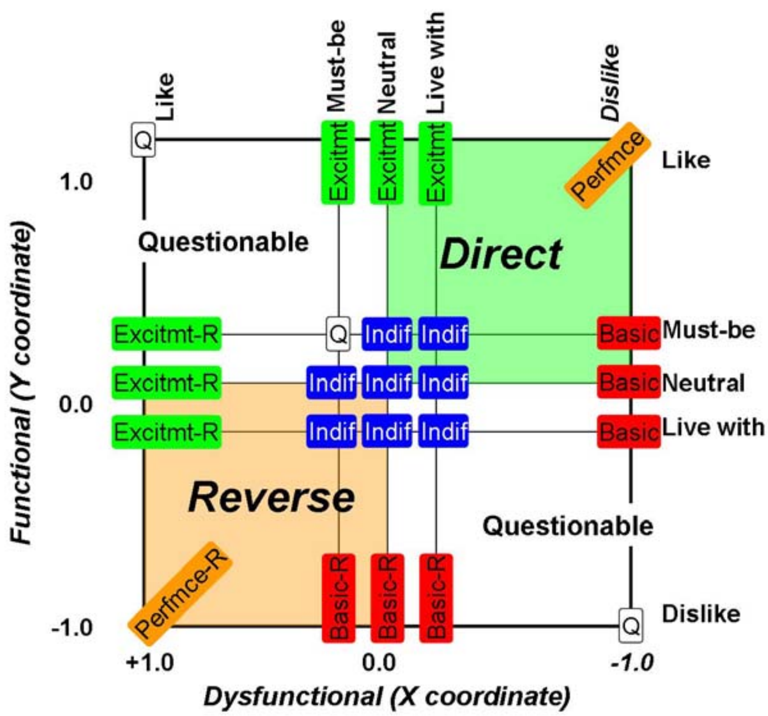

Figure 24. Functionality-Dysfunctionality XY diagram, presentation of location of the different categories. Adapted from DuMouchel.

Because we will compose the answers of the questionnaire, with the self stated questionnaire, it might only be possible to achieve discrete points, aligned to the direction of the answer for "extremely important" importance level. These "extremely important" objectives (thus with an importance multiplier of 1.0), are located in the border of the diagram of Figure 24, starting from a basic quality on the middle right side, proceeding to a performance quality on the top right side, then to excitement qualities on the top middle of the diagram.

By applying the importance weighting, the result is sent closer to the origin, in a proportional way to the importance weight. This aspect was noted to us by Prof. Crawley. We can appreciate in the diagram of Figure 25 those discrete positions. The figure also shows the grouping of those answers according to the priority they receive.

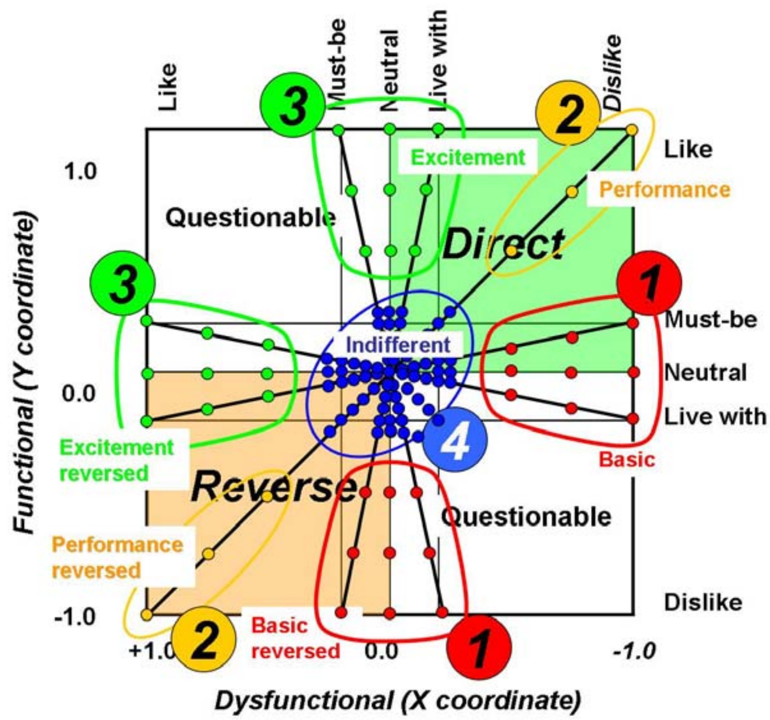

Figure 25. Functionality-Dysfunctionality XY diagram, showing that possible answers to the Kano survey have discrete positions, and presenting the grouping of answers according to priority.

The discrete nature of the answers shows for the case of just one survey. Since the analysis will be done to several surveyees, and stochastic methods will be applied the data, the result will be, actually, a frequency for each of these discrete positions.

We derived from DuMouchel the formulas to calculate the coefficients, for the functional and dysfunctional case. We have extended these expressions to include also reversed objectives.

X_{ij}	Coefficient for the dysfunctional answer of interviewee "i" relative to objective "j"
Y_{ij}	Coefficient for the functional answer of interviewee "i" relative to objective "j"
W_{ij}	Coefficient for the importance answer of interviewee "i" relative to objective "j"
X_j	Expected value of the dysfunctional coefficient of objective j, calculated as a weighted average of each interviewee answer, and the importance they attributed to their answer
Y_j	Expected value of the functional coefficient of objective j, calculated as a weighted average of each interviewee answer, and the importance they attributed to their answer

For the objective j, the dysfunctional coefficient would be

$$X_j = \frac{\sum_i W_{ij} \times X_{ij}}{\sum_i W_{ij}}$$

And its dispersion would be

$$\sigma_{X_j}^2 = \frac{\sum_i W_{ij} \times \left[X_{ij} - \overline{X}_j\right]^2}{\sum_i W_{ij}}$$

The functionality degree would be

$$Y_j = \frac{\sum_i W_{ij} \times Y_{ij}}{\sum_i W_{ij}}$$

And its dispersion would be

$$\sigma^2_{Y_j} = \frac{\sum_i W_{ij} \times \left[Y_{ij} - \overline{Y}_j \right]^2}{\sum_i W_{ij}}$$

The values for functionality and dysfunctional are now normalized, thus their range is between -1 and 1.

4. 6. 3. 4. The search for a priority function

We have identified the different answers as points in a functional-dysfunctional XY diagram. We need to identify a function that will allow mapping those points into a numeric value that prioritizes the objectives according to their criticality.

Looking to the diagram of Figure 25, we identified *three prioritization postulates*, which should be fulfilled by this mapping function

- As we saw in section 4. 6. 3. 1., points located in the ellipsoid of basic objectives (center right), should take precedence over points located on the ellipsoid of performance objectives (to the top right side), and those to the ones located on the ellipsoid of the excitement objectives (to the center top), which precede the indifferent objectives (located in the center of the diagram)

- Each objective category has its opposite due to the reversed answers, and both sides, direct and reverse, have the same priority.

- Inside each ellipsoid, the points closer to the border have priority over the points closer to the center.

These conditions result in the convoluted priority order shown in the graphic of Figure 26.

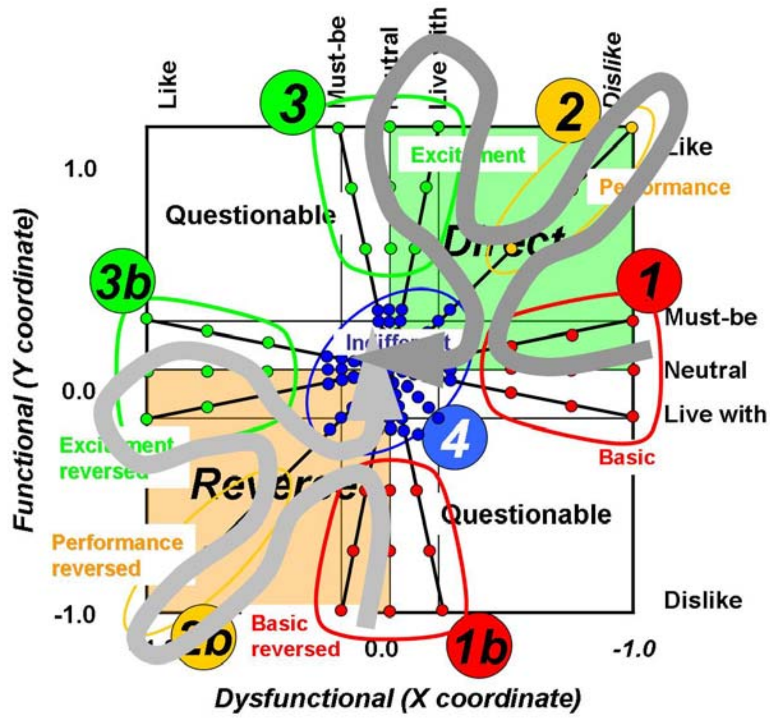

Figure 26. Functional-Dysfunctional XY diagram showing the order of priorities between the different categories of a Kano classification.

Our search started with a linear interpolation, as the simplest function we could think of. We assigned values on the border of the diagram, as shown on Table 14, and built by interpolation the interior of the function.

	Objective type	Diagram point	Priority	Value
Basic	(-1,0)	1	1.00	Center-right
Performance	(-1,1)	2	0.67	Top-right
Excitement	(0,1)	3	0.33	Top-center
Indifferent	(0,0)	4	0.00	Center

Table 14. Assignment of priorities to Kano categories presented in a functional - dysfunctional XY diagram. This option proposes a linear weighting across the categories.

This function did not provide the priorities order we were expecting as can be appreciated in the diagram of Figure 27.

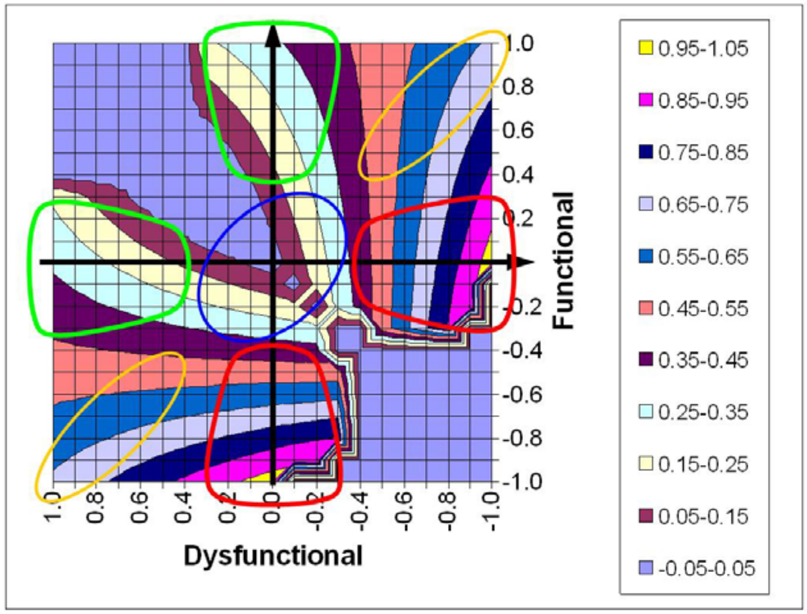

Figure 27. Functional-Dysfunctional XY diagram showing iso-priority lines for a function interpolating linearly between Kano categories.

We then thought of assigning the following values to the extremes, and applying an exponential decay to calculate the intermediate points as shown on Table 15.

	Objective type	Diagram point	Priority	Value
Basic	(-1,0)	1	1.00	Center-right
Performance	(-1,1)	2	0.333	Top-right
Excitement	(0,1)	3	0.111	Top-center
Indifferent	(0,0)	4	0.000	Center

Table 15. Assignment of priorities to Kano categories presented in a functional - dysfunctional XY diagram. This option proposes an exponentially decreasing weighting across the categories.

While the result was not exactly the one we were looking for, it was closer to the prioritization order we were looking for (which is would follow the arrows shown on Figure 26). This closer approximation can be appreciated in Figure 28. The main problem is that “excitement objectives” and “indifferent objectives” have the same priority.

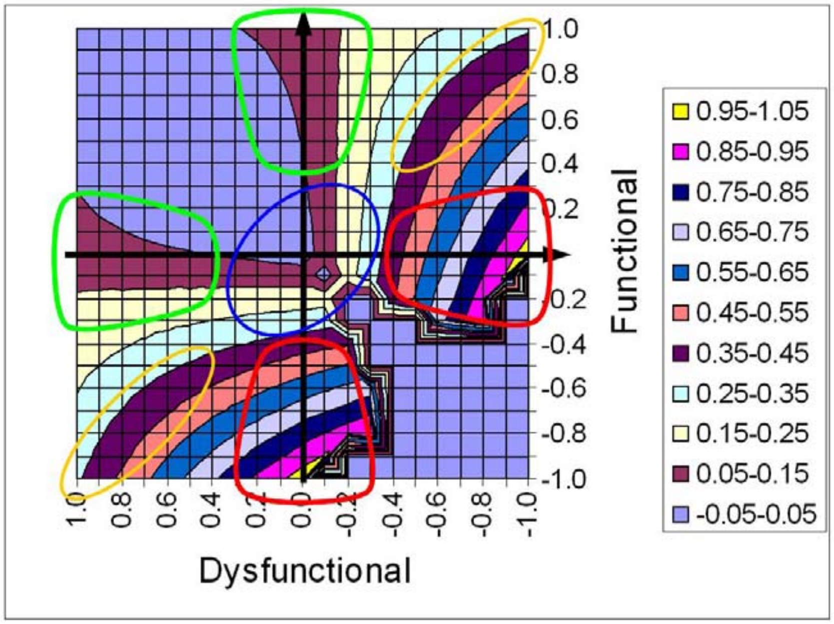

Figure 28. Diagram showing the mapping of priorities following an exponential decay in the borders of the diagram.

After several iterations with different exponents, we arrived at the conclusion that it was not possible to achieve a satisfactory solution using this concept.

We opted to build a function, by assigning values manually, in order to fulfill all the conditions. Then we approximated the function numerically. While this solution is not as clean as we hoped for, it provides adequate treatment for the numerical simulation, and fulfills the conditions required by logical reasoning.

The manual assignment of values can be seen in Table 16. We started by listing every possible answer to the Kano questionnaire, and then, assigned a decreasing priority that followed the *three prioritization postulates* above presented.

Besides, we assigned the value questionable to combinations where the interviewee said they were neutral and at the same time, deemed the objective as very or extremely important.

Dysfunctional If the objective IS NOT present	**Functional** If the objective IS present	**Kano Category**	**Dys func Satf** X	**Func Satf** Y	**Satf Exp** s	**Satisf exp critic**	**Slope critic**	**Not importnt** W = 0.00	**Somewh t importnt** W = 0.25	**Importnt** W = 0.50	**Very importnt** W = 0.75	**Extremly importnt** W = 1.00	**Cluster**
We like it	We like it	*Questionnable*	1	1		-	-	*Quest 99*	*Quest 99*	*Quest 99*	*Quest 99*	*Quest 99*	**n**
We like it	It must be that way	Excitement-Reversed	1	0.2	0.6	0.000	0.400	Ind 62	Ind 61	Exc-R 33	Exc-R 32	Exc-R 31	**3b**
We like it	We are neutral	Excitement-Reversed	1	0	0.5	0.083	0.500	Ind 62	Ind 61	Exc-R 33	Exc-R 32	Exc-R 31	**3b**
We like it	We can live with it	Excitement-Reversed	1	-0.2	0.4	0.167	0.600	Ind 62	Ind 61	Exc-R 33	Exc-R 32	Exc-R 31	**3b**
We like it	We dislike it	Performance Reverse	1	-1	0	0.500	1.000	Ind 52	Ind 51	Perf-R 23	Perf-R 22	Perf-R 21	**2b**
It must be that way	We like it	Excitement	0.2	1	0.6	0.000	0.400	Ind 62	Ind 61	Exc 33	Exc 32	Exc 31	**3**
It must be that way	It must be that way	*Questionnable*	0.2	0.2		-	-	*Quest 99*	*Quest 99*	*Quest 99*	*Quest 99*	*Quest 99*	**n**
It must be that way	We are neutral	Indiferent	0.2	0	0.1	0.417	0.100	Ind 72	Ind 72	*Quest 99*	*Quest 99*	*Quest 99*	**4**
It must be that way	We can live with it	Indiferent	0.2	-0.2	0	0.500	0.200	Ind 72	Ind 72	Ind 71	*Quest 99*	*Quest 99*	**4**
It must be that way	We dislike it	Basic Reverse	0.2	-1	-0.4	0.833	0.600	Ind 42	Ind 41	Bas-R 13	Bas-R 12	Bas-R 11	**1b**
We are neutral	We like it	Excitement	0	1	0.5	0.083	0.500	Ind 62	Ind 61	Exc 33	Exc 32	Exc 31	**3**
We are neutral	It must be that way	Indiferent	0	0.2	0.1	0.417	0.100	Ind 72	Ind 72	Ind 71	*Quest 99*	*Quest 99*	**4**
We are neutral	We are neutral	Indiferent	0	0	0	0.500	0.000	Ind 72	Ind 72	*Quest 99*	*Quest 99*	*Quest 99*	**4**
We are neutral	We can live with it	Indiferent	0	-0.2	-0.1	0.583	0.100	Ind 72	Ind 72	Ind 71	*Quest 99*	*Quest 99*	**4**
We are neutral	We dislike it	Basic Reverse	0	-1	-0.5	0.917	0.500	Ind 42	Ind 41	Bas-R 13	Bas-R 12	Bas-R 11	**1b**
We can live with it	We like it	Excitement	-0.2	1	0.4	0.167	0.600	Ind 62	Ind 61	Exc 33	Exc 32	Exc 31	**3**
We can live with it	It must be that way	Indiferent	-0.2	0.2	0	0.500	0.200	Ind 72	Ind 72	Ind 71	*Quest 99*	*Quest 99*	**4**
We can live with it	We are neutral	Indiferent	-0.2	0	-0.1	0.583	0.100	Ind 72	Ind 72	*Quest 99*	*Quest 99*	*Quest 99*	**4**
We can live with it	We can live with it	Indiferent	-0.2	-0.2	-0.2	0.667	0.000	Ind 72	Ind 72	Ind 71	*Quest 99*	*Quest 99*	**4**
We can live with it	We dislike it	Basic Reverse	-0.2	-1	-0.6	1.000	0.400	Ind 42	Ind 41	Bas-R 13	Bas-R 12	Bas-R 11	**1b**
We dislike it	We like it	Performance	-1	1	0	0.500	1.000	Ind 52	Ind 51	Perf 23	Perf 1	Perf 21	**2**
We dislike it	It must be that way	Basic	-1	0.2	-0.4	0.833	0.600	Ind 42	Ind 41	Bas 13	Bas 12	Bas 11	**1**
We dislike it	We are neutral	Basic	-1	0	-0.5	0.917	0.500	Ind 42	Ind 41	Bas 13	Bas 12	Bas 11	**1**
We dislike it	We can live with it	*Basic*	-1	-0.2	-0.6	1.000	0.400	Ind 42	Ind 41	Bas 13	Bas 12	Bas 11	**1**
We dislike it	We dislike it	*Questionnable*	-1	-1		-	-	*Quest 99*	*Quest 99*	*Quest 99*	*Quest 99*	*Quest 99*	**n**

Table 16. Table showing every possible answer to the dysfunctional, functional and importance questions of a Kano questionnaire; a total of 125 combinations. The table presents the assigned priority, with the lowest numbers assigned to the most important categories. The colors are the same as the corresponding Kano categories in previous diagrams (red for basic, yellow for performance, and green for excitement qualities); in a black and white printout those will come in decreasing intensity of gray.

The first two columns of this table present every combination of functional and dysfunctional answers to the Kano questionnaire, and the next two columns show their Kano classification.

Then the columns labeled X and Y, show the value assigned to the pair of answers by following the table shown in section 4. 6. 3. 3.

The next column introduces the concept of “criticality”. In order to classify the order of importance of the basic, performance and excitement qualities, it seemed that we needed a measure of the position on the XY diagram. After analyzing several alternatives, we found that the priorities are aligned with the expected value of their Kano curve. In other words, a basic curve, as seen in Figure 22, has a negative expected value, a performance curve has an expected value around zero, and an excitement curve has a positive expected value. A negative expected value would signal a higher criticality than a positive expected value.

In order to calculate the expected values, we averaged the value of the answers to the functional and dysfunctional questions, arriving to the value shown under the criticality column. The values range from -0.6, for the most critical objective, which is extremely basic, then proceeds to 0 for performance objectives, and ends in +0.6 for lesser critical objectives in the excitement category.

If we look to the functionality-dysfunctionality XY diagram, these options are arranged in a “polar” coordinate system, with the criticality being the “polar angle” and the importance being the “polar radius”.

The use of a polar angle can be misleading, though; for the neutral categories might exhibit a similar angle than any of the other three higher priority categories. In order to avoid a wrong conclusion about the criticality of the category, we need to measure not only the curve average value, but also the absolute value of its slope. A slope different from zero (either positive or negative) allows to identify performance levels that generate satisfaction. A combination of the “polar angle” in the Functional-Dysfunctional XY diagram and slope of the curve points to the priority of the category.

In order to find the specific point in the Functional-Dysfunctional XY diagram, we needed to compound the criticality value by the importance of the objective. The different values of importance are shown to the right.

In the same area, we have assigned a code for the relative priority of each objective. The most important objectives have a numbering 11, and then priority decreases as codes increase.

As we see there is a discontinuity between objectives that are in the basic category, and are labeled as important, and those that are labeled as somewhat important. We propose that the second kind has even a lower priority than excitement objectives labeled as important.

Table 17 shows on the top row the importance categories, followed by the original importance weighting, and the new importance weight coefficient; and on the leftmost column the criticality level, followed by their Kano category the criticality weight coefficients. The values of the table are found by multiplying the new importance weight coefficient times the criticality weight coefficients.

									importance	Not import	Somewt import	Import	Very import	Extrmly import
									W	**0**	**0.25**	**0.5**	**0.75**	**1**
									importance assigned weight	**0.00**	**0.20**	**0.60**	**0.80**	**1.00**
Dysfunctional	**Functional**	**Kano**	**Dysfunc Satf**	**Func Satf**	**Satf Exp**	**Satisf exp critic**	**Slope critic**							
If the objective IS NOT present	**If the objective IS present**	**Category**	**X**	**Y**	**s**			**Satisf Exp Assigned weight**						
We like it	We like it	*Questionnable*	1	1		-	-	**-**		-	-	-	-	-
We like it	It must be that way	Excitement-Reversed	1	0.2	0.6	0.000	0.400	**0.25**		0.000	0.050	0.150	0.200	0.250
We like it	We are neutral	Excitement-Reversed	1	0	0.5	0.083	0.500	**0.28**		0.000	0.055	0.165	0.220	0.275
We like it	We can live with it	Excitement-Reversed	1	-0.2	0.4	0.167	0.600	**0.30**		0.000	0.060	0.180	0.240	0.300
We like it	We dislike it	Performance Reverse	1	-1	0	0.500	1.000	**0.50**		0.000	0.100	0.300	0.400	0.500
It must be that way	We like it	Excitement	0.2	1	0.6	0.000	0.400	**0.25**		0.000	0.050	0.150	0.200	0.250
It must be that way	It must be that way	*Questionnable*	0.2	0.2		-	-	**-**		-	-	-	-	-
It must be that way	We are neutral	Indiferent	0.2	0	0.1	0.417	0.100	**0.00**		0.000	0.000	-	-	-
It must be that way	We can live with it	Indiferent	0.2	-0.2	0	0.500	0.200	**0.00**		0.000	0.000	0.000	-	-
It must be that way	We dislike it	Basic Reverse	0.2	-1	-0.4	0.833	0.600	**0.90**		0.000	0.180	0.540	0.720	0.900
We are neutral	We like it	Excitement	0	1	0.5	0.083	0.500	**0.28**		0.000	0.055	0.165	0.220	0.275
We are neutral	It must be that way	Indiferent	0	0.2	0.1	0.417	0.100	**0.00**		0.000	0.000	0.000	-	-
We are neutral	We are neutral	Indiferent	0	0	0	0.500	0.000	**0.00**		0.000	0.000	-	-	-
We are neutral	We can live with it	Indiferent	0	-0.2	-0.1	0.583	0.100	**0.00**		0.000	0.000	0.000	-	-
We are neutral	We dislike it	Basic Reverse	0	-1	-0.5	0.917	0.500	**0.95**		0.000	0.190	0.570	0.760	0.950
We can live with it	We like it	Excitement	-0.2	1	0.4	0.167	0.600	**0.30**		0.000	0.060	0.180	0.240	0.300
We can live with it	It must be that way	Indiferent	-0.2	0.2	0	0.500	0.200	**0.00**		0.000	0.000	0.000	-	-
We can live with it	We are neutral	Indiferent	-0.2	0	-0.1	0.583	0.100	**0.00**		0.000	0.000	-	-	-
We can live with it	We can live with it	Indiferent	-0.2	-0.2	-0.2	0.667	0.000	**0.00**		0.000	0.000	0.000	-	-
We can live with it	We dislike it	Basic Reverse	-0.2	-1	-0.6	1.000	0.400	**1.00**		0.000	0.200	0.600	0.800	1.000
We dislike it	We like it	Performance	-1	1	0	0.500	1.000	**0.50**		0.000	0.100	0.300	0.400	0.500
We dislike it	It must be that way	Basic	-1	0.2	-0.4	0.833	0.600	**0.90**		0.000	0.180	0.540	0.720	0.900
We dislike it	We are neutral	Basic	-1	0	-0.5	0.917	0.500	**0.95**		0.000	0.190	0.570	0.760	0.950
We dislike it	We can live with it	*Basic*	-1	-0.2	-0.6	1.000	0.400	**1.00**		0.000	0.200	0.600	0.800	1.000
We dislike it	We dislike it	*Questionnable*	-1	-1		-	-	**-**		-	-	-	-	-

Table 17. Table showing every possible answer to the dysfunctional, functional and importance questions of a Kano questionnaire; a total of 125 combinations. The table presents the assigned weights for every combination. The colors are the same as the corresponding Kano categories in previous diagrams (red for basic, yellow for performance, and green for excitement qualities); in a black and white printout those will come in decreasing intensity of gray.

In order to have a graphical representation, we approximated numerically a function that yields the graphic that follows. The function roughly complies with the constraints we proposed as seen in Figure 29, yet, it is not a smooth surface, as we could preview from the difficult path the priority follows.

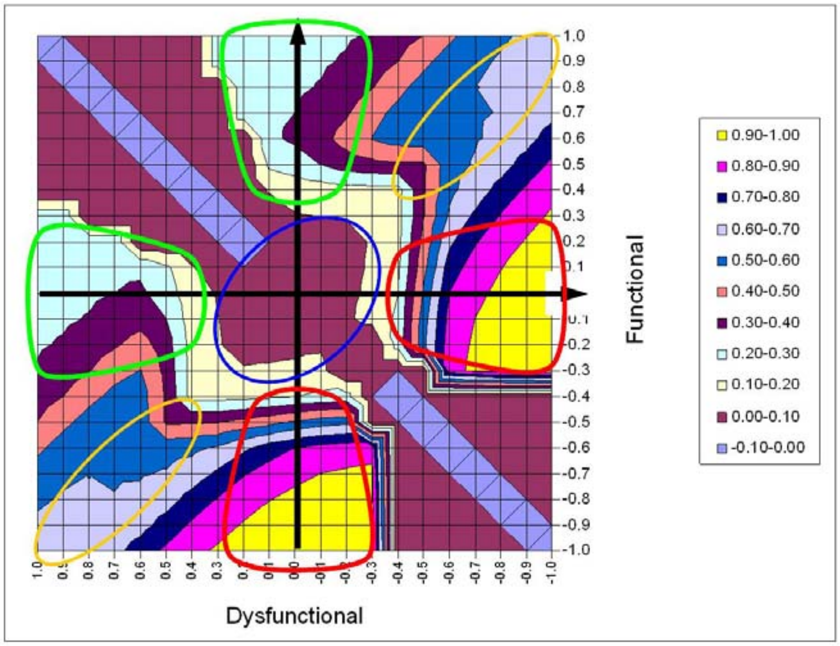

Figure 29. Graphic showing the numeric approximation of the function built by manually assigning coefficients.

Besides not being smooth, the numerical approximation is the not perfect either. The top center area, where excitement objectives reside, presents a lower priority for objectives closer to the border than for some in the middle, and the side closer to the origin on the ellipsoid containing the basic Kano category, is not more important than a large section of the performance ellipsoid.

4. 6. 3. 5. Matrix information to store

We have identified a set of questions that provide a way to separate requirements by order of priority, according to a particular stakeholder. This priority was expressed by the objective's position on a functional-dysfunctional XY diagram. We then created a function that allows prioritizing elements of that diagram, in order to create weights, and thus, specify the elements of the objectives to stakeholder's satisfaction matrix.

As presented in section 4. 1. 2, our work will try to incorporate uncertainty in the analysis, by identifying expected values and standard deviations for each element of the different matrices, and using those parameters to run Monte Carlo simulations.

While for every other step of the model, the values to store for their matrices are, the expected value and dispersion of each matrix element; for this step because of it being built from two values (dysfunctional X and functional Y) trough a function, we have two alternatives:

- Accumulation of the functional Y and dysfunctional X expected values and standard deviation, for each objective and stakeholder. This option stores four numbers per objective and stakeholder.

  In this scenario, each Monte Carlo iteration will create a new pair of X and Y values, to which the prioritizing function is applied. Once the whole matrix is calculated, it is normalized row-wise (per stakeholder), to generate the objectives to stakeholders matrix.

- Accumulation of the output of the prioritizing function, obtained by evaluating the functional X and dysfunctional Y values. In this case we will store the expected value and standard deviation of the prioritization function; these are two numbers per objective and stakeholder. In order to find these parameters, the survey data is used to generate functional and dysfunctional values per each surveyee and objective, value to which the prioritizing function is applied. The expected value and standard deviation are calculated over these accumulated set of results.

  In this scenario, each Monte Carlo iteration will directly create a priority value, based on the stored expected value and standard deviation of the priority, per stakeholder per objective.

We believe, that in order to have an easier and more transparent explanation of any result that might flow from the analysis, it would be more adequate to preserve the functional and dysfunctional values, and only use the function to generate priorities for each iteration.

Finally, because our work surveying stakeholders has proven more demanding than expected, we do not possess actual data for this step. We have built a set of answers for the purpose of illustrating how the model works. While the data and the data noise have been artificially generated, and do not reflect real-world facts, they are based on information collected internally by the MIT-Draper Concept Evaluation and Refinement Research group[20].

Further work, deploying the survey proposed in section 6 will allow for a real implementation.

The data used to generate the coefficients of the Monte Carlo simulation are presented in Appendix 8.3. Those values combined through the prioritization formula, generate a new matrix J for each Monte Carlo iteration.

Below, Table 18 shows the expected value for the matrix J. This table allows identifying what are the most influential factors for each stakeholder.

		Matrix J - transposed	$[J]_{11x23}$ transposed										
Sv Q	**JD**	**Objective**	**Cong**	**Exec**	**Intl**	**Sec**	**Econ**	**Sci**	**Tech**	**NASA**	**Media**	**Educ**	**Vot**
1	1.1	Develop strategic long term planning for the Space Exploration System	0.013	0.014	0.110	0.039	0.013	0.074	0.076	0.107	0.057	0.062	0.107
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.118	0.145	0.042	0.055	0.013	0.076	0.081	0.012	0.059	0.047	0.076
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.142	0.131	0.009	0.009	0.013	0.007	0.008	0.006	0.011	0.012	0.010
4	2.2	Increase positive perception about NASA (political capital)	0.009	0.009	0.009	0.009	0.013	0.007	0.081	0.108	0.011	0.012	0.010
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.009	0.009	0.064	0.009	0.046	0.062	0.079	0.106	0.181	0.194	0.010
6	2.4	Motivate-recognize technical workforce	0.009	0.009	0.101	0.009	0.013	0.075	0.039	0.015	0.011	0.012	0.010
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.094	0.056	0.081	0.043	0.013	0.007	0.008	0.006	0.011	0.012	0.034
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.009	0.009	0.135	0.009	0.013	0.007	0.008	0.006	0.011	0.012	0.010
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.009	0.009	0.009	0.009	0.041	0.104	0.078	0.095	0.011	0.124	0.010
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.095	0.009	0.009	0.105	0.013	0.110	0.008	0.069	0.011	0.012	0.010
11	3.3	Align NASA funding priorities towards space exploration	0.097	0.145	0.009	0.016	0.013	0.051	0.083	0.066	0.011	0.027	0.010
12	4.1	Create interesting and inspiring content for educational use	0.023	0.086	0.009	0.009	0.013	0.082	0.087	0.006	0.118	0.183	0.144
13	4.2	Create entertaining and inspiring content for media	0.009	0.009	0.009	0.009	0.013	0.007	0.008	0.006	0.167	0.116	0.175
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.009	0.009	0.151	0.009	0.013	0.116	0.014	0.006	0.117	0.039	0.010
15	6.11	Create security related dual use technologies	0.009	0.031	0.035	0.130	0.013	0.007	0.008	0.006	0.011	0.012	0.112
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.092	0.093	0.026	0.066	0.013	0.022	0.008	0.006	0.011	0.012	0.010
17	6.13	Provide space presence and freedom of action	0.041	0.034	0.106	0.064	0.013	0.007	0.008	0.006	0.011	0.012	0.010
18	6.14	Provide space acquired earth relevant security data	0.009	0.037	0.009	0.067	0.013	0.007	0.008	0.006	0.011	0.012	0.010
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.009	0.009	0.009	0.137	0.224	0.072	0.121	0.067	0.011	0.012	0.010
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.094	0.036	0.009	0.090	0.124	0.007	0.008	0.108	0.077	0.046	0.113
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.009	0.009	0.036	0.009	0.147	0.007	0.040	0.067	0.059	0.012	0.050
22	6.5	Develop space infrastucture development and operational knowledge	0.009	0.009	0.009	0.092	0.062	0.007	0.128	0.108	0.011	0.012	0.010
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.086	0.095	0.009	0.009	0.143	0.081	0.017	0.006	0.011	0.012	0.042

Table 18. Shows Matrix J, transposed (for a better graphical format). These are the weights used to assess how much satisfaction derives each stakeholder from every objective of space exploration. This matrix is built by evaluating the values X and Y compounded by their importance, for each stakeholder and objective, and is normalized per rows. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

4. 6. 4. Stakeholders to Stakeholders – Matrix H

The input to this step is a vector that shows the increase or decrease in satisfaction of each stakeholder, as a result of a specific architecture. The ideal increase in satisfaction will receive a value of 1 and the ideal decrease will receive a value of -1. The output of this step will be a second stakeholder satisfaction vector, which will reflect the effect of the interactions between stakeholders.

The mapping of stakeholders to stakeholders should represent the propagation of satisfaction derived from indirect value delivery processes. These interactions could be represented by a stream of value delivered between those groups while interacting.

While conceptually, the interaction between the VCS and a stakeholder impacted directly by it is no different than the interaction between any other two stakeholders, it seems impractical to apply our complete model to each pair of stakeholder's interactions. We propose that a simplified model could help capture the most important effects.

The simplified representation will assume that an impacted stakeholder would be affected in an amount equivalent to a linear combination of the impacting stakeholder's satisfaction.

The following additional postulates will be used to build the linear combination:

- In order to build the linear combinations, we will use a set of weights that adds up to a unit, for the reasons suggested in section 4.1.

- The secondary impact should have an effect on stakeholders, smaller than the direct impact. In order to implement this reduction we will introduce a factor **k** smaller than the unit, which we will call the "influence decay factor". We will multiply the result of the linear combination presented in the previous bullet by this factor, in order to reduce its strength.

- The process should be iterative, meaning that, in order to calculate the tertiary effect, we should use the same linear combination and influence decay factor k. Hence we can calculate the n-ary effect (after n iterations), by applying n-1 times the linear combination and k factor.

- The value of the satisfaction vector for the different iterations should be added in order to calculate the full effect over stakeholders of a certain group of architecture decisions, including direct and indirect value streams.

In order to identify the coefficients of the stakeholders' influence linear combination, we should analyze the strength of the influence to each stakeholder group coming from every other stakeholder group. In order to do that, we introduced one question on the survey, where we asked how much time the interviewee's stakeholder group devotes to interact with the other groups of our stakeholders' list.

Our assumption was that an interviewee mentioning certain groups as interacting with his own, would point towards *those groups influencing the interviewees'*.

The sets of weights for each linear combination, ordered row-wise, would permit to build a square shaped matrix, where the relationships between stakeholders will be presented as a Design Structure Matrix, as shown in Figure 30.

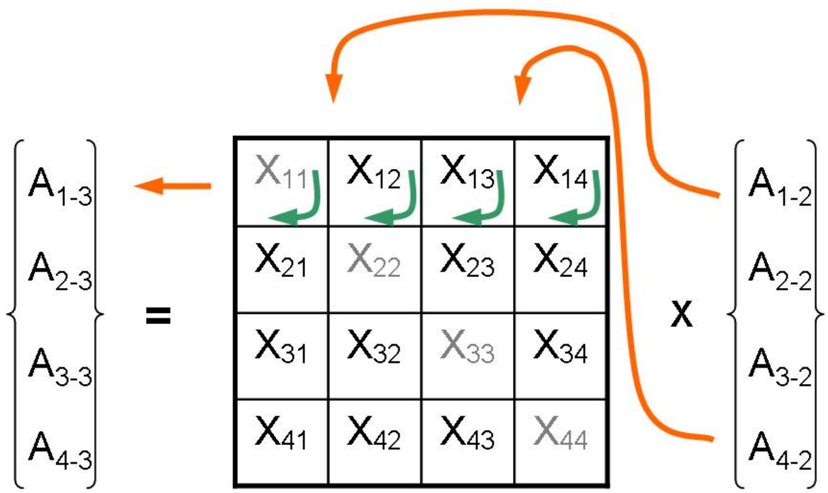

Figure 30. Diagram showing the relationship between the secondary stakeholders' satisfaction vector and the tertiary satisfaction vector, through a DSM matrix.

Because stakeholders do not affect themselves, the diagonal of the matrix would be zero.

Each row presents the linear combination for one stakeholder. This linear combination should include the total effect of other stakeholders on the one analyzed.

As a consequence, the expression for the terminal satisfaction value, the result of a very large number of stakeholder interactions, would be:

Being the direct stakeholder satisfaction S_0

Being k the influence decay factor, and H the stakeholder's interaction square matrix, we can calculate the "i" iteration satisfaction as a function of the "i-1" satisfaction as

$$S_i = k.H \times S_{i-1} \quad \text{(A)}$$

Hence, the terminal satisfaction after a very large number of iterations will be

$$S_{term} = \sum_{i=1}^{\infty} S_i + S_0 \quad \text{(B)}$$

But (A) can also be expressed by replacing the iterations as

$$S_i = k^i . \left(\prod_{j=1}^{i} H \right) \times S_0 \quad \text{(C)}$$

Now, replacing (C) in (B), we would have

$$S_{term} = \sum_{i=1}^{\infty} k^i . \left(\prod_{j=1}^{i} H \right) \times S_0 + S_0$$

If we add the identity to the summation, we can prepare a matrix that will contain all the iterations in just one step

$$S_{term} = \left\{ \sum_{i=1}^{\infty} k^i . \left(\prod_{j=1}^{i} H \right) + I \right\} \times S_0$$

We will call this matrix also with the letter H, but with a sub-index k. In order to differentiate the original matrix H from this new matrix, we will change the name of the original matrix, result of the direct impact of stakeholders to H_0

$$H_k = \sum_{i=1}^{\infty} k^i . \left(\prod_{j=1}^{i} H_0 \right) + I$$

The influence decay factor mentioned in the postulates should represent the decay on the effects of stakeholder's interactions. The notion of failure discount rate has been mentioned previously; yet, we are not going to explore it into depth.

Our comments would be limited to mention that an influence decay factor k implies a discount rate of (1-k). Being k expressed as a fraction of a unit, it would be needed to multiply it by 100% to express it as a percentage discount rate.

Influence decay factors, as we stated above, would be positive numbers, smaller than one. A smaller number (closer to zero) would damp faster the satisfaction that stakeholders receive from other stakeholders; on the contrary, a value closer to one would preserve the amount of influence one stakeholder pass to the others along a large number of iterations.

The diagram of Figure 31 shows how different influence decay factors affect both the total final value, and the time to decay. The diagram has been generated using a matrix H_0 that fulfills the conditions of the four postulates above enunciated.

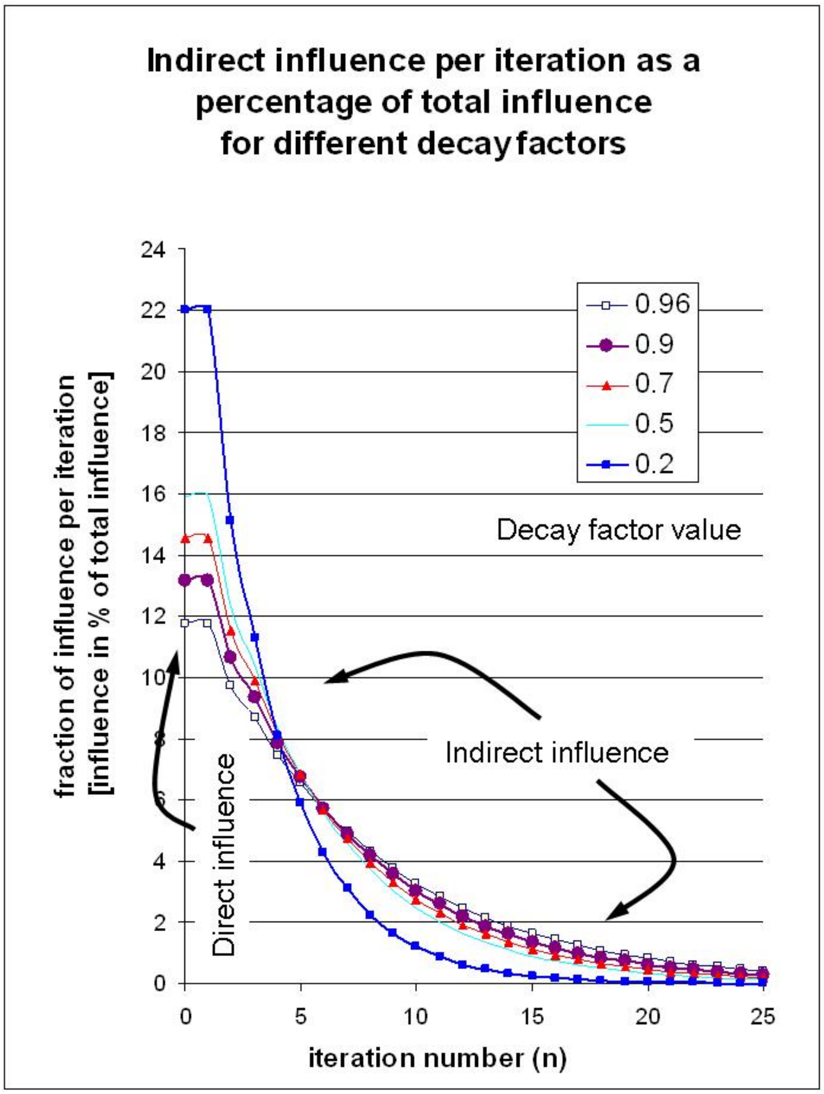

Figure 31. Diagram showing different decay curves for the influence of stakeholders.

In section 3. 9. 3. we proposed an XY diagram or architecture evaluation by comparing architectures using a long term and short term focus. By choosing different influence decay factors it will be possible to evaluate terminal stakeholder satisfaction taking into account different time horizons.

While a low influence decay factor discounts higher each iteration, prioritizing stakeholders that are closer in time and distance to the VCS, thus emphasizing a short term perspective, a high influence decay factor (closer to one) promotes the longer term perspective. The former seems tuned with the dynamics of the political process, and the latter is congruent with the perspective of less chaotic institutions, where longer term value is deemed important.

If, as suggested in section 3. 9. 3., we use the timing of the political process to delineate the boundary between short and long term, we should use a influence decay factor for the short term process such that the 2-4 year time frame dominates.

Now, the question is how many iterations happen each year. We would propose that the number of iterations would depend on how many times the stakeholders think about the problem per period of time. By reflecting about the problem, they are seeking inputs from their environment, and sending signals. We are going to use a crude simplification, by proposing that every stakeholder deals with the problem at the same frequency, which is clearly not correct, and might deserve further work; stakeholders interact between 3 and 12 times per year, and for the purpose of the presentation of this example, we will use 8 as an average. As a consequence, the number of interactions for the average political decision would be 3 years, times 8 interactions, that is about 25, and we will use this number of iterations to calculate the short term stakeholder satisfaction of the architecture.

On the other hand, the longer term perspective, for the space program can be measured in decades. A longer term perspective could have a horizon around year 2030, which is 24 year away, or about 200 iterations. This is the number of iterations we will use to calculate the long term stakeholder satisfaction.

One problem will be that we are not comparing strictly apples with apples, since during those 24 years, while on the one hand, the interaction influence decays, on the other, additional benefits are generated. Nevertheless, since we are trying to assess the individual short and long term value of a specific decision taken today, it makes sense to focus on how the stakeholder satisfaction is affected by increasing the number of iterations between stakeholders.

In order to calculate the influence decay factor we would need to think about the decrease in the influence, as the value and information about the value, travel along time and stakeholders interactions.

We will make another assumption in this step, we would be able to divide projects in 3 classes,

- Projects that never start, and thus were never able to deliver value neither on the short nor on the long term. These projects are just very badly designed.

- Projects which are able to convince short term supporters, but lack the long term value to be sustainable over time. These projects should get a relatively good rating on our short term stakeholder satisfaction.

- Projects that have a superior rating when looked on a long term perspective. Possibly these projects will have to sacrifice some degree of short term stakeholder satisfaction due to a reasoning similar to the one presented in the last part of section 3.10.

The second bullet describes projects that start, but fail because of lack of sustainability. For a government organization, as the one of the example we are presenting, political reasons cause the cancellation after a few years.

The value of this type of project should be marginally affected if the evaluation is done using a fast decay (low influence decay factor), however their value should be affected after 4 to 8 years. Consequently, we will aim to identify an influence decay factor that does not reduce significantly the value of projects in a 3 years lapse, but affects them in a 6 years timeframe. We can translate this time lapses into iterations by using the conversion factor of 8 iterations per year; this gives us 24 and 48 iterations respectively.

Table 19 shows how the model shows value loss when the influence decay factor is lower (or alternatively the discount rate higher). These discount rates are "per iteration" and not per year

Influence Decay factor	Discount rate	Total value	Relative value	Loss of value
0.96	4%	8.51		
0.9	10%	6.29	74%	26%
0.7	30%	3.67	43%	57%
0.5	50%	2.80	33%	67%
0.2	80%	2.21	26%	74%

Table 19. Comparison of total value result of different influence decay factors.

We will assume that projects that sacrifice more than 50% of their value in order to obtain short term results are in danger. Thus, we will select an influence decay factor of 0.5, or alternatively a discount rate of 50%.

Following, Table 20 and Table 21 present the expected values and standard deviations of the stakeholders-to-stakeholders interactions matrices used in the Space Exploration example. While the values are notional, and not the result of data acquired from external sources, we have used the best common sense to present a reasonable guess of what real values should look like.

	Congress	Execut	Intl part	Security	Economic	Science	Tech comm	NASA legacy	Media	Education	Voters
Congress	0.000	0.075	0.025	0.025	0.075	0.075	0.125	0.125	0.175	0.075	0.225
Execut	0.065	0.000	0.109	0.065	0.109	0.065	0.065	0.109	0.152	0.065	0.196
Intl part	0.031	0.219	0.000	0.094	0.094	0.219	0.094	0.094	0.094	0.031	0.031
Security	0.145	0.145	0.048	0.000	0.113	0.081	0.145	0.048	0.048	0.113	0.113
Economic	0.065	0.065	0.022	0.065	0.000	0.109	0.196	0.065	0.109	0.196	0.109
Science	0.104	0.104	0.146	0.021	0.063	0.000	0.104	0.104	0.104	0.146	0.104
Tech comm	0.071	0.071	0.071	0.024	0.214	0.119	0.000	0.071	0.071	0.214	0.071
NASA legcy	0.159	0.159	0.068	0.023	0.114	0.159	0.114	0.000	0.068	0.068	0.068
Media	0.029	0.088	0.029	0.088	0.147	0.147	0.029	0.088	0.000	0.088	0.265
Education	0.088	0.147	0.029	0.029	0.029	0.147	0.088	0.088	0.088	0.000	0.265
Voters	0.022	0.109	0.022	0.152	0.109	0.109	0.065	0.109	0.152	0.152	0.000

Table 20. The table shows the expected values for the Matrix H0 (H with sub-index zero) used for the space exploration example. Each row of this matrix presents the influence of every other stakeholder to the stakeholder of the row heading. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

	Congress	Execut	Intl part	Security	Economic	Science	Tech comm	NASA legacy	Media	Education	Voters
Congress	0.000	0.075	0.025	0.025	0.075	0.075	0.125	0.125	0.175	0.075	0.225
Execut	0.065	0.000	0.109	0.065	0.109	0.065	0.065	0.109	0.152	0.065	0.196
Intl part	0.031	0.219	0.000	0.094	0.094	0.219	0.094	0.094	0.094	0.031	0.031
Security	0.145	0.145	0.048	0.000	0.113	0.081	0.145	0.048	0.048	0.113	0.113
Economic	0.065	0.065	0.022	0.065	0.000	0.109	0.196	0.065	0.109	0.196	0.109
Science	0.104	0.104	0.146	0.021	0.063	0.000	0.104	0.104	0.104	0.146	0.104
Tech comm	0.071	0.071	0.071	0.024	0.214	0.119	0.000	0.071	0.071	0.214	0.071
NASA legcy	0.159	0.159	0.068	0.023	0.114	0.159	0.114	0.000	0.068	0.068	0.068
Media	0.029	0.088	0.029	0.088	0.147	0.147	0.029	0.088	0.000	0.088	0.265
Education	0.088	0.147	0.029	0.029	0.029	0.147	0.088	0.088	0.088	0.000	0.265
Voters	0.022	0.109	0.022	0.152	0.109	0.109	0.065	0.109	0.152	0.152	0.000

Table 21. The table shows the standard deviation for the Matrix H0 (H with sub-index zero) used for the space exploration example. Each row of this matrix presents the influence of every other stakeholder to the stakeholder of the row heading. The standard deviation and expected values are used on the Monte Carlo simulation.

These two tables show the direct impact received by a specific stakeholder, by every other stakeholder. Because the model runs through a Monte Carlo simulation, generating random coefficients for each iteration, we store values for the expected value and standard deviation.

Each row is normalized and represents the set of weights for the influence of the different stakeholders on the stakeholder of the row heading. The original stakeholder is shown with a value of 0, since it does not influence itself.

By applying the formula below, we can calculate the values for H_k matrices for different values k.

$$H_k = \sum_{i=1}^{\infty} k^i . \left(\prod_{j=1}^{i} H_0 \right) + I$$

For the cases of k = 0.5, the resulting matrix of expected values is shown in Table 22 such matrix emphasizes the short term effect of VCS' actions. For the case of k = 0.99, the matrix of expected values is shown Table 23, a matrix with these coefficients emphasizes long term benefits, by reducing the toll interactions between stakeholders pay.

$[H_{0.50}]_{11x11}$	Congress	Execut	Intl part	Security	Economic	Science	Tech comm	NASA legacy	Media	Education	Voters
Congress	0.517	0.044	0.020	0.022	0.044	0.047	0.052	0.052	0.067	0.047	0.088
Execut	0.033	0.527	0.039	0.032	0.051	0.045	0.039	0.048	0.062	0.044	0.080
Intl part	0.027	0.078	0.517	0.036	0.048	0.079	0.046	0.044	0.048	0.036	0.042
Security	0.052	0.060	0.026	0.514	0.052	0.047	0.058	0.034	0.038	0.056	0.062
Economic	0.034	0.042	0.019	0.030	0.526	0.054	0.069	0.037	0.051	0.076	0.062
Science	0.042	0.053	0.049	0.020	0.040	0.530	0.048	0.047	0.051	0.061	0.060
Tech comm	0.035	0.044	0.031	0.020	0.074	0.057	0.525	0.039	0.043	0.079	0.053
NASA legcy	0.056	0.063	0.031	0.020	0.052	0.065	0.051	0.522	0.043	0.045	0.052
Media	0.025	0.048	0.021	0.038	0.059	0.062	0.031	0.043	0.526	0.051	0.095
Education	0.038	0.061	0.022	0.023	0.033	0.062	0.043	0.044	0.048	0.528	0.096
Voters	0.025	0.053	0.020	0.051	0.051	0.054	0.040	0.047	0.061	0.064	0.536

Table 22. Matrix H 0.50, incorporates the expected value of the discounted sumation of the stakeholders interaction, using a influence decay factor of 0.50. This low influence decay factor causes the influence to decay fast, thus, emphasizes short term interactions between stakeholders. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

$[H_{0.99}]_{11x11}$	Congress	Execut	Intl part	Security	Economic	Science	Tech comm	NASA legacy	Media	Education	Voters
Congress	0.136	0.093	0.049	0.053	0.088	0.099	0.084	0.079	0.094	0.100	0.125
Execut	0.067	0.129	0.054	0.057	0.093	0.103	0.086	0.082	0.097	0.103	0.130
Intl part	0.066	0.102	0.085	0.057	0.092	0.107	0.087	0.082	0.095	0.102	0.125
Security	0.069	0.099	0.052	0.087	0.093	0.103	0.088	0.080	0.094	0.105	0.128
Economic	0.067	0.097	0.052	0.056	0.123	0.104	0.089	0.081	0.096	0.107	0.128
Science	0.068	0.099	0.055	0.055	0.091	0.134	0.087	0.082	0.096	0.105	0.127
Tech comm	0.067	0.098	0.053	0.055	0.095	0.105	0.117	0.081	0.095	0.108	0.127
NASA legcy	0.070	0.100	0.053	0.055	0.093	0.105	0.087	0.112	0.095	0.104	0.126
Media	0.066	0.098	0.052	0.057	0.094	0.105	0.085	0.081	0.126	0.104	0.131
Education	0.067	0.100	0.052	0.056	0.091	0.105	0.086	0.082	0.096	0.134	0.132
Voters	0.066	0.099	0.052	0.059	0.093	0.104	0.086	0.082	0.097	0.106	0.157

Table 23. Matrix H 0.99, incorporates the expected value of the discounted sumation of the stakeholders interaction, using a influence decay factor of 0.99. This high influence decay factor (close to 1) causes the influence to decay slowly, thus, emphasizes long term interactions between stakeholders. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

4. 6. 5. Stakeholders to Resources – Matrix V

The input for this step is the vector of terminal stakeholder satisfaction change and the output should be a vector expressing which resources are increased and which resources are decreased.

The interest of mapping stakeholders to resources is to understand how an increase in satisfaction of a specific stakeholder will impact on his willingness to liberate or restrict resources. Our model postulates that an increase in stakeholder satisfaction will result in an increase in architecture value, and thus a higher willingness of stakeholders to provide resources under their control to the VCS.

Because the needs of the VCS of our example are multiple, and not only restricted to funds, but also include political capital, workforce, and technology, a matrix that will link stakeholders and resources could be used for this step.

The translation between a change in stakeholder satisfaction and a change in resources delivery should be done by linking the control of each stakeholder on the resources of interest to the VCS. In order to prepare the expression that would provide such value, we should first aim to identify the resources, and then, for every resource, the parties that controls it. Once these parties are identified, we should be looking to model a linear combination of the change of satisfaction of those parties, as justification for the change on the supply of the resource being analyzed.

Ideally, the linear combination should be assessed by measuring the capacity of each stakeholder to influence the resource allocation process. This direct assessment might be easier for some stakeholders and resources than others; nevertheless, the linear combinations that would describe some of the most important needs of the VCS, such as political capital, might be especially difficult to identify.

For this first iteration of the model, we propose that the matrix that maps stakeholders to resources should be assessed through a self-evaluation process by each stakeholder, through the proposed survey. Yet, the lack of data to populate the model adequately, will require that in order to show how it works, we would need to populate the matrix using concepts derived from our work at the MIT-Draper Concept Evaluation and Refinement Research group[20].

Table 24 and Table 25 show the data used for the Matrix V in the example of the Space Exploration initiative. The data shown is conceptual and not result from a process of data gathering. Its purpose is to illustrate the example.

			$[V]_{23\times11}$										
SvQ	**JD**	Objective – VCS' need to satisfy	Cong	Exec	Intl	Sec	Econ	Sci	Tech	NASA	Media	Educ	Vot
1	1.1	Develop strategic long term planning for the Space Exploration System	0.061	0.061	0.184	0.061	0.184	0.184	0.020	0.184	0.000	0.000	0.061
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.067	0.067	0.067	0.067	0.067	0.200	0.200	0.200	0.067	0.000	0.000
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)											
4	2.2	Increase positive perception about NASA (political capital)	0.081	0.081	0.081	0.081	0.027	0.081	0.000	0.081	0.243	0.000	0.243
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.000	0.000	0.000	0.000	0.034	0.103	0.103	0.103	0.310	0.310	0.034
6	2.4	Motivate-recognize technical workforce	0.031	0.031	0.000	0.031	0.281	0.031	0.031	0.094	0.281	0.094	0.094
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues											
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration											
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.243	0.243	0.027	0.081	0.081	0.081	0.000	0.081	0.081	0.000	0.081
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.077	0.077	0.077	0.231	0.077	0.231	0.000	0.231	0.000	0.000	0.000
11	3.3	Align NASA funding priorities towards space exploration	0.365	0.365	0.081	0.027	0.027	0.081	0.027	0.000	0.027	0.000	0.000
12	4.1	Create interesting and inspiring content for educational use											
13	4.2	Create entertaining and inspiring content for media											
14	5.1	Provide easily and quickly accesible data for use on science knowledge											
15	6.11	Create security related dual use technologies											
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)											
17	6.13	Provide space presence and freedom of action											
18	6.14	Provide space acquired earth relevant security data											
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.073	0.073	0.073	0.220	0.220	0.024	0.073	0.220	0.024	0.000	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.032	0.032	0.097	0.032	0.290	0.032	0.097	0.161	0.097	0.097	0.032
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.086	0.086	0.029	0.086	0.257	0.029	0.086	0.257	0.029	0.029	0.029
22	6.5	Develop space infrastucture development and operational knowledge	0.032	0.032	0.290	0.097	0.097	0.032	0.097	0.290	0.000	0.032	0.000
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)											

Table 24. Table showing the expected values for Matrix V which presents the weights of the parties that control resources of interest to the VCS. The lines that are grayed out are considered not of interest to the VCS of the example (the space exploration initiative). All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources.

SvQ	JD	Objective – VCS need to satisfy	Cong	Exec	Intl	Sec	Econ	Sci	Tech	NASA	Media	Educ	Vot
1	1.1	Develop strategic long term planning for the Space Exploration System	0.050	0.040	0.038	0.000	0.005	0.013	0.000	0.009	0.000	0.000	0.019
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.007	0.007	0.018	0.009	0.010	0.025	0.037	0.025	0.013	0.000	0.000
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)											
4	2.2	Increase positive perception about NASA (political capital)	0.013	0.020	0.020	0.006	0.007	0.009	0.000	0.007	0.054	0.000	0.046
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.000	0.000	0.000	0.000	0.002	0.022	0.024	0.009	0.049	0.009	0.004
6	2.4	Motivate-recognize technical workforce	0.008	0.004	0.000	0.003	0.012	0.005	0.007	0.012	0.040	0.011	0.021
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues											
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration											
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.056	0.015	0.003	0.026	0.015	0.013	0.000	0.013	0.013	0.000	0.008
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.007	0.023	0.008	0.095	0.022	0.018	0.000	0.022	0.000	0.000	0.000
11	3.3	Align NASA funding priorities towards space exploration	0.049	0.044	0.015	0.005	0.002	0.009	0.008	0.032	0.006	0.000	0.000
12	4.1	Create interesting and inspiring content for educational use											
13	4.2	Create entertaining and inspiring content for media											
14	5.1	Provide easily and quickly accesible data for use on science knowledge											
15	6.11	Create security related dual use technologies											
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)											
17	6.13	Provide space presence and freedom of action											
18	6.14	Provide space acquired earth relevant security data											
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.003	0.008	0.011	0.043	0.025	0.001	0.008	0.033	0.005	0.000	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.016	0.015	0.006	0.004	0.073	0.004	0.020	0.015	0.002	0.022	0.008
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.001	0.018	0.002	0.007	0.053	0.006	0.006	0.035	0.006	0.006	0.002
22	6.5	Develop space infrastucture development and operational knowledge	0.004	0.004	0.011	0.017	0.004	0.005	0.013	0.029	0.000	0.004	0.000
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)											

Table 25. Table showing the standard deviation for Matrix V which presents the weights of the parties that control resources of interest to the VCS. The lines that are grayed out are considered not of interest to the VCS of the example (the space exploration initiative). All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The standard deviation is used to generate the random coefficients in the Monte Carlo simulation.

4. 6. 6. From Resources to VCS satisfaction – Matrix K

The input for this process is a vector that presents the increase or decrease of resources resulting from a specific architecture. The output of this process will be a *number* that expresses the overall satisfaction of the VCS with the amount and mix of resources received.

Once the resource supply variation has been identified, it would be needed to measure how critical are those resources for the VCS. As shown on the tree hierarchy of Figure 15, we place on top of the decision process the VCS, an idea that is somehow controversial, yet most important to increase the sustainability of the VCS. To place the VCS on the vertex guarantees its survival.

A caveat on what is our example's VCS; we should understand that our example's VCS is the Space Exploration Strategy, and not NASA as an institution. NASA, labeled as NASA-Legacy is one of the stakeholders that provides resources, and presents demands to the Space Exploration enterprise. Were NASA to survive, and the Space Exploration project to fail, we would have missed our goal.

In order to assess how critical is each resource for the survival of the VCS, we propose to use a Kano analysis similar to the one done in section 4. 6. 3. for the case of stakeholders, with the main difference that in this section we are surveying one only stakeholder (the VCS), which simplifies the case.

The Kano questionnaire leads to a survey similar to the one used for stakeholders, but this time distributed internally at the VCS. The surveyees will answer how important are the different resources for the VCS needs, and those answers will provide a set of weights that multiplied by the vector of resources would identify the overall satisfaction of the VCS with the resources stream, caused by a specific architecture.

Two caveats are important to mention.

- Resources in type and amount might be architecture specific. While some architectures might require specific resources, that are not common to the majority of architectures, and thus potentially demand special stakeholders to provide them, this will not be generally the case. The most common cases will involve a fairly generic list of resources needed by the vast majority of architectures, provided by easy to identify stakeholders.

- Resources availability might be different than the VCS needs for a specific architecture. For an architecture to be evaluated, it should be possible to implement without taking into account additional resources, coming from a future feedback loop. Since the decision to implement architectures is done in the present, then the resources available are the ones the VCS possess in the present time before any feedback has taken place.

Architectures that tend to decrease the amount of resources delivered, when compared with the SQA should be avoided altogether. As a consequence, every architecture should pass the litmus test of providing at least more resources than the SQA. These resources’ excess, coming from the feedback loop, will allow increasing the benefits delivered over time, through the use of resources accumulated at the VCS.

A growth in resources accumulation at the VCS side will allow daring more challenging and demanding projects, due to the freedom that internal accumulation provides. A caveat on resources accumulation is that some resources, such as political capital, are not really possessed, hence their accumulation is dubious, and will remain always volatile.

The values used for the Space Exploration example are presented in Appendix 8.3, as the first column, Explorers. This data is not the result of an actual data gathering, but has been prepared from the material prepared by MIT-Draper Concept Evaluation and Refinement Research group[20]. The actual data gathering would have included a Kano survey, and would have produced a list of values similar to the one shown.

Table 26 presents the information used to generate the Monte Carlo simulation. A matrix K is prepared for each Monte Carlo iteration, by using the information on expected values and standard deviations of each coefficient, in a similar way as proposed for matrix J.

Sv Q	JD	Objective	X.imp	Y.imp	x disp	y disp
1	1.1	Develop strategic long term planning for the Space Exploration System	-0.836	-0.168	0.116	0.006
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	-0.533	0.000	0.014	0.002
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.000	0.000	0.002	0.006
4	2.2	Increase positive perception about NASA (political capital)	-0.559	0.000	0.000	0.003
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	-0.642	0.970	0.031	0.017
6	2.4	Motivate-recognize technical workforce	-0.642	0.970	0.037	0.003
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.000	0.000	0.005	0.000
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.000	0.000	0.008	0.000
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	-0.877	-0.186	0.003	0.000
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	-0.593	0.435	0.005	0.039
11	3.3	Align NASA funding priorities towards space exploration	-0.877	-0.186	0.010	0.009
12	4.1	Create interesting and inspiring content for educational use	0.000	0.000	0.004	0.001
13	4.2	Create entertaining and inspiring content for media	0.000	0.000	0.002	0.003
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.000	0.000	0.002	0.000
15	6.11	Create security related dual use technologies	0.000	0.000	0.004	0.000
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.000	0.000	0.009	0.002
17	6.13	Provide space presence and freedom of action	0.000	0.000	0.003	0.011
18	6.14	Provide space acquired earth relevant security data	0.000	0.000	0.000	0.000
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	-0.758	-0.179	0.015	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	-0.613	0.435	0.037	0.003
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	-0.545	-0.126	0.002	0.001
22	6.5	Develop space infrastucture development and operational knowledge	-0.877	-0.203	0.056	0.005
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.000	0.000	0.002	0.006

Table 26. Matrix showing the expected values and standard deviation for X, Y, for Explorers as stakeholders. This information is used to calculate the Matrix K of criticality of VCS needs.

Table 27 presents the expected values for Matrix K. This table allows to identify which needs are more critical to the VCS.

Sv Q	JD	Objective	$[K]_{1x23}$ *transposed*
1	1.1	strategic long term planning	0.097
2	1.2	short-term attainable results	0.068
3	2.1	domestic positive perception about the Congress and Executive Branch	0.006
4	2.2	Increase positive perception about NASA	0.076
5	2.3	understanding of the Space Exploration to non-technical groups	0.055
6	2.4	Motivate-recognize technical workforce	0.055
7	2.5	Increase US foreign policy influence	0.006
8	2.6	Increase foreign citizens posive perception about their governments	0.006
9	3.1	Promote funding for the Space Exploration System	0.098
10	3.2	Promote funding sharing of investments	0.058
11	3.3	Align NASA funding priorities towards space exploration	0.098
12	4.1	Create content for educational use	0.006
13	4.2	Create content for media	0.006
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.006
15	6.11	Create security related dual use technologies	0.006
16	6.12	Improve security qualified space access	0.006
17	6.13	Provide space presence and freedom of action	0.006
18	6.14	Provide space acquired earth relevant security data	0.006
19	6.2	Improve space access measured as cost and risk reductions	0.096
20	6.3	Promote space related commercial activities, inc comm, tourism	0.060
21	6.4	Promote commercial acqusition of space good & service (includes COTS)	0.077
22	6.5	Develop space infrastucture development and operational knowledge	0.098
23	6.6	Create NON SECURITY related dual use technologies	0.006

Table 27. Matrix K showing the different weights on the needs of the VCS. The matrix is transposed, for a better graphical representation in this printed work. .

4. 6. 7. From Stakeholders' satisfaction to Stakeholders' consensus

The input of this step is the vector Sterm of terminal satisfaction of stakeholders, and the output is a number representing the consensus of the stakeholders, when presented a specific architecture.

As previously presented in section 3. 9. 1., we attempt to measure the satisfaction level of the different stakeholders, and calculate the dispersion of that satisfaction level.

A high level of agreement, represented by every stakeholder having roughly the same satisfaction level, no matter if high or low, will lead to a low dispersion. We will use the inverse of this dispersion to provide a measure of the consensus between stakeholders.

The formula to calculate the standard deviation of the stakeholders consensus is shown in 4.2. The methodology is to calculate the expected value for stakeholder's satisfaction at each Monte Carlo iteration and use that value to calculate the deviation from the expected value for each stakeholder, using the usual formulation for Standard deviation from statistics. This standard deviation and its consequent consensus measure is calculated per each Monte Carlo iteration.

Because a high consensus would mean a low standard deviation, we propose the consensus is measured as the inverse of the calculated standard deviation.

4. 6. 8. Other applications

This work is a first approach to a new idea, and its purpose is to present it, and to encourage further research. We envision other areas of application where multiple and opposite objectives need to be balanced:

Particularly interesting are the cases of

- Corporate strategy and game theory, where several models attempt to present the internal and external tensions that businesses have to deal with.

- Disruptive technologies, where the different variables that interact into a disruptive model can be represented through a disruption vector.

- National Political Processes, which could easily be adapted from the Space Enterprise model already drafted

4. 6. 9. Value flow and Causality flow

We devised the model for this research while thinking through the case of space exploration strategy for NASA. This allowed us to test each of the different postulates and tools proposed; tests that in some cases resulted in modifications.

This use case-building methodology helped us to understand the actual applicability of the model we present, and whether it will help to take decisions in the real world. The downside of implementing and testing at the same time is that the model might lose generality and become a solution for a one of a kind problem.

Recently, we were able to observe how the model could be applied to a different problem. A large corporation that works in the energy market approached the MIT Aeronautics and Astronautics department, looking for advice on concept generation and value analysis for a very large project the corporation was facing. The differences between NASA's space exploration project and this corporation's project were many, including the different ownership and organizational structure, different type of benefits delivered, different level of development in technology; and yet, there were several striking similarities.

Among those similarities were the fact that both organizations deal with very large projects in the billions of dollars range, which deliver value over large time frames, both organizations deal with high uncertainty, and both design and operate cutting edge technology in extremely unforgiving environments.

The project was an excellent drill for the newly developed tools providing an excellent opportunity to apply the model to a different environment.

The result of going in a rapid sequence through the different steps we presented in sections 3 and 4, forced us to analyze the order in which the steps should be rationally applied. Our previous work for NASA did not make this order apparent, since our understanding of the method and case evolved in parallel.

The steps that an analysis should follow provided us some interesting insights which we will present with the help of Figure 32. In this diagram, value flows clockwise, as in the diagram presented in Figure 6, but causality flows mostly backwards, starting on top of the diagram, on step 1.

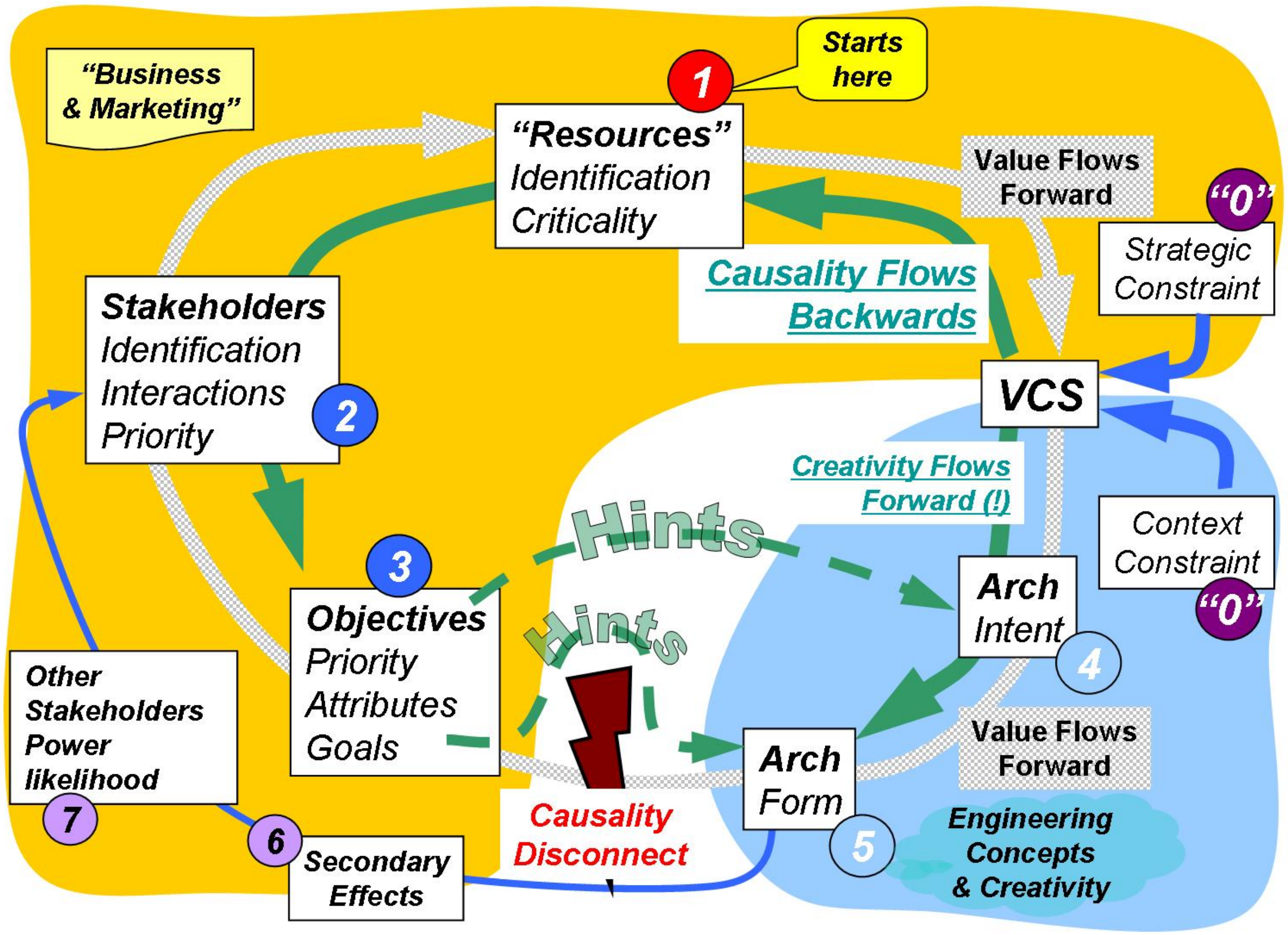

Figure 32. Diagram that shows the mostly counterclockwise direction of the causality flow, steps 1, 2 and 3, using a solid arrow; causality flows clockwise only in the engineering concepts section, steps 4 and 5. As a contrast, the value delivery always flows clockwise as shown with a checkered arrow.

- The first insight we discovered is that causality flows, mostly, in a direction opposite to value.

  The first step of the analysis should be to assess what are the resources the VCS needs, as presented in Figure 32, step 1; once identified those, we should look for their suppliers, and we will name those suppliers "stakeholders", as shown in step 2. As presented previously, our work proposes that every stakeholder should supply something of interest to the VCS.

  Once stakeholders are known, we should identify the most complete list of stakeholder needs, from where we could derive objectives. Since we need to assess how well these objectives are fulfilled, and objectives might not be directly observable on the architecture, we should derive from those objectives a set of engineering related metrics, all these operations are done in step 3.

  These steps follow a counterclockwise direction. As a contrast, value flows clockwise, the value is delivered from the VCS through fulfillment of objectives to stakeholders; stakeholders on their turn provide resources back to the VCS.

  It might seem counterintuitive to start by the end, but, because our higher objective is the provide sustainability to the VCS, which is guaranteed by an adequate supply of resources, we deem identifying those resources and their criticality as the highest vertex of the decision making tree.

- The second insight we discovered is the discontinuity of the architecture causality.

  As it can be noticed in the previous bullet, we did not mention steps 4 and 5; our next insight is that it is not possible to go from step 3 to step 4, and derive from engineering proxies the architecture. The architecture follows a clockwise flow that starts with the "intent" which declares the architect attitude towards the problem, and is the initial seed for a creativity process that produces the architecture tree and its different questions and answers. As far as we know, it is not possible to declare an algorithm that based on upstream information (stakeholder needs), would generate a complete set of architecture concepts.

  This is not to be confused with the enumeration of architecture forms once the concepts have been chosen.

  As a consequence, there is a discontinuity in the causality flow, and the best effort to cross the discontinuity is to "hint" both the objectives and the proximate metrics to the architect decision maker. It is however, through a human and chaotic process, that the architect mind will generate the decisions to be taken and their possible values.

We identified two reasons we believe are the cause for this discontinuity:

- The concept of emergence, which states that the functions a system provide result of a complex and often difficult to predict interaction between elements of the system. As a consequence, it is relatively complex but possible to go from the set of elements that compose a system and predict properties and functions of the system, it is impossible or extremely difficult to identify a mapping that, given a function to be delivered, will produce a set of architecture decisions that reproduce the function

- The second reason is that the architecture vector we devised is optimized to be easily understood by the group that is linked with the functional device. The architecture vector describes an architecture by enumerating the decisions the architect should take, thus, it looks towards the architecture with a technology oriented perspective.

  As a contrast, the objectives satisfaction vector looks to the architecture from the perspective of the stakeholders, thus not only it has a higher level perspective, by aggregating functions, but also is less technically oriented, presenting a vision of how the functions will affect stakeholders. It is going to be quite difficult to have those two visions aligned for systems as complex as the ones for which this model is used.

This second insight shed light over the disconnection inside an organization between technology groups and strategy and value oriented groups.

While the technology groups are proactive, and create ideas based on an internal seed result of the human brain ability to combine thousands of concepts and some randomness; the strategy groups are outwardly oriented, and strive to derive conclusions from information they receive from the exterior, following what should be a top down rational process.

However the main problem is that both information flows travel in opposite directions, with causality following a counterclockwise flow Figure 32 and the creative process following a clockwise flow, the same that the value creation process presents.

This causes both flows to collide in an area where technical experts propose solutions, hopefully hinted by higher level objectives, and strategists, linked to the "business-strategy" side of the organization, propose ways to measure those solutions.

This collision is not always easy to manage. The culture of technology organizations treat as "fluffy" or "soft", any objective that does not flow from a numerical proof. This logically provides an upper hand for the technical side to influence the architecture definition.

- The third insight is the explicit presentation of the strategic constraint as a "zero" step.

  In section 3. 2. 4. 6, we presented the idea that the leadership of a corporation or a government agency provides "strategic constraints" for their Value Creating Systems' architectures. However, once we faced as a first step the need to define what the VCS needs are, it became obvious that, if there is no strategic constraint, those needs are not defined.

  As a consequence, the strategic constraint reduces the uncertainty of the design process since it limits the design domain by providing a foundation on which to start the causality process we present in this section.

  We also introduced the concept of the "Context Constraint"; this constraint represents the limits of physic laws, public regulations deemed unchangeable, technology limitations inside the desired timeframe, and every other constraint derived from exterior forces. The charter of an organization, being it governmental or private, if not possible to change by the organization, also constitutes a context constraint.

  A special case of the context constraint is affordability. We have not presented a dedicated section on the cost of the architecture, but we have stated that architectures that require resources in excess of what the VCS possess are not to be considered in the evaluation. Systems Architecture theory states that Value is the ratio between benefit and cost[1]; in that sense, a reduced cost would increase value.

  As a contrast we believe that the maximization of value occurs when, the benefit is maximized without exceeding the resources available. This is our concept for affordability. We should emphasize that the word "resources" should be understood in a broad sense, as it includes also financial resources, and the possibility of accessing them. We believe that choosing to reduce the amount of benefits delivered, in order to keep some reserve is a strategy constraint, result of a leadership decision.

These two constraints, one internal, strategically based, the other external, and not possible to influence, constitute the background for the generation of possible and *potentially possible* concepts, and identification of actual and *potential* needs. The set of constraints should be constant for every architecture we aim to evaluate.

We believe that these ideas provide additional information in order to build a correct Multi-Stakeholder evaluation model.

5. Interviews

The effort to collect data for the implementation of this model, for the instance of Space Exploration included the interview of over 30 representatives of stakeholder groups. These interviews were held in Washington, DC and Boston, MA between the months of June and November 2005, and included representatives of every stakeholder group.

Table 28 presents the list of interviewees, stating to which stakeholder group they belong. Because the interviews were non attributional, we are not able to reveal the names of the interviewees.

Ord	Name	Interv Date	Stakeholder Group
1	Harmonic study		Voters-Taxpayers
2	Mr. A1	21.Jul.05	Congress
3	Mr. B1	25.Jul.05	Congress
4	Mr. C1	27.Jul.05	Congress
5	Mr. D1	27.Jul.05	Congress
6	Mr. E1	02.Aug.05	Congress
7	Mrs. F1	03.Aug.05	Congress
8	Mr. A2	13.Jul.05	Executive Branch
9	Mr. B2	15.Jul.05	Executive Branch
10	Mr. C2	05.Aug.05	Executive Branch
11	Mr. D2	15.Aug.05	Executive Branch
12	Mrs. F2	24.Aug.05	Executive Branch - Democrat
13	Mr. A3	18.Jul.05	Security - Defense
14	Mr. B3	01.Aug.05	Security - Defense
15	Mr. A4	21.Jul.05	Aerospace Corporations
16	Mr. B4	26.Jul.05	Aerospace Corporations
17	Mr. C4	08.Aug.05	Aerospace Corporations
18	Ms. A5	03.Aug.05	Entrepreneurial Space
19	Mr. B5	18.Aug.05	Entrepreneurial Space
20	Mr. A6	19.Jul.05	Scientific Community
21	Mr. B6	27.Aug.05	Scientific Community
22	Mr. A7	13.Jul.05	NASA Exploration oriented
23	Mr. B7	22.Jul.05	NASA Exploration oriented
24	Mr. C7	25.Jul.05	NASA Exploration oriented
25	Mr. D7	23.Aug.05	NASA Exploration oriented
26	Mrs. A8	27.Jul.05	NASA Legacy
27	Mr. B8	16.Aug.05	NASA Legacy
28	Mr. C8	18.Aug.05	NASA Legacy
29	Mr. A9	22.Aug.05	Media
30	Mr. B9	23.Aug.05	Media
31	Mrs. C9	11.Aug.05	Media
32	Mr. A10	21.Jul.05	Engineers-Technologists community
33	Ms. A11	11.Aug.05	Educators K-12
34	Ms. B11	11.Aug.05	Educators K-12
35	Mr. A12	20.Jul.05	International Partners
36	Mr. B12	28.Jul.05	International Partners
37	Mr. C12	25.Aug.05	International Partners
38	Mr. D12	25.Aug.05	International Partners

Table 28. List of the interviews made during the months of July and August 2005, to representatives of stakeholder groups in Washington DC. The interviews were used to validate and extend the list of stakeholders' needs previously identified.

We are not presenting all 38 interviews, but, excerpts of those that show the most salient perspectives. These insights were extremely useful to identify some additional stakeholder objectives, and to confirm the remaining ones.

5.1. Mr. A1

Representative from the Congress

21.Jul.05

It is important for a successful Space Exploration strategy to show early results; as an example, we have sent an instrument on board of an Indian satellite going to the moon.

It is also important to try to reuse as much hardware as possible to save time and money; Russians don't throw any hardware. If we were to do that, we would already have the technology to build the Saturn V.

The International Space Station shouldn't be thought as worthless; international cooperation and the end of the cold war are due to it.

International cooperation could be helpful, Russians have expertise on Nuclear technology, and Dutch have expertise on other technologies. This kind of cooperation is possible now that we are not anymore in a cold war model, and based in blocks. Comparing with the commercial world, Cisco, as an example goes to do business where the business is.

The branch of the defense closer to the exploration paradigm might be the Navy, since their perspective is traveling for long stays, surviving away from home for long periods.

Different cultures require different goals from Exploration. For example, in Europe is very important to show Astronauts in TV. Even when Russian economy has changed impressively in the last 10 years, their space program has to be able to be operated with very little investment; the Baikonur base is an amazing example on how to run a space program on barebones.

A danger for the program is trying to do too many things on just a 0.7% of the federal budget, and without business tools. NASA cannot fire and hire like Kodak or HP. This time is unlike Apollo, where things were build ad hoc, right now there is already an Agency running, and it is difficult to cut parts of it, such as the Aeronautics Directorate.

The Aeronautics Directorate has been smart about research, has not only underlined how important they are to solve NASA needs for the missions to come but also is spread across 4 different centers.

The program for Space Exploration cannot create everything new, but has to transform the Agency from inside. It is needed to bootstrap doing a little part and keep building over time.

This need of building over time, while showing results is the result of the Congress' need for validation of the project. The creation of a core and the addition of elements as needed. As a contrast, Bush Sr. (41) proposal, the Space Exploration Initiative, requested as much as 500 Billion dollars at the outset.

The goal of going to Mars can be dangerous for the project, because of sending too much of the benefit, too far away in time. It would be a better strategy at the Senate to try to focus on the moon, while keeping the door open for going to other places.

5.2. Mr. B1

Representative from the Congress – House of Representatives – (R)

25.Jul.05

NASA is not comfortable stating goals, yet they should do that, and we (the Congress) would assess them. If we see extreme discomfort from some parties, we might begin to ask questions, getting cues from the American Astronomical Society, or the National Academies of Science. These two can be very helpful on providing a healthy tension.

We are familiar with people at the different NASA centers; most likely we would call them over the phone instead of trying to deal with the office of Legislative affairs at NASA, which is a political office. (NB- by the time these comments were made, they referred to the previous leadership at Legislative Affairs. A new appointee, Mr. Brian Chase, took over the direction of the office by August 2005).

The Shuttle and the ISS are 40% of NASA budget, and that budget has been spent in doing nothing in the last 2 years. Going forward, there is a need for a new CEV, a mission to the Hubble telescope or a module to de-orbit it, 1 billion dollars additional funding for the James Webb Space Telescope.

The House of Representatives is strongly supporting the vision, yet, it needs to not affect the funding of any other program, to be, as promised, affordable and achievable. Representatives are skeptical that NASA can do everything it proposes to do in exploration without taking money from other programs; for this reason, the House has built firewalls between programs.

The Senate as a contrast seems to be not that supportive of the vision. They are asking for not retiring the Shuttle, converting the ISS into a National Research Lab in order to provide new science duties for it, besides research on human psychology in space. The Senate might be going in a different direction than the vision.

It would be ideal to have a program, within budget and schedule and with so much momentum by the next election, that it cannot be cancelled. NASA understands that they cannot afford any slip-up.

Yet, if a war starts, not only NASA would be cancelled but also other programs.

NASA gets a lot of scrutiny compared with the percentage of the budget they get. The press is fast to report on successes, but also failures. There is a close community between the reporters that cover NASA, and congressional science committees.

We would like to receive faster answers from NASA when we ask questions. Sometimes it takes 10 days for a question to be answered. In this aspect, the new administration (Griffin) is a breath of fresh air. The 16 studies (CER) were a consensus solution; NASA should be directed by a doer (like Griffin) and not going through so much reflection.

A plan that does not appear credible could damage the program. An example is the Orbital Space Plane, which did not support scrutiny, an example for today, might be a wildly optimistic proposal of flying the Shuttle 28 times. It seems that NASA is so closed on itself, that once a program starts, NASA optimizes for its own goals, and forgets the original goals of the program.

The chairman of the committee on science and technology has a very strong saying on the Space program. In order to become chairman, the member has to be admitted to the committee early in your career, and then through seniority acquire a more prominent position. The party will reward you with such a position if the member votes in the mainstream of the party

5.3. Mr. C1

Representative from the Congress – House of Representatives (R)

27.Jul.05

There are many perspectives to Human Spaceflight and Exploration. While science is the most important of NASA goals for the Chairman of the Committee, other members do not value Earth Sciences. In some level this is a partisan issue, since Al Gore was very interested in climate change, and when the Republicans came to power, things became difficult for Earth Sciences.

There are reasons for both sides (against and in favor of doing Earth Sciences); whether climate change is a fiction or there is not enough known. There are members that believe that the money spent on space should be used to learn more about this planet.

On aeronautics, many members do not know what NASA does on Aeronautics. Yet, there is a lot they could help to improve lost competitiveness, as it could be seen with the penetration of Airbus.

Something NASA could do is to be straightforward about their plans, what are the costs, what are the weaknesses, and strengths. We expect that the new Administrator (Griffin) would be as straightforward as he is said to be.

The credibility of NASA is very important, not only when dealing with the Congress and the White House, but also when dealing with contractors. NASA needs to have credibility on its mid term horizon. No one expects the plans to be perfect, but, we expect a sense of where are we going.

In practice, NASA can "re-program" its own money, and report to the Congress about those internal transfers.

The initial bill was made by the Democrats; it required many capabilities on the ISS. The Senate also had that position. We were trying not to tie NASA's hands on the ISS. The agreement was achieved by softening the language, enough so to have most groups satisfied.

The Senate is more restrictive when dealing with NASA, situation that worries the White House. Mrs. Hutchinson, a Texan, is the Chairman of the sub-committee on Science and Space at the US Senate, the Ranking Member is Mr. Bill Nelson, a Democrat from Florida. They both want to see that their centers (Johnson Space Center, and Kennedy Space Center) continue doing business as they were. This is a concern for the White House Exploration plans.

Exploration is not about security or inspiring kids; it is about exploration for exploration's sake. Every other reason is probably not as legitimate, since there might be other ways to inspire or provide security.

To avoid NASA's overreaching, they should do a decadal survey, ranking their science programs. People will try to ask for everything, but a decadal plan will allow giving priorities to requests.

We don't know how much is spent on their public affairs office. This is the only Agency with a TV station, magazines, and promotional videos. The Agency should not use Taxpayer's money to support its own agenda. There are caps on how much is possible to spend on propaganda, and laws preventing to lobby the Congress.

The interest on Space Exploration will increase if they find something interesting elsewhere or when they arrive on the moon. That would bring excitement.

The interest will decrease with another accident or a CEV failure. Another potential problem is budget deficits; were those to continue, who knows what might happen.

Space is similar to Agricultural interests. Most members do not know how funding works; yet because of patriotism (the small farmers), a small minority gets its way through. Other members do not care much to question or learn. That is way the Congress is supportive, but not willing to spend more money.

The balance has to be maintained on the type of program you can afford for the money that is available.

While Republicans are not necessarily going to lose control of the Congress, it seems that Democrats would support the space program by 2008.

A security related issue might put all the plans on hold. Another danger is not getting any benefits back to the public.

5.4. Mr. D1

Representative from the Congress (R) – Science Authorizing Committee – Space and Astronautics Subcommittee

27.Jul.05

The goals of the science house committee are to provide good stewardship of the funds of the Taxpayer. We look upon the Agencies to make sure they are doing what they are supposed to be doing.

NASA faced a difficult time after Apollo. Nixon did not want to continue with the level of expense, thus, NASA had to fight for its own survival. The Shuttle was the result of that survival fight, but, looking back it seems a mistake.

The Vision for Space Exploration is positive. It would be great to have an explicit endorsement by the House.

Now after the Vision was presented, there was a need to define what the Vision is really for. The steps on the proposal were return to flight the Shuttle, finish the assembly of the ISS, retire the Shuttle, and land on the moon by 2020. Some people want to have the retirement of the Shuttle on a fixed date on 2010.

The goal on the President's Vision is agreed, Griffin has articulated it, and the House of Representatives has approved it. Instead of a convoluted effort from NASA to try to satisfy everybody, the President said these are the goals, and through the voting of the members, we represent the people; the direction for NASA is set.

A 65% of Americans support spaceflight, the question is how much to spend. Realistically numbers are going to increase but just a few percent points. It would be wise from NASA to reduce the number of Shuttle flights to a minimum, while balancing the commitment to International Partners and workforce.

The requirements should be clarified before laying out contracts, and priorities on expenditure should be set.

Griffin has many contacts as a result of being in this business for 30 years. This is a contrast with the previous administration, which was not going in the right direction.

He is trying to bring in the American Astronomical Society to the day to day operations. He has also returned some funds to Aeronautics and Earth Sciences as compared to the previous administration policy. House Representatives were not satisfied by the previous administration excessive emphasis on Exploration. If the projections are to be believed, science expenditure grows, the ISS is off the books by 2016, and Space Exploration and the CEV get 3 billion dollars per year.

The House Representatives are not overly concerned about having a gap between the retirement of the Shuttle and the new CEV operations. A NASA that successfully executes the Vision, with a planned landing on the moon by around 2018 is a very good plan.

National pride and satisfaction might be the only tangible short term benefits of Human Spaceflight and landing people on the moon. Yet these are not the final goals but the initial steps of a space-faring nation, which is a worthwhile goal.

Earth Sciences and Aeronautics don't need too much support; it is Exploration which has to show continuous progress. We encourage them to do a moderate amount of Public Relations.

NASA can do the argument in favor for Space Exploration. It will not be seen unjustified to present the argument that it is in the human nature, and spirit to explore. The argument has to be convincing to an Iowa farmer.

It is important to retire the Shuttle by 2010, due to budget restrictions and the inherent lack of safety of the vehicle.

Were the National Academies of Science to report that science is not satisfied, we would need to see how to balance NASA's portfolio. Space science, Earth science and Aeronautics provide benefits. The former has a longer period of maturation (Kepler planetary formulation hinted Rutherford his atomic model, which allowed for the use of nuclear energy), but the last two clearly provide tangible near term benefits.

Certain members of the science committee see this as the last chance of debate for whether we should or should not have a human spaceflight program. Nevertheless, most people agree we are not to think whether humans or robots; both will be there.

Some members have interest on the status quo; there are programs in their states which represent jobs. There is a need for reasonable good arguments for a workforce transition plan, to avoid the problems that happened when Apollo closed.

NASA could use the support they have got from the President and the House or Representatives to reign on parochial interests. While leadership can be used, Griffin changed his point from supporting the EELV to using a Shuttle Derived Vehicle to win the support of some members with interest in the status quo.

For the support to increase substantially, a more tangible reason to send humans should be found. Other circumstance, like an unforeseen event could also do that.

The support would decrease in case the Congress and the White House have different priorities. It also would be hindered if it takes too much time to show some results.

Some parts of the operation of the Congress are laid on personalities. It was Tom Delay who single-handedly had the appropriation bill approved. Every program has to have an appropriation bill every year; but not necessarily an authorization bill.

5.5. Mr. B2

Representative from the Executive Branch

15.Jul.05

NASA could help the Executive Branch's Office of Management of the Budget (OMB) through making its budget more understandable by providing details such as:"

- Where is the money going?
- What is the acquisition strategy?
- What are the requirements?
- Do we need legislation?
- How does this fits with other programs?
- When is it going to be available? How much uncertainty in schedule and cost?

So far the investments are made on trust, there is a leap of faith. It is better to prepare answers to the difficult questions when dealing with the OMB than when talking to the Congress.

The Budget making process start point is a list of priorities and recent shifts in them, agreed by all the Agencies. It is very hard to make long time projections.

Budget amendments are initiated by the Agencies, and start with a discussion with the OMB, when this first hurdle has been passed; they are submitted to the

Congress. In any case amendments are "Budget neutral", the additional money required has to come from another area of the government.

We find that NASA has not been as transparent as we would like with its answers to the OMB. The new administration has improved a lot, as compared to the times when O'Keefe was administrator.

Griffin, after hearing Congress' concerns, proposed the acceleration of the CEV. In general we agree with the idea, yet it raised questions such as how is the CEV going to the moon. As with any new idea, if it is not on the President's priority agenda, then the Agency has to fight it on its own, and solve issues like the implications on the budget, or the technical constraints because of a faster schedule.

When the Executive Branch's Office for Science and Technology (OSTP) and the OMB do not agree on the proposed change, it is more difficult that it will be successful, nevertheless, both agencies are very close on their perspective on NASA.

NASA interacts mostly with the OMB, the OSTP, and the White House National Security Council.

The OMB most important priorities for NASA are

- The most important is to not fly the Shuttle after 2010
  This is driven by the Columbia accident. Any non-shuttle human vehicle will have an escape tower that will render it less dangerous

  A Shuttle derived architecture might make sense even if savings are not that large as projected. Nevertheless, it would be important to validate the claimed savings if committing to a Shuttle-Derived architecture.

- Also very important is to reduce the deficit by 50% by 2009

- A third priority is going to the moon by 2020

- And finally all the other needs, such as, final configuration of the ISS, whether it would be possible to complete it or operate it without the Shuttle

In order to change a policy stated by the President, many signatures are needed, including the President's.

The policies are not of the person who is in charge of the Presidency, but of the Presidency as an institution. Were Democrats to win the 2008 President's election, a sudden change might not happen, because of the bipartisan support of space.

For the case of the EELV decision, since the power players on space policy are based on Texas, Alabama, and Florida, and the EELV's are defense vehicles not produced in those states (Comment by editor – the EELV production is concentrated in Alabama), it might be difficult to change the status quo.

Additional goals not mentioned on the Vision are the use of a Shuttle Derived vehicle, the development of new rocket technology, and the reduction on funding on Aeronautics, since it seems there is not a clear goal on it.

Besides the Apollo program, this might be the time when Space Exploration has been given the highest priority. This priority might decrease in case something unexpected happen. The next president will not be as strong a support as this administration, but, hopefully the program will be well cemented in the next 3 years.

The OMB would not want to use its discretionary budget to finance Space Exploration. These funds are reserved for new initiatives. We do know that there is going to be problems with Social Security.

While NASA funds are supposed to keep growing with inflation that might not necessarily will happen. The new CEV might require a smaller workforce, and be less supported by Congress as a result; yet, longer moon stays would require more jobs.

The general attitude of the government is reactive, and the Vision started as a reaction to the Columbia disaster. The Vision was born from a relatively low level group of which I was member at the OMB; on the other side, there was a very high level group looking for a proposal to deal with the Columbia accident. The Government realized that Space would always be dangerous, and that it was not worth to risk Astronauts lives on missions to Low Earth Orbit (LEO). The proposition of returning to the moon and ultimately to Mars is exciting to the public. We did misread the public on the Hubble de-orbiting issue; the telescope captured the imagination of the public.

Among the issues discussed in the group was to use a CEV that is not able to dock to the ISS in order to lock-in on the project.

Other programs that can take the place of the space exploration are exploration of the oceans or the earth. In general the Federal Government is not doing programs to improve the happiness of its citizens, but to set the country as a world leader.

Were NASA to focus on the moon, the private sector could take over the access to LEO. The prospects of space tourism are also important, since a sizeable population group has large disposable incomes

The OMB is able to affect the budget on a 10% level. When the bill reaches the House of Representatives, the corrections are on the order of just 2%.

For the 05-06 Fiscal Year the OMB requested NASA the preparation of 3 scenarios for funding on 16, 16.5 and 17B. At the end the number was 17B, which is the number NASA asked for at the beginning. Since this amount was above the authorization of the President (3% increment), there was a need to go up to the Presidential level for that change. The OMB needs to refer to the OSTP for additional funding levels.

In general the Congress tries to be incrementalist, meaning the budget from this year is based on the one of the previous year, on which corrections are made. The bigger the deviation from the previous year, the more difficult it would be to approve it on the floor.

The OMB protects politician's political capital, by making recommendations on the need to modify policy. As an example, the cancellation of the Shuttle although good from the budget perspective will require the expense of some political capital.

The personal opinion of the interviewee on Space exploration is that through tax incentives and the reduction of legislation barriers the private sector should be encouraged to participate, traveling to LEO or even the moon. The Government might not be the most efficient way to expend money.

The reduction of costs due to the use of private contractors will allow launching more science mass thus increasing research. As an example the ISS should be served by entrepreneurs.

Also to reduce the cost burden, international cooperation should be used.

Finally, NASA expends less than 1% of the Federal Budget, yet, it's a three times larger than the National Science Foundation, which does more science-wise than the 5B than NASA expends in science.

5.6. Mrs. F2

Representative from the Executive Branch - Democrat

24.Aug.05

Public should be included in the list of stakeholders NASA analyzes, which is not usually done. NASA thinks of itself as serving Scientifics.

A survey made by Harmonic International [cite] presents that 85% of people think NASA is better than the average Agency [see the actual numbers]; nevertheless, the public is not aware what NASA does.

When presented with a list of functions,

- Knowledge is on top
- Inspiration is on the bottom of the list of things that NASA does
- Less than 5% think that NASA helps make airplanes safer.

Because of Federal Agencies' restrictions, it is difficult for NASA to directly survey the public.

The interviewee said the vision might not be sustainable, since it will make reductions on things that the public wants, such as earth sciences and aeronautics.

If democrats get elected to the White House, they will review the whole project. By that time (2008), it might be possibly too late to change the CEV, but not the decision of using a heavy lift vehicle. The depth of the review to be made on 2008, will depend on how much has been done on the architecture implementation.

She observes that the use of EELVs instead of an inline stick for human launches is a better option.

The process of surveying the public should continue, to understand what programs are popular, and have them deliver.

NASA should try to connect with the entrepreneurial space community, and stop antagonizing the private sector.

NASA strategy for the next years should be based on a mix of

- Fear because of an asteroid impact, and the need for preparation to deflect them
- Greed in the form of positive economic benefits, such as telecommunication and weather satellites. NASA could contribute to sustainability in this area
- Glory through the Astronauts reaching for the moon again

She mentions that other Federal Agencies have advertisements, and it might be fair to show, the impact on the economy and the return on investment on the money spent on space exploration. Federal Agencies also use advertisements to recruit people who want to do a good work.

The space race was a main component of the cold war, but it also was through space that the cold war ended.

Comparing NASA with other science promoting agencies like NIH and NSF, even though they are smaller than NASA, they have managed to triple their budget. These agencies provide roughly 90% of their funds to researchers, which in the case of NASA is less than 1%. NASA uses a large part of its budget to pay large aerospace corporations, in which people have in general some sense of mistrust, because commercial entities have to profit from contracts.

NASA perspective on marketing is to prepare press releases. Unfortunately, there has been an excess of promises, and benefits.

NASA is very difficult to work with. One of NASA's clients was able to create liver tissue on orbit; yet they have to pay over 1M USD/yr to keep flying. There are real benefits, but, people do not publicize those.

5.7. Mr. B3

Representative from Security - Defense

01.Aug.05

Commonality in terms of industrial base is an important aspect of a space program from the defense perspective. This leads to take advantage of synergies and economies of scale, the development of common technology needs, and the use of common networks for information flow.

This is not new, as an example, Cape Canaveral is run by Air Force. NASA and the Department of Defense (DoD) support each other. Nevertheless, there are also issues

- Is not always clear who is in charge
- There might appear parochial interests that affect programs.
- Neither Agency wants to depend on the other's largesse, since that affects the reliability and availability of resources. As an example, whereas NASA can use foreign launchers (Soyuz) for some payloads, the DoD is not able to do that with its payloads.

Technology development and being able to be the first ones to land in planetary bodies make important space exploration to every DoD branch. But, since Space exploration does not go into the requirements for any branch, it tends to be relegated.

While NASA, being a civil agency is not mandated to support DoD, at the same time, NASA possesses resources that are of interest to the DoD. In order to coordinate the use of those resources, there is a high level council meets 3 times a year, and there are many DoD detailees at the Constellation project (Exploration Systems hardware)

An example of how NASA and DoD interests are not always harmonized is the case of Cassini. The vehicle selected for launch was a Titan, whose costs increased steadily because of low production. The Army understood the problem, and wanted to provide NASA a fixed price, but that would mean to sell the launcher for a discounted price. The Congress did not allow the Army to do that. At the end the mission was successful, but, because of government budget is stove-piped, sometimes is difficult to collaborate.

The interviewee also mentioned a model developed on the Army, about the factors that affect success, based on external stakeholders' analysis

The model, developed by Mr. Claude Bolton, Army Secretary of Staff for Acquisitions, evaluates Internal metrics, such as clarity of requirements, or experience on execution, and external metrics such as clarity of vision, and advocacy power; producing a probability of success model.

5.8. Mr. C5

Entrepreneurial Space

25.Aug.05

The initial exploration of the North American frontier by Lewis and Clark was only half way of the result. It was through settlers, bankers, and farmers that the benefits arrived. In the same way, NASA has to open the way, but it is the private sector which will at the end provide the broader benefits. Bigelow's CEO understand that he might not see the day of getting a positive cash flow, yet, that will happen.

If capitalism works well on earth, it should also be beneficial on space. The Government should provide the infrastructure, so the entrepreneurs can invest.

Pharmaceutical companies would have an important role in funding space entrepreneurship. But, before that happens, NASA should understand that they need not harm the private sector by competing with it. NASA should behave towards space entrepreneurship as a good customer.

Aerospace is one of few areas with a cost-plus structure. The business world operates under a fixed price for a fixed service.

While the private sector might not go to Mars on itself, we are constantly pushing the envelope on technologies.

When comparing Kissler Aerospace and Space X, we see that Space X is trying to build based on a real commercial model, and Kissler is not.

Entrepreneurs value simplicity in contracting.

There is still lack of infrastructure; there is no affordable means to reach orbit. NASA should play a positive role looking to fill those voids, for example encouraging corporations to service the ISS. The ISS should start to be used, instead of a continued building effort.

The ISS was sold as providing the cure for Cancer, yet, there were very few attempts to do pharmaceutical research. Even when payloads flown, they were not a priority for the crew, and the cost was excessive.

Bigelow proposes to build a space hotel, and the first cash flow would come from tourism; nevertheless, the real revenue would come from materials and pharmaceutical research done at microgravity.

At this point, the only option to do microgravity research are the Russians, yet, the ITAR non proliferation act makes very complicated to deal with international partners. The ITAR regulation is killing North American space, because of the export restrictions. International clients avoid using North American parts because of the complication of dealing with the regulation.

Furthermore, now North America has lost some capabilities due to low order volume; there is now a need to acquire foreign components in some cases.

At the end the ITAR regulation reduces the safety of the country, since other nations have become sources for components and they don't have any kind of control.

This is the second generation of entrepreneurial space. The previous one was the one of the Single Stage To Orbit rocket, Rotary Rocket and Kissler. Those were engineers doing business, idea rich but cash poor people. This second wave has money making experience, and is well financed.

To get a good design for the CEV is important. This is something we don't want to change for 30 years.

At the end the Congress will pay NASA's bills. Shuttle was developed to keep the people from Apollo employed at the centers, and to continue sustaining the Iron Triangle (Congress, Contractors, and NASA). The entrepreneurial community will not disrupt the Triangle on the short term.

The remaining modules of the ISS should not fly. International partners' modules shouldn't fly either. At the end what space agencies care about is that technologies are developed, and salaries paid; to not fly the modules will not be fatal to other countries agencies. The ISS is understood as a political instrument at other countries.

At NASA, the workforce that is not possible to re-assign should be fired, and a BRAC (program to close Army locations) should be used to close some Centers.

NASA suffers from changing policies every 4 years. That is an important reason to move quickly, and develop a system in years instead of decades.

5.9. Mr. B7

Representative from NASA Exploration oriented

22.Jul.05

The initial state of the system needs to be taken into account when designing, it is never the case of starting with a blank sheet of paper. As an example the decision to use a Shuttle Derived vehicle is also supported by the existing industrial base, even as we know the Shuttle is not as reliable as we hoped it would be.

It is not only needed to answer the right answers, but, most times people are not asking the right questions.

In the case of the Shuttle design, NASA was fixated on a reusable concept, even when it was clearly more expensive. The idea was that over many flights the fixed costs would be diluted. At the same time, the need for many flights required to compromise with many clients, which added complexity to the vehicle, increasing the costs even more.

The Shuttle had to comply with military specifications, because of the interest to serve the US Air Force. At the same time, the US Air Force could not trust all their payloads to an only vehicle for a reliability question, which became apparent after the Challenger accident. This event triggered the development of the EELV family.

At the same time that the Shuttle was burdened with extra costs because of having to accommodate many different clients, the development of the EELV family eroded its customer base, and reduced the number of missions that would be required from the Shuttle. Both effects combined rendered extremely expensive to flight the Shuttle.

NASA is a discretionary tool of the President. in the case of the Shuttle it was used by Nixon to win the elections in California at that time. In the end, the Shuttle solved a political requirement and not a technical one, actually.

The ISS motivations have gone through several iterations. In the 80s it was about keeping NASA centers working, in the 90s it was used to end the cold war. Clinton used it as a way to funnel money to Russian scientists.

Different groups value different things from Space exploration. For example the while the public values pictures from the Hubble or landing on mars, the Congress values employment.

Johnson used the Space program as a tool to industrialize the South, which was still suffering the effects of the civil war, after almost a century.

The most important issues at NASA are

- What does the new NASA structure should look like?
- What is the balance between the work centers and technology and research centers?
- How to manage the tradeoff between mission efficiency and political sustainability?
- How to make sure the organization is working as one?

The different NASA centers use to be independent. While they respond to the Administrator, they are routinely visited by their Congress representatives who gather feedback on the conditions.

The independence of the centers is not too different of a feudal organization, with courts and Barons. The priorities of the Centers might be different to what is prioritized on the global strategy by Headquarters. It is then of importance to exercise leadership through power and money (fear and greed) to align the organization around the global strategy goals. There are specifically strong tensions between Johnson Space Center and Headquarters.

In order to do meaningful research, it is more important to have stable funding than to have more funding. Ames Research Center managed to diversify its portfolio for this reason; now they research on Biology, Nanotechnology, Materials, and not only Aeronautics as before.

The average age of the NASA employee is increasing, because of the freeze in hiring of the 90s, and the lack of money to replace the experienced workforce.

The funding of science is an area of the Government where technology and policy intersect. A Principal Investigators could be very selfish about its own programs, and look for a local optimum, even at the sacrifice of the whole; this makes important to set priorities in science.

The Congress is driven by popularity. NASA is seen at the Congress as a portfolio of programs. Some Senators do not care much about the Agency, yet, people from states where there are no Centers might commute to a Center to work. In general the Congress prefers sustainable programs, which provide constant jobs, since the project of going to the moon and Mars might get cancelled.

We are not anymore on the 60s where the Astronauts were a symbol for the United States. It is not a central theme for Presidential elections, yet the emotional aspects are important. Religion on space still is a controversial theme.

Space is a low touch technology (as compared with computers, which many people is able to interact with).

There is a necessity to define the paradigm we have for Space. Whether we are

- Saganites and care about science
- Von Braunians and care about footsteps and emotion
- O Neill interested in space colonies and commercial utilization. This group is supported by the Libertarians, whom see space exploration as the continuation of the North American frontier image.

The correct way to frame the tension between capabilities and requirements is to focus on the capabilities needed to deliver objectives, which could be technical, political, commercial, educational or scientific

The CAIB concluded that the Shuttle work on LEO was not worth the risk of lives. There is more glory on landing an unmanned probe in Mars than into improving a Shuttle turbopump

5.10. Interview Mr. C8

Representative from NASA Legacy

Aug 18, 2005

NASA is a very large organization where inertia is a major problem.

There were two paths that Civil Space could have followed in North America

- Entrepreneurial, started in the 30s and 40s in Pasadena by Theodore von Kármán and Frank Molina, which was embraced by Caltech and resulted on the Jet Propulsion Laboratory
- Government directed, headed by Wernher Von Braun, with a strong central command, influenced by the researchers previous experience in Europe

It is known that Von Braun won this dilemma, not only because of his engineering skills, but also thanks to his self-promotional genius. Von Braun set up the Architecture of what became the North American Civil Space program, highly regulated by the state, and centered on the Astronauts as protagonists-heroes. Dr. Von Braun might be described by as the prototypical Amoral Technology Utopian, willing to sacrifice people for the greater good.

Another legacy of the culture implemented by Von Braun could be described through the metaphor of the “Self-Licking Ice Cream” (sic). NASA customers, stakeholders, and political decision makers have to deal with an organization that on the surface might seem to care about them, but in reality is aligned only with its own goal of survival.

The lack of accountability results on positions being covered by individuals that might not be able to perform the required duties presenting a clear example of the Peter Principle of Incompetence

The reality is that the Agency is boring, studying climate change, air traffic, and some space science. The emotion on Human Spaceflight is not there anymore. Very smart people decide on architectures that make sense but have no emotional component. For example the ESAS study looks very much alike going back to the future, just another instantiation of Apollo.

The Shuttle might not be able to flight 19 times as needed to complete the ISS, but, it would be needed to emphasize the launch of the International Partners modules, to honor our commitments. My personal preference would be to finish as soon as possible the ISS assembly, even if that means to not attach additional trusses.

Griffin might be following the advice of interested parties on Human Spaceflight. It is not only NASA employees' careers, but also contractors which have a vested interest in preserving the status quo.

There is a self-sustaining iron triangle, where NASA's high management provides contracts to Aerospace Corporation, who promote Congressmen re-elections, who in turn provide money to NASA's high management programs. This feedback loop is self sustaining, and keeps programs alive and reinforces the status quo.

[Note by the thesis author: the central proposal of this research is the study of a loop very similar to the one described. Whereas the interviewee identifies only 3 actors, our proposal includes many others that also have an important role defining the success or failure for an Space Architecture]

NASA's administrator needs to find additional funds to implement the Vision for Space Exploration; at least 85% of the funds are going to be spent on outside contractors. It is then difficult to save money by NASA internal cost cutting. Some estimate the deficit between 4.5 and 7 Billion dollars.

In order to improve the contracting efficiency, NASA should acquire expertise defining requirements. A large percentage of the decision makers at the Agency do not have expertise building hardware, something that Griffin does. Project managers do their presentations at NASA Headquarters in Washington, where people without expertise in hardware take decisions that are not optimal. As a contrast, Robert Seamans used to meet managers at their offices in the Centers, offices that were no more than 100m away from the hardware.

Bigelow Aerospace offices sit on top of the hardware they build.

NASA has become much insulated, with Program Managers working from their offices in Washington. The contractors are now the arms and legs of the agency, and the source for innovation; while at the same time, they are not given latitude to innovate.

The future for space lays on the commercial and entrepreneurial organizations. NASA has problems to attract talent; the process is very much driven by seniority, and politics. Norm Augustine understood politics is what drives the Agency.

If scientist get along and present a consensus vision, they are successful getting their point across. Astronomers are very good on this, through their decadal plan; as a contrast, earth scientists are not. At the end, Congress seeks validation from the National Academies of Science.

The North American people are only woken up by Pearl-Harbor like events, like the Sputnik or the World Trade Center disaster. Once an event of this kind happens, we focus the nation on the issue. While another space accident with loss of life will hinder Space Exploration for many years, an asteroid on the path of Earth might have a positive effect.

China acts in a different way, they have a cultural decision making process, investing over the long term. The North American leadership has not been very welcoming to the Chinese space program.

NASA spends a large budget reaching people; yet better than use marketing is to do things that actually are interesting. That is what Elon Musk, Howard Hughes, and Robert Bigelow are doing. The ISS and the Shuttle are out of reach of the common man.

The association of interest in represented by the Iron Triangle will isolate and attack anyone that is against the preservation of the Status Quo.

The future lies on the entrepreneurial space. People and companies on the area to observe over the next years are

- Burt Rutan who is an excellent designer,
- Eric Andersen who is focusing on space adventures,
- Elon Musk who is producing a non man-rated vehicle,
- Jeff Bezos who is aiming towards the microsatelite market
- Gary Hudson the leader of T/Space is a very persistent Aerospace entrepreneur
- Charles Miller has a great business model
- The interviewee has faith on Bigelow Aerospace, which is fully funded by Robert Bigelow.
- Kistler operates under a different model, hiring people from Boeing, expending large amounts of money, and financing the company through syndication.

6. Surveys

6.1. Literature review

Our survey preparation work showed us the daunting effort behind a research that involves relying on third parties good will to acquire vital information.

While doing literature review on the topic, we were expecting to find a compelling argument for keeping our web based questionnaire within a certain number of questions; yet the studies on this aspect are not abundant.

While some studies on mail questionnaires found that there is a no correlation on the length of the study with the response rate[28] [29]; others found a weaker correlation on the length, and stronger on the title of the survey[30]

We found out that the longer time a surveyee is going to spend answering questions, without the provision of an incentive is between 5 to 10 minutes[31], reason that prompted us to keep the survey short, and limit to no more than 36 questions for the Kano questionnaire.

Another source of support for this decision was the study done on the book "Research Methodologies in Supply Chain Management"[32], where a web-based survey abandonment rate was measure along the number of screens presented. From 4830 invitations sent both electronically and by post, 23% or 1112 individuals actually reached the site, and finally only 506 (11%) provided timely and complete answers. The individuals were promised to participate in a lottery for a 5000 Euros price.

From the 1112 subjects who reached the site, a 24% or 272 abandoned the survey in the introductory page. The researchers also observed a nearly constant abandonment rate over the main 15 screens of 1.2% per screen, which totaled 212 subjects.

As a result, we could expect for every 100 invitations, to receive 23 answers, of which, 11 will be sent on a timely and complete manner, for a 15 screens long survey.

An interesting guideline is that "Sentences should not exceed 20 words, and should be presented with no more than 75 characters per line. If elderly respondents are anticipated, then this limit should be reduced to between 50 and 65 characters per line. Paragraphs should not exceed 5 sentences in length"[33]

We also incorporated the recommendations of the Massachusetts Institute of Technology Committee on the Use of Humans as Experimental Subjects (COUHES), including the need to inform surveyees of the fact that

- Their participation is voluntary
- They may decline to answer any or all questions
- They may decline further participation, at any time, without adverse consequences
- Their confidentiality and/or anonymity are assured

(Text taken from[34])

The MIT-COUHES requires this information to be disclosed both in the invitation to participate and in the instructions to answer, inside questionnaire.

Besides, as recommended by the COUHES, we are not using any coercion to participate in our research, the data will be collected through a Web-based application that preserves anonymity, and the access to the data will be kept restricted in order to keep it safe.

6.2. Introductory e-mail message from the researcher

The letter that follows is sent to the surveyees via email. It incorporates the main guidelines suggested on chapter 16 of the book "Educational and Social Science Research"[35]

Cambridge, February 27, 2006

Dear Mr. X,

We would like to count with your help.

We are conducting a survey to understand which goals will enable a broad based support for the Space Exploration project. The results of this survey will be presented to NASA, in order to help them make trades across technical designs.

Your opinion as representative of the YY community is very important, because it will allow us to map accurately the Space Exploration related goals of the YY community.

This survey is voluntary, and your answer will be kept confidential, as it will be used only in combination with others from the YY community. You might decline answering any question and at any point you might discontinue participation on the survey without any consequence.

We have estimated the survey should not take more than GG minutes, it can be taken by following this link:

http://www.zoomerang.com/survey.zgi?p=WEB224K4US96UJ

We would need your contribution no later than Friday, March, 4th, 2006.

If additionally, you could forward this letter to colleagues of yours, who could spare some minutes to help us; that would be extremely appreciated. It will not be possible to answer twice in the same computer though.

If you are interested in the results of this research, please send us a blank email to the address spacearch_survey@mit.edu. We should have them ready before May 2006.

Thank you very much for your contribution.

Sandro Catanzaro

Research Assistant

Space Architecture Group - Department of Aeronautics and Astronautics

Sloan School of Management

MIT

6.3. Questionnaire Introduction Text

The following text is shown to the surveyees in the first page of the questionnaire, once they follow the link mentioned on the letter of 6.2

YY community Survey

We would like your help to better understand the benefits of space exploration. We ask that you answer this survey as a representative of the *YY community*, including ZZ. The results will be used to make recommendations for the Space Exploration program at NASA.

We want you to think of the Space Exploration Activities as the set of products, processes and organizations that implement the exploration of the Solar System, Moon, Mars and beyond, according to the 2004 White House Vision for Space Exploration.

This survey is voluntary, and your answer will be kept confidential, as it will be used only in combination with others from the YY community. You might decline answering any question and at any point you might discontinue participation on the survey without any consequence.

Part A of the survey asks three questions about each potential objective of Space Exploration Activities.

The first question asks how the space exploration community would react to the presence of a particular objective; the second how it would react to the absence of the objective. The third question asks about the relative importance of the objective.

Part B has 2 questions, related to understanding the strength of the influence exercised by the community you represent

Thank you very much for your help.

Sandro Catanzaro

Department of Aeronautics and Astronautics

Sloan School of Management

MIT

6.4. Thanks and Survey Closed

This text is shown to the surveyee after the survey they finish the survey

Thank you very much!

We would like to thank you very much for providing data for our research. Your input is very important to us.

For any further information, please contact us by e-mail

sandro.catanzaro@sloan.mit.edu

The text that follows is shown to potential surveyees, while the survey is not open

The YY community survey is closed at this moment

Thank you for your interest. At this moment this survey is closed. For any further information, please contact us by e-mail sandro.catanzaro@sloan.mit.edu

6.5. Questionnaire – Part A

This first part of the questionnaire aims to identify the stakeholder particularities, in order to avoid over-representation.

We will ask only the question pertaining to the specific stakeholder group. That is, if the questionnaire is sent to a surveyee affiliated with the US Congress, he/she will only receive the questions on Political and House affiliation. We will balance any over-representation of surveyees, normalizing the votes, according to the actual political participation in this case.

1.1 **Explorers**

What category is closer to your activities?

A Operator of Exploration systems
B Designer of Hardware or Software for Exploration systems
C Strategic Planner and Manager
D Other

2.1 **US Congress**

What party do you identify yourself with

A Democrat
B Republican
C Other
D Prefer not to Answer

2.2 **What House of the Congress are you affiliated with**

A Senate
B House of Representatives

3.1 **Executive Branch**

What party do you identify yourself with

A Democrat
B Republican
C Other
D Prefer not to Answer

4.1 **International Partners**

To what continent your country belongs

A Asia
B Europe
C America

5.1 **Security**

With what branch of the defense forces are you linked

A Air Force
B Army
C Marines

D Navy
E Security related – not linked to any branch
F Prefer to not answer

6.1 **Economic**

With which of the following groups do you identify your community
A Large and medium aerospace corporation
B Entrepreneurial Space
C Future Space resource extraction
D Telecommunications and imaging private services

7.1 **Science**

With which science field is your research more closely related
A Earth Sciences
B Astronomy
C Planetary Geology
D Biology

8.1 **Technologists community**

With which technology field is your work more closely related
A Space related engineering
B Non space related engineering
C Biological sciences
D Information technology

9.1 **NASA legacy**

With what center do you consider your cohort affiliated
A NASA Headquarters
B Ames Research Center
C Dryden Flight Research Center
D Glenn Research Center
E Goddard Space Flight Center
F Jet Propulsion Laboratory
G Johnson Space Center
H Kennedy Space Center
I Langley Research Center
K Marshall Space Flight Center
L Stennis Space Center Marshall Space Center

9.2 **With what directorate do you consider yourself affiliated**

A Exploration Systems
B Space Operations
C Science
D Aeronautics

10.1 **Media**

To which media category do you consider your work related
A Space related media
B General public media

11.1 Education

To which education segment is your activity linked

A K-12 public
B K-12 private
C College - undergraduate
D Graduate

12.1 Voters

What is the highest grade in school you completed

A Elementary
B High School
C Some undergraduate
D Bachelors
E Graduate

12.2 Do you consider yourself interested in Space Exploration

A Yes
B No

6.6. Questionnaire – Part B

This first part of the survey will be based on a Kano Quality survey as described in section 0. We will present the surveyee with between 6 and 12 groups of 3 questions, out of the list of 23 groups that could be found on Appendix 8.2 This limitation is the result of the comments on length for a free interview made on 6.1

Table 29 indicates which stakeholder will be asked which question. The squares indicate the how strong we believe is the link between the stakeholder and the objective. Stakeholders with a weak link will have a white square in the corresponding objective, and thus, will not be asked about that specific objective. A strong link is indicated with a letter H, and a medium strength link with a letter M. This results are an assessment done by the researchers at the MIT-Draper Concept Evaluation and Refinement Research group[20].

Sv Q	JT	Who to ask what?	Explorers	Congress	Execut	Intl part	Security	Economic	Science	Tech comm	NASA legacy	Media	Education	Voters
1	1.1	Develop strategic long term planning for the Space Exploration System	H	H	H	H	M		H	H	H	M	M	H
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	H	H	H	H	M		M	H	H	M	M	H
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)		H	H									
4	2.2	Increase positive perception about NASA (political capital)	H							M	H			
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	H			M		M	M	H	H	M	H	
6	2.4	Motivate-recognize technical workforce	M			H			H	H	H			
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues		H	H		M							H
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration				H								
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	H					H	H	H	H		H	
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	H	M			M		M		H			
11	3.3	Align NASA funding priorities towards space exploration	H	M	H		M		H	H	H		H	
12	4.1	Create interesting and inspiring content for educational use		M	M				H	H		M	H	H
13	4.2	Create entertaining and inspiring content for media						M				H	M	H
14	5.1	Provide easily and quickly accesible data for use on science knowledge				M		M	H	M		M	M	
15	6.11	Create security related dual use technologies			M		H							
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)		M	M		H							
17	6.13	Provide space presence and freedom of action		M	M		H							
18	6.14	Provide space acquired earth relevant security data			H		H							
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	H				M	H	M	H	H			
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	M	M	M		M	H			H	H	H	H
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	H									M		M
22	6.5	Develop space infrastucture development and operational knowledge	H				M	M		H	H			
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)		M	M			H	M	H				H
		High priority	10	4	6	4	4	4	6	10	11	2	5	7
		Medium	2	7	6	2	8	4	5	2	0	6	4	1
		Total	**12**	**11**	**12**	**6**	**12**	**8**	**11**	**12**	**11**	**8**	**9**	**8**

Table 29. Questions to ask per stakeholder group. The table was built through the assessment of researchers at the MIT-Draper Concept Evaluation and Refinement Research group, who were surveyed on the strenght of the link between each stakeholder group and objective.

We are using the same numbering as in the survey questions Appendix 8.2 and the objective's tree in Figure 33.

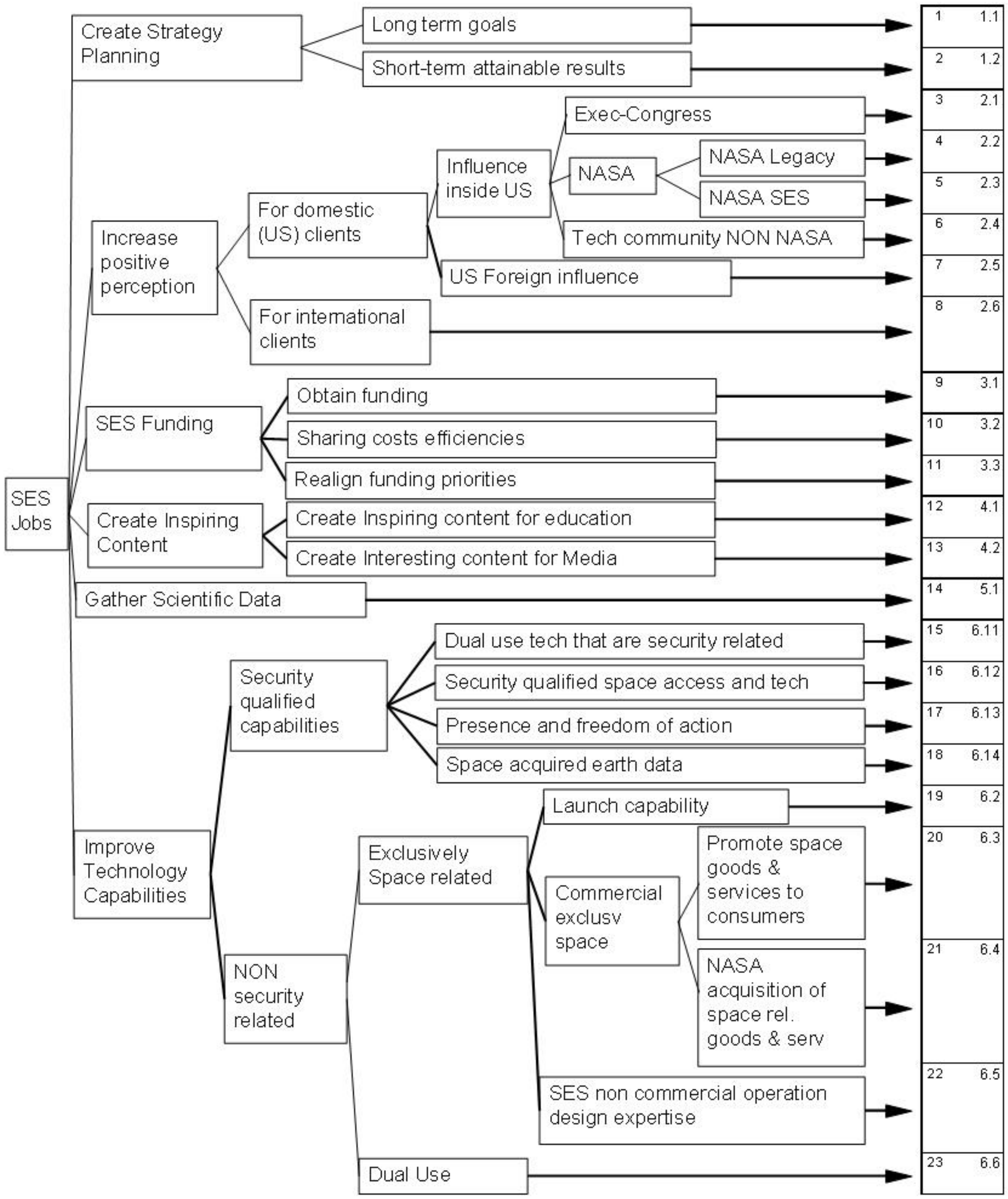

Figure 33. The Figure shows the construction of an objective tree that ensures the objectives are not overlapping.

The number of words in each question is somehow above the guidelines of 20 words[35]; 84% of the questions will be

- below 23 words for the functional question (first question in each group of three)
- below 14 words for the dysfunctional question (second question)
- below 26 words for the importance question (third question)

We believe this will not be an issue, since the group of three questions refer to the same concept, then the effort of the surveyee will be most intense for the first question, where we are approximately inside the suggested limit.

6.7. Part C

Questions on interactions

After the questions of the Kano Survey are answered, the surveyee will be shown the two questions that follows, which are our intent to measure the strength of the influence of the specific community, and the interactions of this community with others

Q1

This last page of the survey tries to identify how strong is the influence of the community you represent over the Space Exploration enterprise.

Our measure of influence will be the changes to the Space Exploration budget, that

- Happened in the last 20 years (1985-2006); please use a recent history perspective

- Were caused mainly by the community you represent. If it were a coalition, please state the percentage that could be attributed to your community.

- Included Space Exploration related missions such as human and robotic missions such as ISS assembly and use, Hubble launch and servicing, Mars robotic missions, Cassini-Huygens mission, future return of humans to the Moon and Mars human exploration.

Low: 0% to 2%

Medium: 2% to 5%

Medium High: 5% to 10%

High: 10% to 20%

Very High: 20% to 40%

Extremely High: Above 40%

Q2

Please distribute 100 points proportionately to the time spent by the community you represent, interacting with the community in the list.

Do not worry about making the sum exactly 100, we will compensate for discrepancies.

- Public-Taxpayers-Voters
- US Executive Branch
- US Congress
- NASA as it was previously to the Vision for Space Exploration
- NASA dedicated to exploration
- Science Community
- Security and Defense Community
- Commercial and Industrial interests
- International Partners
- Media and content creators
- Educators

7. Model Application and Conclusions

7.1. Model results

We are going to analyze two decisions of the four presented in the architecture vector introduced in section 4. 5. 1.; using two alternative valuation methods. We will use the Launcher size decision to show how the criterion of feedback value vs. consensus among stakeholders works, as presented in section 3. 9. 1, and we will use the decision of the first moon landing date to show how the criterion based on short term and long term value works, as presented in section 3. 9. 3.

7. 1. 1. Feedback Value vs Consensus using the Launcher Decision as an example

Traditional analysis to select the optimal launcher size is done by looking into the benefits of one position or another[36] from the perspective of different groups. But, as in any problem with multiple stakeholders, the priority would depend on which stakeholders are deemed more important, a step where the analysis becomes subjective.

Our methodology presents a criterion to prioritize across stakeholders from the perspective of sustainability, by looking into the stakeholders' ability to provide resources needed for the survival of the Value Creating System. While this prioritization methodology would increase the amount of resources the VCS receives, it might also increase its exposure to risk, by maximizing the fraction of resources received from a few powerful groups.

For that reason we think it is important to compare this feedback value with the ability of the architecture to be supported by a wide coalition. To measure the broadness of this support we use the measure of consensus among stakeholders.

The diagram we present in Figure 34 presents the trade between those two factors for one of the architect's decisions.

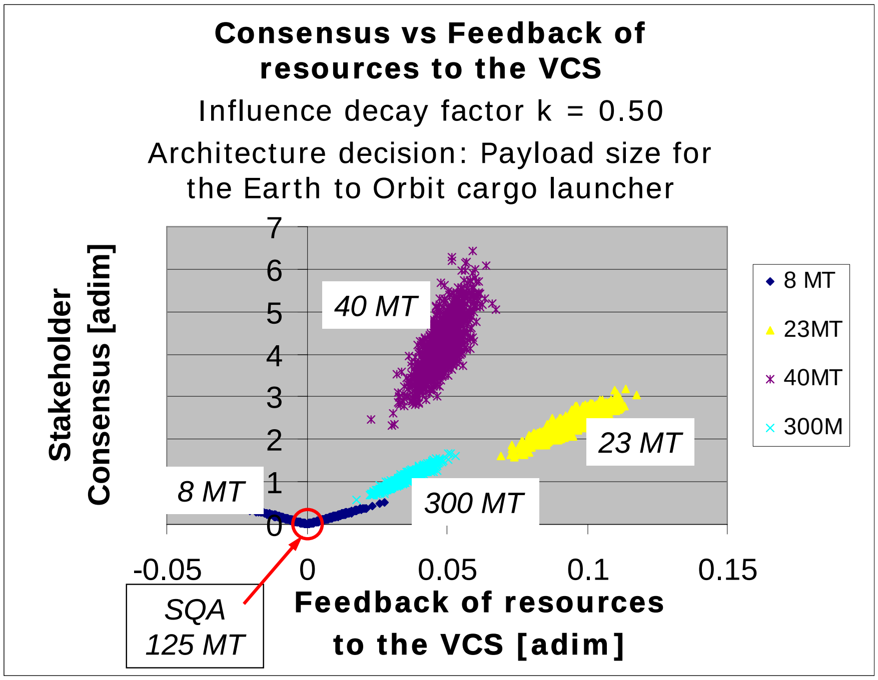

Figure 34. The diagram compares feedback of resources and stakeholder satisfaction consensus generated by different architecture options. The architecture options compared in this diagram are related to the cargo launcher size. The decay factor of the interactions between stakeholders is 0.50 for this case, consequently long term effects are damped, and short term benefits are underscored.

As previously explained we propose to separate a continuous variable, as this one, in brackets. For this case, the brackets are centered in 8MT, 23MT, 40MT, 125MT and 300MT.

We also stated that one of the architectures is thought to be the Status Quo position (Status Quo Architecture, SQA), with which every other alternative is compared. It is then that the value feedback positive axis implies an *increase* in the amount of feedback received, and the negative side a *decrease*, when compared with the SQA. The SQA architecture is situated with a value 0 in the origin of the diagram.

In the diagram of Figure 34 the SQA is 125MT; as a consequence, every point for the 125MT architecture is *exactly* at the origin. The points on the diagram for every other architecture are how much would *change* the Value feedback or the Stakeholder Consensus, if that architecture is chosen *instead of* the SQA.

On the vertical axis we show the agreement between stakeholders on the architecture value, measured as the inverse of the dispersion of their satisfaction. When stakeholders exhibit a similar satisfaction level for a given architecture, the satisfaction dispersion is lower, rendering its inverse, and thus consensus higher.

This analysis is performed for every interesting tip of the architecture tree. It will save some time to identify points where the analysis could be *ceteris paribus*; meaning that every other thing remains equal, or no other variable is changed except the ones that must be changed to modify the value of the analyzed architecture decision.

As we predicted in section 3.10, the different options present a negative slope efficient frontier, with an option such as 40MT launcher with higher consensus, and an option like 23MT with higher feedback of resources. The options 8MT, 125MT and 300MT seem dominated by these two.

We also argued that different influence decay factors would affect the distribution of value. The diagram of Figure 35presents the same launcher size decision but, with a slower decay factor (a closer to one value). This influence decay factor provides a slower damping of the value exchange between stakeholders; thus provides a longer term perspective of what the architecture means.

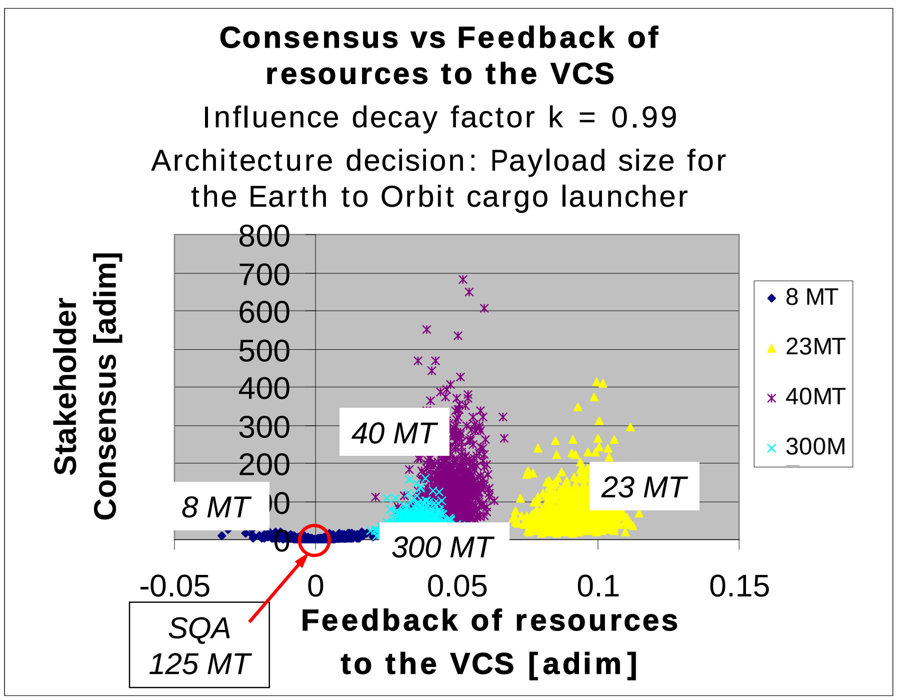

Figure 35. The diagram compares feedback of resources and stakeholder satisfaction consensus generated by different architecture options. The architecture options compared in this diagram are related to the cargo launcher size. The decay factor of the interactions between stakeholders is 0.99 for analysis, consequently long term effects are underscored, and short term benefits damped. .

As we see in the diagram, the 23MT architecture still provides a higher value, but, the consensus of both has increased. This higher consensus is caused by a homogenization effect result of an *increased* "egalitarism".

This egalitarism is the result of a high influence decay factor, resulting on a slow decay of the influence between stakeholders, which means that the benefit delivered to one stakeholder is transferred without losing strength to every other stakeholder that interacts with it. The egalitarism is equivalent to a low friction value transference between stakeholders, utopic and desirable, but not the rule of today's interactions. By modifying the influence decay factor it is possible oscillate between a perspective closer to egalitarism and another oriented towards self benefit.

The efficient frontier, that has a negative slope as described, makes clear a decision central to any project. Whether it is possible to exercise leadership and impose less popular decisions, with the hope that, over the long term these decisions will generate enough feedback of value, allowing for an increase benefits across all the beneficiaries. Architectures with less popularity alienate some groups; those groups reduce the architecture's consensus level; simultaneously these architectures use the resources saved in order to increase the satisfaction of powerful stakeholders.

A central point of our work is to make evident that the decision maker, based on the amount of resources' reserve possessed, will decide whether the VCS could afford the risk of alienating groups or not. This decision would be taken by weighing whether the VCS can survive the case of losing support of some of the fewer powerful members of their supporting coalition, through the use of the reserve of resources possessed.

To alienate supporting groups increases the risk for two reasons; on the one hand, because the alienated groups will seek actively to change the decision, and on the other because the number of members of the supporting coalition will be reduced, thus the defection of one of them produces a stronger effect. Furthermore, this smaller supporting coalition wins power inside the VCS, since the VCS needs to follow more closely their desires to avoid losing any of them.

The power of a VCS is represented by the amount of reserves it possesses; vast resource reserves provide freedom to implement even the least popular decisions, hoping for a long term benefit, even in case of defecting parties.

On the contrary, a weaker VCS, characterized by a low amount of freely disposable resources, will need to implement highly consensual strategies, whose value is smaller, but their stability higher. Whereas the benefits of a consensual decision are lower, the multiplicity of supporting parties allows for the eventual loss of support of a particular group without endangering the whole system. This trade is shown Figure 36.

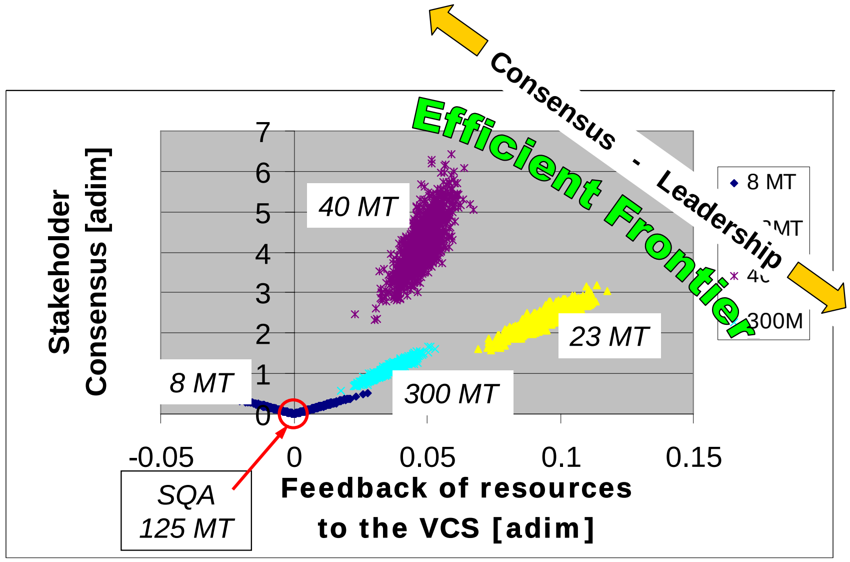

Figure 36. The diagram compares feedback of resources and stakeholder satisfaction consensus generated by different architecture options. In this diagram is shown the trade between Leadership oriented options, which alienate some stakeholders, but provide a higher feedback of resources to the VCS, and Consensus oriented options that provide a similar degree of satisfaction to every stakeholder, at the expense of sacrificing some future feedback of resources to the VCS.

7. 1. 2. Short term benefits vs Long term benefits using the moon landing date as an example

We have presented a criterion for choosing among architectures based on feedback of value. An interesting perspective is that the long term benefit is what really matters when analyzing architectures; yet, there might be need for short term benefits to support the system in the short term.

Following that criterion, we would choose a short term oriented strategy when the VCS is weaker, or when it is not certain the VCS would be able to survive long enough to deliver those long term benefits.

To illustrate this criterion, we will use the example of the date of the first landing on the moon.

As we see in Figure 37, different values of the influence decay factor change the amount of value received back by the VCS. The diagram presents on one axis the amount of long term resources feedback to the VCS and on the other the amount of short term resources feedback. While the diagram of Figure 34 and Figure 35 compare resources feedback to the VCS on the horizontal axis vs consensus on the vertical axis, in this case, both axis present resources feedback, but using two different influence decay factors.

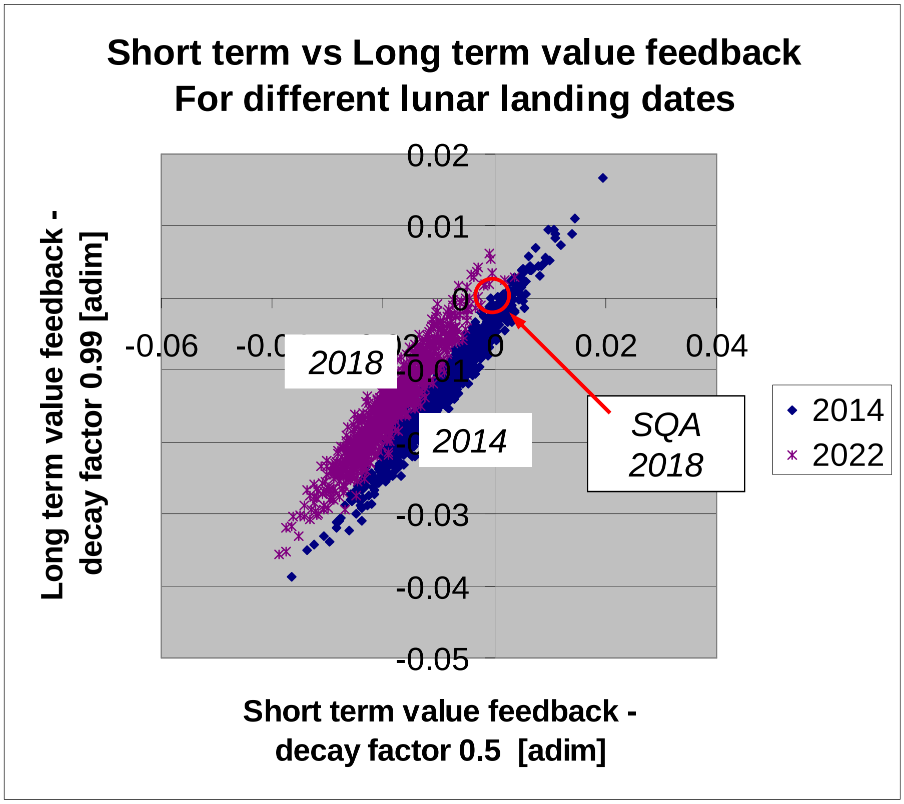

Figure 37. Diagram showing different feedbacks of value to the VCS, when the system is subject to different decay factors.

The horizontal axis shows the amount of resources feedback to the VCS when we use a small influence decay factor (meaning a short term perspective, or a fast decay of the influence between stakeholders); the vertical axis presents the same magnitude but, when the influence decay factor is larger, (meaning a long term perspective or slow decay of the influence between stakeholders).

The data we used on our analysis would suggest that an earlier landing on the moon would have a higher value when short term benefits are emphasized; on the contrary, a later landing date provides higher benefits over the long term. It is to remember that *the data used is conceptual*, and not acquired from stakeholder surveys; we are using it to illustrate the example, not to extract conclusions - *This research does not proposes that a later landing has long term benefits.*

It is interesting to note that short term benefits are not only short in time, but also in “indirectness”. The closer the stakeholder is to the VCS (fewer indirect steps to reach the stakeholder), the smaller the damping the benefits it receives will suffer.

Two other aspects are of interest in this diagram:

A better assessment of the relationships between stakeholders is needed to clarify the decision because under the criterion shown in this section, there is no clear separation between the two decisions we are analyzing.

The analysis of the relationships between stakeholders, presented through matrix H, could be strengthened by looking into the paths through which value would flow, and how strong these paths are. Besides, the data we have used has not been acquired directly from the sources; a wider data acquisition should provide more granularity.

A further refinement of the stakeholder matrix H is possible, by separating the layers through which value flows between stakeholders. These layers of informational, political, economic, and security benefits might present different influence decay factors, and allow for a finer tuning of the model.

Finally, it is possible that, after our efforts trying to acquire more data, and refining the model, there is still no clear separation between architectures. That would signal that stakeholders are not able to distinguish one from the other, leaving freedom to technical decision criteria to take place.

The second aspect of interest is that we see that both architectures seem dominated by the SQA, which is to land on the moon on 2018. Because we compare the other architectures with the SQA, the SQA answer is presented in the diagram as the point (0,0), *exactly*. For the case of this decision, it seems that the best course of action is to keep the present status quo situation and aim towards landing on 2018.

A separate issue is how different architects, when deciding, might bias the analysis based on their own internal decay factors. This would lead to different decisions.

On the one hand, political driven processes tend to be short term driven. The longest time the executive leadership manages the value creating process is 8 years, and elections happen every 2-3 years. This drives a dynamic aiming towards short term results.

The political process decision maker uses lower influence decay factors, prompting for a fast decay of value while it propagates.

On the other hand, our analysis centered on NASA, and space exploration, derives tangible value in a much longer timeframe, measured in decades, a situation that causes a disconnect with the political process, whose incentives are short termed.

This disconnect is more evident when we in academia analyze these decisions. We usually look beyond the short term, and operate with a high influence decay factor (closer to one), discounting future benefits by a small amount. The decisions we take are rooted in overall long term benefit, yet we might lose vision of short term need for survival before the long term benefit is delivered. Furthermore, we might not discount enough the fact that the potential long term value would be delivered to a different group of people, due to a generational change.

The disconnect of the timeframes between the incentives to the suppliers of funds and the benefits that space efforts bring has been a major revelation for us. This disconnect causes the characteristic volatility of civilian space, which results in lack of tangible benefits, for civilian space invests a disproportionate amount of time and resources towards keeping a steady funding source (in other words, reducing the uncertainty in the supply of resources).

In doing so, civilian space leadership acts with a small influence decay factor (high discount rate) and emphasizes actions that deliver short term benefits, over the overall long term interest of stakeholders.

7.2. Implication chain

An initial promise of our research was to show not only results, but also what causes those results to happen. A danger of highly quantitative models is to be seen with mistrust, not allowing the decision maker and the organization at large to know what really drives the answer.

A model that tries to link factors as diverse as this one is especially prone to skepticism; we attempt the non trivial goal of solving the equation of global value exchange. Without a clear explanation of what is the basis for our insights, this model will not have credibility

We will show the implication chain for the first diagram (consensus vs value feedback). It is possible to apply the same reasoning for the other criteria.

In order to do this analysis, we have highlighted in green the cells of each matrix in the top 10% percentile and in yellow the top 30% percentile. (These will show as dark grey and light gray on a black and white printout). We realize the printouts are quite small, and most likely not readable; the intent of showing them is illustrative, showing how the information was extracted.

Since, as we shown, the causality flows backwards, we will start by analyzing what are the most pressing needs for the VCS we analyze, that is the Space Exploration System. That information is shown on Matrix K, presented in Table 27, and copied here below Table 30. The cells of the matrix that are shaded have the higher values, and thus the stronger link between factors.

Sv Q	JD	Objective	$[K]_{1x23}$ *transposed*
1	1.1	strategic long term planning	0.097
2	1.2	short-term attainable results	0.068
3	2.1	domestic positive perception about the Congress and Executive Branch	0.006
4	2.2	Increase positive perception about NASA	0.076
5	2.3	understanding of the Space Exploration to non-technical groups	0.055
6	2.4	Motivate-recognize technical workforce	0.055
7	2.5	Increase US foreign policy influence	0.006
8	2.6	Increase foreign citizens posive perception about their governments	0.006
9	3.1	Promote funding for the Space Exploration System	0.098
10	3.2	Promote funding sharing of investments	0.058
11	3.3	Align NASA funding priorities towards space exploration	0.098
12	4.1	Create content for educational use	0.006
13	4.2	Create content for media	0.006
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.006
15	6.11	Create security related dual use technologies	0.006
16	6.12	Improve security qualified space access	0.006
17	6.13	Provide space presence and freedom of action	0.006
18	6.14	Provide space acquired earth relevant security data	0.006
19	6.2	Improve space access measured as cost and risk reductions	0.096
20	6.3	Promote space related commercial activities, inc comm, tourism	0.060
21	6.4	Promote commercial acqusition of space good & service (includes COTS)	0.077
22	6.5	Develop space infrastucture development and operational knowledge	0.098
23	6.6	Create NON SECURITY related dual use technologies	0.006

Table 30. Matrix K showing the different weights on the needs of the VCS. The matrix is transposed, for a better graphical representation in this printed work. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

In Matrix K, the shaded squares are the ones that point towards the main Space Exploration needs.

- Long term strategic planning
- Funding for Space Exploration
- NASA alignment towards space exploration
- Space access improvement
- Operational/developmental knowledge

The next step is to identify which parties control the resources deemed critical to the VCS, presented in the precedent list. To that purpose we will use Matrix V from Table 24 and copied here below as Table 31, which links VCS' needs and their suppliers.

			$[V]_{23\times11}$										
SvQ	JD	Objective – VCS' need to satisfy	Cong	Exec	Intl	Sec	Econ	Sci	Tech	NASA	Media	Educ	Vot
1	1.1	Develop strategic long term planning for the Space Exploration System	0.061	0.061	0.184	0.061	0.184	0.184	0.020	0.184	0.000	0.000	0.061
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.067	0.067	0.067	0.067	0.067	0.200	0.200	0.200	0.067	0.000	0.000
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)											
4	2.2	Increase positive perception about NASA (political capital)	0.081	0.081	0.081	0.081	0.027	0.081	0.000	0.081	0.243	0.000	0.243
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.000	0.000	0.000	0.000	0.034	0.103	0.103	0.103	0.310	0.310	0.034
6	2.4	Motivate-recognize technical workforce	0.031	0.031	0.000	0.031	0.281	0.031	0.031	0.094	0.281	0.094	0.094
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues											
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration											
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.243	0.243	0.027	0.081	0.081	0.081	0.000	0.081	0.081	0.000	0.081
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.077	0.077	0.077	0.231	0.077	0.231	0.000	0.231	0.000	0.000	0.000
11	3.3	Align NASA funding priorities towards space exploration	0.365	0.365	0.081	0.027	0.027	0.081	0.027	0.000	0.027	0.000	0.000
12	4.1	Create interesting and inspiring content for educational use											
13	4.2	Create entertaining and inspiring content for media											
14	5.1	Provide easily and quickly accesible data for use on science knowledge											
15	6.11	Create security related dual use technologies											
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)											
17	6.13	Provide space presence and freedom of action											
18	6.14	Provide space acquired earth relevant security data											
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.073	0.073	0.073	0.220	0.220	0.024	0.073	0.220	0.024	0.000	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.032	0.032	0.097	0.032	0.290	0.032	0.097	0.161	0.097	0.097	0.032
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.086	0.086	0.029	0.086	0.257	0.029	0.086	0.257	0.029	0.029	0.029
22	6.5	Develop space infrastucture development and operational knowledge	0.032	0.032	0.290	0.097	0.097	0.032	0.097	0.290	0.000	0.032	0.000
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)											

Table 31. Table showing the expected values for Matrix V which presents the weights of the parties that control resources of interest to the VCS. The lines that are grayed out are considered not of interest to the VCS of the example (the space exploration initiative). All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

The stakeholders that control the resources that satisfy the needs critical to the VCS (as a first approximation) are

- Congress
- Executive Branch
- International partners,
- Security,
- Science and
- NASA Legacy

These stakeholders interact among them, and exchange value. Our model uses Matrix H to map the exchange of value between stakeholders. For this explanation, we will use only the matrix generated through a low influence decay factor (implying a fast decay or a short term perspective), which is shown Table 22 and copied here below as Table 32.

$[H_{0.50}]_{11x11}$	Congress	Execut	Intl part	Security	Economic	Science	Tech comm	NASA legacy	Media	Education	Voters
Congress	0.517	0.044	0.020	0.022	0.044	0.047	0.052	0.052	0.067	0.047	0.088
Execut	0.033	0.527	0.039	0.032	0.051	0.045	0.039	0.048	0.062	0.044	0.080
Intl part	0.027	0.078	0.517	0.036	0.048	0.079	0.046	0.044	0.048	0.036	0.042
Security	0.052	0.060	0.026	0.514	0.052	0.047	0.058	0.034	0.038	0.056	0.062
Economic	0.034	0.042	0.019	0.030	0.526	0.054	0.069	0.037	0.051	0.076	0.062
Science	0.042	0.053	0.049	0.020	0.040	0.530	0.048	0.047	0.051	0.061	0.060
Tech comm	0.035	0.044	0.031	0.020	0.074	0.057	0.525	0.039	0.043	0.079	0.053
NASA legcy	0.056	0.063	0.031	0.020	0.052	0.065	0.051	0.522	0.043	0.045	0.052
Media	0.025	0.048	0.021	0.038	0.059	0.062	0.031	0.043	0.526	0.051	0.095
Education	0.038	0.061	0.022	0.023	0.033	0.062	0.043	0.044	0.048	0.528	0.096
Voters	0.025	0.053	0.020	0.051	0.051	0.054	0.040	0.047	0.061	0.064	0.536

Table 32. Matrix H 0.50, incorporates the expected value of the discounted sumation of the stakeholders interaction, using a influence decay factor of 0.50. This low influence decay factor causes the influence to decay fast, thus, emphasizes short term interactions between stakeholders. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

As we see, the matrix is strongly diagonal, meaning that the strongest influence comes from the original stakeholder. As a consequence, in order to maximize the supply of the resources needed for Space Exploration, our best strategy is to satisfy the list of six stakeholders presented above.

In order to satisfy these most powerful stakeholders, we should identify their needs. We would analyze matrix J, which is shown in Table 18, and copied here as Table 33 to extract the factors that drive those stakeholders' satisfaction.

		Matrix J - transposed	$[J]_{11x23}$ *transposed*										
Sv Q	**JD**	**Objective**	**Cong**	**Exec**	**Intl**	**Sec**	**Econ**	**Sci**	**Tech**	**NASA**	**Media**	**Educ**	**Vot**
1	1.1	Develop strategic long term planning for the Space Exploration System	0.013	0.014	0.110	0.039	0.013	0.074	0.076	0.107	0.057	0.062	0.107
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.118	0.145	0.042	0.055	0.013	0.076	0.081	0.012	0.059	0.047	0.076
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.142	0.131	0.009	0.009	0.013	0.007	0.008	0.006	0.011	0.012	0.010
4	2.2	Increase positive perception about NASA (political capital)	0.009	0.009	0.009	0.009	0.013	0.007	0.081	0.108	0.011	0.012	0.010
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.009	0.009	0.064	0.009	0.046	0.062	0.079	0.106	0.181	0.194	0.010
6	2.4	Motivate-recognize technical workforce	0.009	0.009	0.101	0.009	0.013	0.075	0.039	0.015	0.011	0.012	0.010
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.094	0.056	0.081	0.043	0.013	0.007	0.008	0.006	0.011	0.012	0.034
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.009	0.009	0.135	0.009	0.013	0.007	0.008	0.006	0.011	0.012	0.010
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.009	0.009	0.009	0.009	0.041	0.104	0.078	0.095	0.011	0.124	0.010
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.095	0.009	0.009	0.105	0.013	0.110	0.008	0.069	0.011	0.012	0.010
11	3.3	Align NASA funding priorities towards space exploration	0.097	0.145	0.009	0.016	0.013	0.051	0.083	0.066	0.011	0.027	0.010
12	4.1	Create interesting and inspiring content for educational use	0.023	0.086	0.009	0.009	0.013	0.082	0.087	0.006	0.118	0.183	0.144
13	4.2	Create entertaining and inspiring content for media	0.009	0.009	0.009	0.009	0.013	0.007	0.008	0.006	0.167	0.116	0.175
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.009	0.009	0.151	0.009	0.013	0.116	0.014	0.006	0.117	0.039	0.010
15	6.11	Create security related dual use technologies	0.009	0.031	0.035	0.130	0.013	0.007	0.008	0.006	0.011	0.012	0.112
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.092	0.093	0.026	0.066	0.013	0.022	0.008	0.006	0.011	0.012	0.010
17	6.13	Provide space presence and freedom of action	0.041	0.034	0.106	0.064	0.013	0.007	0.008	0.006	0.011	0.012	0.010
18	6.14	Provide space acquired earth relevant security data	0.009	0.037	0.009	0.067	0.013	0.007	0.008	0.006	0.011	0.012	0.010
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.009	0.009	0.009	0.137	0.224	0.072	0.121	0.067	0.011	0.012	0.010
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.094	0.036	0.009	0.090	0.124	0.007	0.008	0.108	0.077	0.046	0.113
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.009	0.009	0.036	0.009	0.147	0.007	0.040	0.067	0.059	0.012	0.050
22	6.5	Develop space infrastucture development and operational knowledge	0.009	0.009	0.009	0.092	0.062	0.007	0.128	0.108	0.011	0.012	0.010
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.086	0.095	0.009	0.009	0.143	0.081	0.017	0.006	0.011	0.012	0.042

Table 33. Shows Matrix J, transposed (for a better graphical format). These are the weights used to assess how much satisfaction derives each stakeholder from every objective of space exploration. This matrix is built by evaluating the values X and Y compounded by their importance, for each stakeholder and objective, and is normalized per rows. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

From the matrix, we can see, what drives satisfaction for the 6 most influential stakeholders.

To increase the satisfaction of the Congress and Executive branch, we should

- Develop short term results
- Increase their political capital by linking them to the Space exploration
- Align funds towards space exploration

To increase the satisfaction of international partners we should provide

- Increase the positive perception of foreign citizens about their government
- Long term strategic planning
- Provide easy access to scientific data

To increase the satisfaction of security interests we should

- Create dual use security related technologies
- Improve space access

To increase the satisfaction of the scientific community we should

- Provide a large amount of scientific data
- Promote sharing of investments
- Promote funding for the space exploration system

To increase the satisfaction of NASA Legacy we should

- Do long term planning
- Increase NASA positive perception
- Promote space related activities

The satisfaction of these objectives can be linked to the increase of their engineering proxies. We also perceive there is a grouping of stakeholders, with two of them sharing objectives, and proxies needed to satisfy those objectives.

For the Executive branch and Congress, an ideal architecture would

- Reduce the time to achieve the first successful results
- Reduce the investment needed to the first successful results
- Have many high visibility events linked to the Congress and Executive branch
- Realign NASA's workforce towards space exploration

The remaining 4 stakeholders, international partners, science, NASA and security, share some proxies, but present a less compact set of interests.

- Present foreign nationals in HVE
- Have a long term planning
- Reduce cost to LEO access
- Reduce failure rate to LEO access
- Provide a large amount of scientific data
- Fund research related to space exploration
- Increase science time while exploring other bodies.

Looking to the different vectors P that result from architecture decisions see that some architectures touch the points of our interest.

Table 34 presents the different vectors P that would result from the options presented by architecture decision number 1, which asks about the date of the first landing on the moon.

$\overline{P}_{33}$ for A_1	2014	2018	2022
Number of years of planning in advance	-26.2%	0.0%	20.3%
Savings to first result	23.9%	0.0%	-9.6%
Reduction in Time to first result	36.9%	0.0%	-126.2%
High Visibility Events (HVE) linked to the Executive Branch Vision for Space Exploration, and Congress' bills	63.1%	0.0%	-100.0%
Popular acceptance of space policy and high level space exploration goals	24.4%	0.0%	-15.2%
HVE linked to NASA technical implementation of Space Exploration	26.2%	0.0%	-36.9%
Positive perception about NASA as a whole	-7.9%	0.0%	7.3%
Ability to show benefits to non-engaged groups	-32.5%	0.0%	36.9%
Hours of class dedicated to space exploration at middle school	0.0%	0.0%	0.0%
NASA technical workforce salary as a % of average tech salary	6.3%	0.0%	0.0%
Fraction of the space budget paid by foreign partners	20.3%	0.0%	0.0%
Number of HVE that are first page on newspapers of non-allied countries	46.5%	0.0%	-100.0%
Fraction of the space exploration activities involving public diffusion of foreign partners participation	-32.5%	0.0%	36.9%
Strategies leading funding lock-in from Congress and other fund sources	16.6%	0.0%	-20.3%
Fraction of the architecture that is possible to share	-36.9%	0.0%	26.2%
Fraction of NASA's workforce realigned towards space exploration	41.1%	0.0%	-14.0%
Opportunities to generate interesting material	-4.7%	0.0%	0.0%
HVE that make it to a TV newscast	0.0%	0.0%	23.9%
Amount of data available, measured on # researchers times # of years to analyze it (?)	-20.3%	0.0%	30.6%
Amount spent on research related to space exploration	-46.5%	0.0%	30.6%
Science time while exploring other bodies	-46.5%	0.0%	30.6%
Fraction of architecture investment that can be used for security purposes	-32.5%	0.0%	12.7%
Delay from launch need identification to execution	-16.6%	0.0%	0.0%
Fraction of architecture launched on security qualified vehicles	0.0%	0.0%	0.0%
Reduction in time for the first outpost	5.9%	0.0%	0.0%
Fraction of time the farthest outpost is populated	0.0%	0.0%	63.1%
Fraction of data infrastructure that has dual security related use	0.0%	0.0%	46.5%
Red Cost of sending material to LEO	0.0%	0.0%	0.0%
Red Launch failure rate	0.0%	0.0%	20.3%
commercial space related business by year 2018	20.3%	0.0%	-26.2%
Fraction of Space Exploration budget spent outside NASA	-5.2%	0.0%	4.9%
Time of accumulated development and operation knowledge	12.7%	0.0%	0.0%
Fraction of space related investment that has application besides space	-26.2%	0.0%	20.3%

Table 34. The expected values for each element of Engineering Proxies vector P, when evaluating through the vectorial function f, each answer to the decision presented by the first element of the architecture vector A. This first decision of the architecture vector is "what year should the first landing on the moon be"; the elements of P are expressed in a logarithmic scale. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

Table 35 presents the values that vector P would acquire when subject to the decision of the moon landing capability of the Crew Exploration vehicle. Table 36 shows what values might take P when each energy option for a lunar base is evaluated. Table 37 presents the values that P would take when presented with different payload sizes on the cargo launchers to earth orbit.

$\overline{P}_{33}$ *for* A_2	cap-land	nocap	cap-noland
Number of years of planning in advance	10.7%	0.0%	5.5%
Savings to first result	2.7%	0.0%	1.5%
Reduction in Time to first result	-63.1%	0.0%	-63.1%
High Visibility Events (HVE) linked to the Executive Branch Vision for Space Exploration, and Congress' bills	-36.9%	0.0%	-36.9%
Popular acceptance of space policy and high level space exploration goals	0.0%	0.0%	-7.3%
HVE linked to NASA technical implementation of Space Exploration	0.0%	0.0%	-36.9%
Positive perception about NASA as a whole	7.3%	0.0%	-7.9%
Ability to show benefits to non-engaged groups	16.6%	0.0%	-20.3%
Hours of class dedicated to space exploration at middle school	0.0%	0.0%	0.0%
NASA technical workforce salary as a % of average tech salary	12.2%	0.0%	6.3%
Fraction of the space budget paid by foreign partners	0.0%	0.0%	0.0%
Number of HVE that are first page on newspapers of non-allied countries	0.0%	0.0%	-36.9%
Fraction of the space exploration activities involving public diffusion of foreign partners participation	0.0%	0.0%	0.0%
Strategies leading funding lock-in from Congress and other fund sources	30.6%	0.0%	30.6%
Fraction of the architecture that is possible to share	0.0%	0.0%	0.0%
Fraction of NASA's workforce realigned towards space exploration	12.2%	0.0%	7.5%
Opportunities to generate interesting material	0.0%	0.0%	0.0%
HVE that make it to a TV newscast	0.0%	0.0%	0.0%
Amount of data available, measured on # researchers times # of years to analyze it (?)	0.0%	0.0%	-2.8%
Amount spent on research related to space exploration	-4.7%	0.0%	-4.7%
Science time while exploring other bodies	0.0%	0.0%	0.0%
Fraction of architecture investment that can be used for security purposes	0.0%	0.0%	0.0%
Delay from launch need identification to execution	0.0%	0.0%	0.0%
Fraction of architecture launched on security qualified vehicles	0.0%	0.0%	0.0%
Reduction in time for the first outpost	-16.6%	0.0%	-16.6%
Fraction of time the farthest outpost is populated	8.7%	0.0%	8.7%
Fraction of data infrastructure that has dual security related use	0.0%	0.0%	0.0%
Red Cost of sending material to LEO	0.0%	0.0%	0.0%
Red Launch failure rate	0.0%	0.0%	0.0%
commercial space related business by year 2018	20.3%	0.0%	0.0%
Fraction of Space Exploration budget spent outside NASA	-1.0%	0.0%	-1.0%
Time of accumulated development and operation knowledge	8.7%	0.0%	4.4%
Fraction of space related investment that has application besides space	0.0%	0.0%	0.0%

Table 35. The expected values for each element of Engineering Proxies vector P, when evaluating through the vectorial function f, each answer to the decision presented by the second element of the architecture vector A. This second decision of the architecture vector is "should the Crew Exploration Vehicle have the capability to land on the Moon"; the elements of P are expressed in a logarithmic scale. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

$\overline{P}_{33}$ for A_3	Pole-nuc	Pole-sol	Eq-nuc	Eq-solar	No-Base
Number of years of planning in advance	29.0%	10.7%	29.0%	20.3%	0.0%
Savings to first result	-3.1%	-0.6%	-3.1%	-1.5%	0.0%
Reduction in Time to first result	-26.2%	20.3%	0.0%	-26.2%	0.0%
High Visibility Events (HVE) linked to the Executive Branch Vision for Space Exploration, and Congress' bills	46.5%	46.5%	26.2%	26.2%	0.0%
Popular acceptance of space policy and high level space exploration goals	-15.2%	18.9%	-7.3%	13.0%	0.0%
HVE linked to NASA technical implementation of Space Exploration	63.1%	46.5%	63.1%	46.5%	0.0%
Positive perception about NASA as a whole	14.0%	20.3%	-7.9%	14.0%	0.0%
Ability to show benefits to non-engaged groups	-32.5%	23.9%	-46.5%	23.9%	0.0%
Hours of class dedicated to space exploration at middle school	36.9%	63.1%	36.9%	63.1%	0.0%
NASA technical workforce salary as a % of average tech salary	12.2%	6.3%	12.2%	6.3%	0.0%
Fraction of the space budget paid by foreign partners	-63.1%	36.9%	-63.1%	36.9%	0.0%
Number of HVE that are first page on newspapers of non-allied countries	-36.9%	46.5%	-36.9%	46.5%	0.0%
Fraction of the space exploration activities involving public diffusion of foreign partners participation	-63.1%	36.9%	-63.1%	36.9%	0.0%
Strategies leading funding lock-in from Congress and other fund sources	23.9%	16.6%	23.9%	16.6%	0.0%
Fraction of the architecture that is possible to share	11.4%	11.4%	11.4%	11.4%	0.0%
Fraction of NASA's workforce realigned towards space exploration	22.9%	18.7%	18.7%	14.4%	0.0%
Opportunities to generate interesting material	8.7%	8.7%	8.7%	8.7%	0.0%
HVE that make it to a TV newscast	30.6%	30.6%	23.9%	23.9%	0.0%
Amount of data available, measured on # researchers times # of years to analyze it (?)	30.6%	30.6%	16.6%	16.6%	0.0%
Amount spent on research related to space exploration	30.6%	30.6%	16.6%	16.6%	0.0%
Science time while exploring other bodies	163.1%	163.1%	163.1%	163.1%	0.0%
Fraction of architecture investment that can be used for security purposes	4.4%	0.0%	4.4%	0.0%	0.0%
Delay from launch need identification to execution	0.0%	0.0%	0.0%	0.0%	0.0%
Fraction of architecture launched on security qualified vehicles	-4.7%	-14.8%	-4.7%	-14.8%	0.0%
Reduction in time for the first outpost	-63.1%	-63.1%	-83.4%	-83.4%	0.0%
Fraction of time the farthest outpost is populated	42.8%	42.8%	42.8%	42.8%	0.0%
Fraction of data infrastructure that has dual security related use	0.0%	0.0%	0.0%	0.0%	0.0%
Red Cost of sending material to LEO	-20.3%	-20.3%	-20.3%	-20.3%	0.0%
Red Launch failure rate	0.0%	0.0%	0.0%	0.0%	0.0%
commercial space related business by year 2018	20.3%	20.3%	20.3%	20.3%	0.0%
Fraction of Space Exploration budget spent outside NASA	-1.0%	1.0%	-1.0%	1.0%	0.0%
Time of accumulated development and operation knowledge	30.6%	30.6%	16.6%	16.6%	0.0%
Fraction of space related investment that has application besides space	1.8%	4.4%	1.8%	4.4%	0.0%

Table 36. The expected values for each element of Engineering Proxies vector P, when evaluating through the vectorial function f, each answer to the decision presented by the third element of the architecture vector A. This third decision of the architecture vector is "what energy source should a base on the moon have"; the elements of P are expressed in a logarithmic scale. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

$\overline{P}_{33}$ for A_4	8 MT	23MT	40MT	125MT	300MT
Number of years of planning in advance	-26.2%	-26.2%	-5.9%	0.0%	10.7%
Savings to first result	-1.5%	-2.1%	-0.6%	-0.3%	0.9%
Reduction in Time to first result	-63.1%	36.9%	0.0%	0.0%	0.0%
High Visibility Events (HVE) linked to the Executive Branch Vision for Space Exploration, and Congress' bills	-100.0%	-36.9%	-16.6%	0.0%	77.1%
Popular acceptance of space policy and high level space exploration goals	-15.2%	-7.3%	-7.3%	0.0%	13.0%
HVE linked to NASA technical implementation of Space Exploration	14.0%	46.5%	0.0%	0.0%	0.0%
Positive perception about NASA as a whole	1.5%	14.0%	0.0%	0.0%	0.0%
Ability to show benefits to non-engaged groups	16.6%	36.9%	16.6%	0.0%	-9.6%
Hours of class dedicated to space exploration at middle school	0.0%	0.0%	0.0%	0.0%	0.0%
NASA technical workforce salary as a % of average tech salary	12.2%	12.2%	0.0%	0.0%	-14.0%
Fraction of the space budget paid by foreign partners	63.1%	63.1%	0.0%	0.0%	0.0%
Number of HVE that are first page on newspapers of non-allied countries	14.0%	26.2%	0.0%	0.0%	46.5%
Fraction of the space exploration activities involving public diffusion of foreign partners participation	36.9%	36.9%	0.0%	0.0%	0.0%
Strategies leading funding lock-in from Congress and other fund sources	-83.4%	-32.5%	0.0%	0.0%	0.0%
Fraction of the architecture that is possible to share	63.1%	63.1%	26.2%	0.0%	0.0%
Fraction of NASA's workforce realigned towards space exploration	-50.9%	-50.9%	12.2%	0.0%	0.0%
Opportunities to generate interesting material	0.0%	0.0%	0.0%	0.0%	0.0%
HVE that make it to a TV newscast	16.6%	16.6%	0.0%	0.0%	16.6%
Amount of data available, measured on # researchers times # of years to analyze it (?)	0.0%	0.0%	0.0%	0.0%	-20.3%
Amount spent on research related to space exploration	4.4%	4.4%	0.0%	0.0%	-20.3%
Science time while exploring other bodies	0.0%	0.0%	0.0%	0.0%	0.0%
Fraction of architecture investment that can be used for security purposes	23.9%	23.9%	12.7%	0.0%	0.0%
Delay from launch need identification to execution	-163.1%	-163.1%	0.0%	0.0%	133.5%
Fraction of architecture launched on security qualified vehicles	-32.5%	-32.5%	0.0%	0.0%	0.0%
Reduction in time for the first outpost	-16.6%	-16.6%	-6.3%	0.0%	5.9%
Fraction of time the farthest outpost is populated	8.7%	8.7%	0.0%	0.0%	-32.5%
Fraction of data infrastructure that has dual security related use	46.5%	46.5%	0.0%	0.0%	0.0%
Red Cost of sending material to LEO	42.8%	42.8%	0.0%	0.0%	-20.3%
Red Launch failure rate	50.9%	50.9%	27.3%	0.0%	-26.2%
commercial space related business by year 2018	63.1%	63.1%	36.9%	0.0%	0.0%
Fraction of Space Exploration budget spent outside NASA	2.0%	2.0%	1.0%	0.0%	0.0%
Time of accumulated development and operation knowledge	8.7%	8.7%	0.0%	0.0%	0.0%
Fraction of space related investment that has application besides space	23.9%	23.9%	0.0%	0.0%	0.0%

Table 37. The expected values for each element of Engineering Proxies vector P, when evaluating through the vectorial function f, each answer to the decision presented by the fourth element of the architecture vector A. This fourth decision of the architecture vector is "what payload size should the Earth to Low Earth Orbit cargo launcher be"; the elements of P are expressed in a logarithmic scale. All the data on this table, (including the consideration that some of these needs are not of interest to the VCS) is conceptual and has not been acquired from external sources. The darker gray squares (green for color printouts) are the top 10 percentile, the lighter gray squares (yellow for color printouts) are the top 30 percentile; both suggest which are the most influential factors of this matrix.

As previously presented, we make the assumption that each of these decisions can be taken independently of the others. A more elaborated case would actually evaluate a complete architecture based on 30 to 40 high level decisions. Those decisions, structured as an architecture tree shown in section 4. 4. 1 would lead to a limited number of Architecture vectors. Each of these Architecture vectors, would be evaluated by the vectorial function f, leading to different vectors P.

The example we present is not structured as a tree, in order to illustrate in a simplified manner the model.

In order to analyze the size of the cargo launcher, we extracted the relevant information from the different Vectors P in Table 37, and we prepared Table 38. The negative coefficients on the rows related to the Executive branch and Congress, when analyzing smaller launchers points towards a lesser interest of these stakeholders on smaller launchers; on the contrary they show a positive attitude towards a larger launcher, because of the high visibility event it would generate, as we can appreciate in the third row and fifth column positive coefficient.

		8 MT	23MT	40MT	125MT	300MT
Executive and Congress	Savings to first result	-1.5%	-2.1%	-0.6%	-0.3%	0.9%
	Reduction in Time to first result	-63.1%	36.9%	0.0%	0.0%	0.0%
	High Visibility Events (HVE) linked to the Executive Bran	-100.0%	-36.9%	-16.6%	0.0%	77.1%
	Fraction of NASA's workforce realigned towards space e	-50.9%	-50.9%	12.2%	0.0%	0.0%
International partners, science, NASA legacy and security	Number of years of planning in advance	-26.2%	-26.2%	-5.9%	0.0%	10.7%
	Fraction of the space exploration activities involving public diffusion of foreign partners participation	36.9%	36.9%	0.0%	0.0%	0.0%
	Amount of data available, measured on # researchers times # of years to analyze it (?)	0.0%	0.0%	0.0%	0.0%	-20.3%
	Amount spent on research related to space exploration	4.4%	4.4%	0.0%	0.0%	-20.3%
	Science time while exploring other bodies	0.0%	0.0%	0.0%	0.0%	0.0%
	Red Cost of sending material to LEO	42.8%	42.8%	0.0%	0.0%	-20.3%
	Red Launch failure rate	50.9%	50.9%	27.3%	0.0%	-26.2%

Table 38. The table is extracted from the vector P. It shows only the main proxy drivers, and relevant architectures.

As a contrast, the other 4 stakeholders are highly positive about an architecture with a smaller launcher, which can be appreciated on the positive values of the first two columns for the last 7 rows; and appreciate less an architecture with a larger launcher, which can be observed on the negative coefficients of the last column for the last 7 rows.

It is to be noted that the data from which this table is derived has not been acquired using the survey recommended by this research on section 6. The implementation of that survey would allow a fact based analysis. Hence, the data of Table 38 is *conceptual* and its purpose is to *illustrate* the model, *not to suggest* that actually the government dislikes smaller sized launchers.

The model also shows that satisfying International partners, Security, Science and NASA Legacy provides a larger amount of resources back to the VCS, than satisfying the Congress and Executive branch.

This is due to the combination of amount of satisfaction potentially delivered to the stakeholders, and their ability to control the more critical resources. Figure 38 (a copy of Figure 34), presents this effect graphically, with the 23MT decision farther to the right than the 300MT decision.

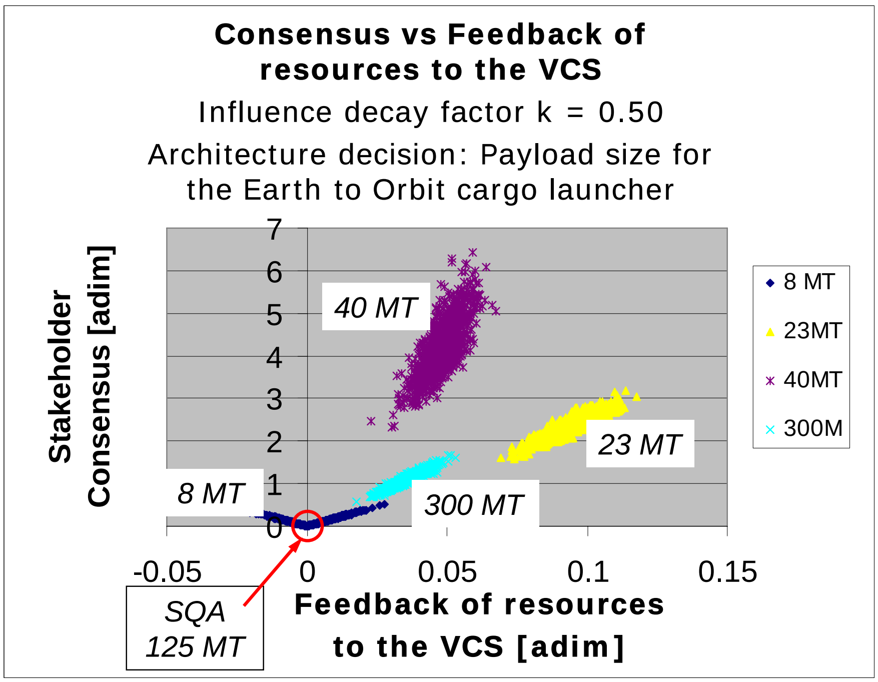

Figure 38. The diagram compares feedback of resources and stakeholder satisfaction consensus generated by different architecture options. The architecture options compared in this diagram are related to the cargo launcher size. The decay factor of the interactions between stakeholders is 0.50 for this case, consequently long term effects are damped, and short term benefits are underscored.

Finally, we see can see in Table 38 that the architecture with a 40MT launcher does not deliver a large amount of value, but does not alienate severely any stakeholder. That insight also can be appreciated in Figure 38, where the 40MT decision has a superior value of consensus (higher on the vertical axis).

This reasoning line can be repeated using statistical hypothesis testing tools. The use of these tools would allow to calculate probabilities of dominance in one or another dimension. The use of Expectation Maximization algorithms seem especially adaptable to these ends.

7.3. Research insights

During our research we have arrived at several insights. They are not central to our work, but we believe they have value on their own.

- System Vectorial Dynamics Probability Model

  We introduced the idea that System Dynamics treatment for social problems needs to be extended by the use of flows that are vectorial in their nature and by the incorporation of probability. These modifications do not seem to be especially difficult, either from a conceptual perspective or from a numerical implementation aspect.

  This extension to the System Dynamics tool will allow solving problems where its applications used to be rejected as quantitative oriented in excess.

- Sustainability multi-stakeholder analysis places the VCS as supreme decision maker

  Sustainability of a system, be it a natural organism, a corporation, a government agency or any other entity, is linked to its ability to secure resources critical to its survival. The prosperity of the system would be linked to secure an excess of resources, allowing for growth.

  As a consequence, in order to increase the sustainability and prosperity of any Value Creating System, once a strategy to follow is identified, the architect should identify the needs that the strategy presents, and name as stakeholders the groups that control the resources which solve those needs.

  It should be understood that in order to become a stakeholder, the group should control some resource of interest to the VCS. While benefiting groups that do not control resources might deserve praise, it consumes scarce VCS resources, and constitutes charity. Charity can be performed as long as the VCS possesses a surplus of resources.

  Hence, the strategy a VCS should follow is to increase its sustainability by increasing the satisfaction of stakeholder groups, through satisfaction of those stakeholders' needs.

  For the case of the VCS and the stakeholders, the words "resources" and "needs" should be understood in a broad sense, including not only funds, but also any other ingredient required for the VCS to deliver value.

- Multi-stakeholder analysis as a tiered decision making process, using matrices

  Traditional decision making tools place the customer as dictator of the design of the system. In doing so, we try to oppose the natural forward flow of value in creative organizations from intent to form; knowing without asking the customers, what is best for them. These decision making tools build functions that combine different objectives' satisfaction into an overall customer satisfaction.

Because we place the VCS architect as dictator of our analysis, by selecting the resources the VCS needs, we arrive to a tiered decision making scheme, where the root level is the decision made at the VCS, and the subsequent levels are the stakeholders' ability to control resources of interest, the exchange of value between stakeholders, and finally the needs stakeholders exhibit. As we see our model is a branched tree, where on the last step are the needs stakeholders (customers) present, and which were analyzed by traditional tools.

We propose to use matrix algebra and vectors to operate through this tree, through the application of the proposed SVDPM tool. Furthermore, while traditional decision making uses the expected value of a decision as a criterion to select the best answer, we additionally propose to incorporate the analysis uncertainty to the model providing a richer information to the decision maker. This uncertainty treatment is incorporated in the SVDPM tool we propose.

By multiplying matrices, it is possible to derive the outcome of a determinate architecture decision, and even the probability of that outcome, based on the information acquired.

- Causality disruption on the value delivery process

During our research we had the opportunity to observe that while value travels from the VCS to objectives, to stakeholders and finally to resources given back to the VCS, in order to prioritize according to our model, the causality to prioritize travels in the opposite direction. Our model states that the first determination should be what resources are valuable for the VCS, then who provides those valuable resources and how good is their control over them, how do these parties exchange value among them, and finally what are their needs.

When the determination of what constitutes valuable resources, is done through a purely commercial frame, it results on a net present value model of future cash flows. Because our model does not assume that future monetary flows are the only ingredient for success, we start by identifying which are the ingredients the VCS would need for its prosperity; initiating our analysis, thus, at the VCS.

Perhaps more important is that we were unable to continue the causality cycle back to the architecture from the stakeholders' needs. It was not possible to identify a meaningful way to map those stakeholders needs (objectives) to forms in the architecture, a situation that we believe is caused by the phenomenon of emergence, and by the direction creativity follows.

While emergence makes it difficult, if not impossible, to understand how a function could be broken down to molecular elements, it is the chaotic creative process that makes absolutely impossible the sought after mapping.

The creative process flows forward, from the VCS strategy to an intent, to a concept and finally to satisfaction of stakeholders' needs, as we said, through a chaotic process. While it seems almost impossible to predict how the forward creativity flow will result, and what the creative process will generate, the level of difficulty escalates when what we expect is to calculate an inverse to that forward function, that is, to determine from the needs what would be the concepts which could satisfy those needs.

There is as a consequence a disconnection between the logical rational sequence that is possible to follow backwards from the VCS to a list of objectives, and the creativity process that flows forward from the VCS to a concept and form. Managing this collision successfully, through "hinting" efficiently from the objectives to the creative process is the conundrum of the management of technological organizations.

7.4. Final words

Through our work on this research we have learned not what to think but how to think about value delivery. It is the expectation of the author that future researchers, teased by this work, will try to complete it, correct it, and confirm it.

The applications of this proposal are multiple, and range from the simplest tasks, to the most complex social human endeavors. We hope it will be useful.

8. Appendixes

8.1. Wall of Value and Objective tree

We are presenting in this appendix two results.

The first one is a diagram (Figure 33) showing a tree structure for the list of objectives. This was done in order to ensure that the objectives covered the complete space of needs, as proposed by the stakeholders, and that the list of needs did not have any overlaps.

The numbers on the left indicate objective number in the vector of the model (see section 3. 2. 4), which is also the number of question in the Kano Survey (see Appendix 8.2).

The second result is a partial extract of the columns of the Wall of Value needs database, as prepared by the MIT-Draper Concept Evaluation and Refinement Research group[20]. The list of objectives used on the Space Exploration case was prepared following this list and the interviews presented in section 5

This database was prepared by several researchers, members of the value sub-team. Dr. Geilson Loureiro, Dr. Eric Rebentisch and the author had the compilation responsibility.

Wall of Value Table

1. Resource And Planning – Direct
Loop : Exploration knowledge; Stakeholder : Commercial Space resource exploration and development; Stakeholder Need : reliable and accurate knowledge of the resources available in space
Stakeholder's need: identify profitable space resources
Wall of Value Objective : To enable the development of commercial space resources BY identifying the location and characteristics of resource for exploitation

2. Resource And Planning - Direct
Loop : Exploration knowledge; Stakeholder : Explorers Space resource exploration and development; Stakeholder Need : reliable and accurate knowledge of the resources available in space
Stakeholder's need: identify space resources that provide sustainability to the SE
Wall of Value Objective : To enable the characterization of space resources BY identifying the location and characteristics of resource for exploitation

3. Resource And Planning - Direct
Loop : Exploration knowledge; Stakeholder : Explorers Space resource exploration and development; Stakeholder Need : effective search for space resources
Stakeholder's need: train explorers to search for resources with efficiency
Wall of Value Objective : To enable effective search for space resources BY utilizing all existing knowledge to plan the next stages of exploration

4. Resource And Planning - Indirect
Loop : Exploration knowledge; Stakeholder : public workforce; Stakeholder Need : jobs
Stakeholder's need: generate and maintain jobs related to space resources extraction
Wall of Value Objective : To increase or maintain the number and stability of rewarding jobs BY developing knowledge of resources

5. Resource And Planning - Indirect
Loop : Exploration knowledge; Stakeholder : commercial ; Stakeholder Need : revenues and profits

Wall of Value Objective : To grow business, revenue and profits BY exploiting knowledge of resources

6. Resource And Planning - Political
Loop : Exploration knowledge; Stakeholder : Public general; Stakeholder Need : to understand the direct, indirect and workforce benefits from exploration knowledge
Stakeholder's need: provide easy to access information about the benefits of SE
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits from space exploration BY receiving easily accessible information frequently about well-executed exploration activities

7. Resource And Planning - Political
Loop : Exploration knowledge; Stakeholder : NASA; Stakeholder Need : to inform the public, other stakeholders of the direct, indirect and workforce benefits of exploration knowledge
Stakeholder's need: develop NASA political support through diffusion of easy to access information about Exploration knowledge
Wall of Value Objective : To increase public understanding of direct and indirect benefits of space exploration BY communicating easily accessible information frequently about well-executed exploration activities

8. Resource And Planning - Political
Loop : Exploration knowledge; Stakeholder : Executive; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from exploration knowledge
Stakeholder's need: develop political capital for the executive branch through showing to the public the benefits of SE
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from well-executed space exploration

8. Resource And Planning - Political
Loop : Exploration knowledge; Stakeholder : Congress; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from exploration knowledge
Stakeholder's need: develop political capital for the congress through showing to the public the benefits of SE
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from well-executed space exploration

9. Science Knowledge - Direct
Loop : Science knowledge; Stakeholder : Scientific community Scientists ; Stakeholder Need : Understanding of Universe
Stakeholder's need: deliver data that increases/enables scientific knowledge of the universe
Wall of Value Objective : TO Increase scientific knowledge BY studying results of exploration (video, data, images, samples)

10. Science Knowledge - Direct
Loop : Science knowledge; Stakeholder : NASA ; Stakeholder Need : Scientific exploration
Stakeholder's need: perform studies that increase the knowledge of the universe
Wall of Value Objective : TO Increase number of results from exploration BY conducting studies

11. Science Knowledge - Direct
Loop : Science knowledge; Stakeholder : Other Government Agencies DoC/NOAA; Stakeholder Need : Environmental data and monitoring
Stakeholder's need: develop scientific knowledge of interest to other gob agencies about the environment
Wall of Value Objective : To Increase knowledge of Earth's environment BY developing Technology Capabilities (e.g. sensors that can be used for environmental monitoring) that are of interest of other agencies

12. Science Knowledge - Direct

Loop : Science knowledge; Stakeholder : Other Government Agencies DoC/NOAA; Stakeholder Need : Environmental data and monitoring
Stakeholder's need: develop sensing technologies of interest to other civil gob agencies
Wall of Value Objective : To Increase knowledge of Earth's environment BY developing Technology Capabilities (e.g. sensors that can be used for environmental monitoring) that are of interest of other agencies

13. Science Knowledge - Direct
Loop : Science knowledge; Stakeholder : Scientists All; Stakeholder Need : Quality results from exploration
Stakeholder's need: transmit data using high bandwidth / high quality means
Wall of Value Objective : To increase fidelity of transmitted data BY using high quality transmission means (e.g. HDTV)

14. Science Knowledge - Direct
Loop : Science knowledge; Stakeholder : Security providers (DoD, NRO, etc); Stakeholder Need : Environmental data
Stakeholder's need: develop security assets of interest to security agencies
Wall of Value Objective : To increase quality of environmental data provided to DoD BY improving inter-agency data transfer capability

14. Science Knowledge - Direct
Loop : Science knowledge; Stakeholder : Security providers (DoD, NRO, etc); Stakeholder Need : Environmental data
Stakeholder's need: produce environmental data of interest to the security agencies
Wall of Value Objective : To increase quality of environmental data provided to DoD BY improving inter-agency data transfer capability

15. Science Knowledge - Indirect
Loop : Science knowledge; Stakeholder : public workforce; Stakeholder Need : jobs
Stakeholder's need: enable job creation of stable jobs through the application / diffusion of scientific knowledge acquired at the SE
Wall of Value Objective : To increase or maintain the number and stability of rewarding jobs BY developing science knowledge

15. Science Knowledge - Indirect
Loop : Science knowledge; Stakeholder : Scientists University and Independent Researchers; Stakeholder Need : Research grants
Stakeholder's need: provide grants to university and independent researchers working on scientific knowledge related to SE
Wall of Value Objective : To increase ability to perform space science research BY receiving grants based on exploration activities

16. Science Knowledge - Political
Loop : Science knowledge; Stakeholder : Public general; Stakeholder Need : to understand the direct, indirect and workforce benefits from science knowledge
Stakeholder's need: increase the public understanding of the benefits of science knowledge developed while exploring
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits of science knowledge BY receiving easily accessible information frequently about scientifically-useful knowledge generated by exploration

17. Science Knowledge - Political
Loop : Science knowledge; Stakeholder : NASA; Stakeholder Need : to inform the public, other stakeholders of the direct, indirect and workforce benefits of science knowledge
Stakeholder's need: develop NASA's political capital explaining benefits of scientific knowledge derived from the SE
Wall of Value Objective : To increase public understanding of direct and indirect benefits of science knowledge BY communicating easily accessible information frequently about scientifically-useful knowledge generated by exploration

18. Science Knowledge - Political
Loop : Science knowledge; Stakeholder : Executive; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from science knowledge
Stakeholder's need: develop executive branch political capital by associating it with scientific knowledge derived from the SE
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from scientifically-useful knowledge generated by exploration

19. Science Knowledge - Political
Loop : Science knowledge; Stakeholder : Congress; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from science knowledge
Stakeholder's need: develop congress political capital by associating it with scientific knowledge derived from the SE
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from scientifically-useful knowledge generated by exploration

20. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Public Curious and interested; Stakeholder Need : learn directly about the human and robotic experience
Stakeholder's need: provide information about the H&RSEE (human and robotic Space Exploration Experience) to the public
Wall of Value Objective : To increase directly available information and its impact on the public BY creating interactive communication with events on the mission

21. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Media general; Stakeholder Need : inform and inspire with broadly interesting and exciting news about exploration
Stakeholder's need: provide interesting news about the H&RSEE
Wall of Value Objective : To increase public attention BY publishing or broadcasting high visibility news events

22. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Media interested in developing space themes (movies, documentaries, theme parks); Stakeholder Need : inform and inspire with high quality commercially successful space themed products and services
Stakeholder's need: provide adequate information about the HR for development of space based themed products and services
Wall of Value Objective : TO promote space themes in entertainment BY increasing positive visibility and access to space exploration events

23. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Media space focused; Stakeholder Need : inform and inspire with timely, accurate and informative news about exploration
Stakeholder's need: provide timely and accurate information about the HR to specialized space relate media
Wall of Value Objective : TO promote comprehensive understanding of progress BY increasing timeliness and breadth of access to events

24. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Educators Public Outreach Institutions (museums); Stakeholder Need : inform and inspire with high quality exhibits which attract and inform
Stakeholder's need: provide adequate HR material for interesting public exhibits including museums
Wall of Value Objective : TO increase quality and quantity of museum exhibits BY transmitting exploration activities, creating interactive opportunities, and preparing summaries

25. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Public general; Stakeholder Need : inspiration and general understanding of the human and robotic experience
Stakeholder's need: inspire the public through sharing of the HR
Wall of Value Objective : To increase the broad knowledge and inspiration of the public BY cooperating with educators, media and direct information delivery services

26. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Executive ; Stakeholder Need : inspiration and specific understanding of the human and robotic experience, and its risks
Stakeholder's need: increase PK by increasing the understanding of the risks of the SE
Wall of Value Objective : To develop public inspiration and identification with exploration objectives BY communicating timely and accurate knowledge about the human and robotic exploration experience and its risks

27. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Congress ; Stakeholder Need : inspiration and specific understanding of the human and robotic experience, and its risks
Stakeholder's need: increase PK by increasing the understanding of the risks of the SE
Wall of Value Objective : To develop public inspiration and identification with exploration objectives BY communicating timely and accurate knowledge about the human and robotic exploration experience and its risks

28. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Educators General (K-12); Stakeholder Need : inform and inspire with informative and well developed teaching materials on exploration
Stakeholder's need: provide inspiring and informative educational materials for K12 about the HR
Wall of Value Objective : To inform and inspire young students BY developing timely, interesting, and easily accessible teaching resources for K-12 educators from human and robotic exploration activities

29. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Educators University and space/technology focused; Stakeholder Need : inform and inspire with specific teaching materials on exploration and access to recent news and results
Stakeholder's need: provide inspiring and informative educational materials with university level about the HR
Wall of Value Objective : To inform and inspire college students BY developing timely, interesting, and easily accessible information and teaching resources for university educators from human and robotic exploration activities

30. Informing And Inspiring - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Other Agencies Educational (DoEd, state Ed depts.); Stakeholder Need : inspire youth into science
Stakeholder's need: help increase offer of adequate technical workforce for other gob agencies by promoting youth to study science through sharing of the HR
Wall of Value Objective : TO promote youth interest for science BY increasing positive visibility of space exploration events

31. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : public youth and future workforce; Stakeholder Need : to be inspired and motivated to study math, science and technology
Stakeholder's need: promote youth participation in technical jobs by sharing the HR
Wall of Value Objective : To inspire youth to study math, science, and technology BY communicating timely, interesting, and easily accessible information about human and robotic exploration activities

32. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Security providers (DoD, NRO, etc) youth and future workforce; Stakeholder Need : to continue to attract a skilled and motivated

workforce

Stakeholder's need: inspire and attract present and future workforce to work for security agencies through sharing of the HR
Wall of Value Objective : To create both the perception and reality of simulating and rewarding science and technology jobs BY increasing positive visibility of results of technology jobs

33. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Other gob agencies (NOAA, DoE, FAA, EPA) youth and future workforce; Stakeholder Need : to continue to attract a skilled and motivated workforce
Stakeholder's need: inspire and attract present and future workforce to work for gob agencies through sharing of the HR
Wall of Value Objective : To attract a skilled and motivated workforce BY communicating knowledge gained through the human and robotic exploration experience to workers currently in and yet to enter the workforce

34. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Commercial youth and future workforce; Stakeholder Need : to continue to attract a skilled and motivated workforce
Stakeholder's need: inspire and attract present and future workforce to work at scientific research positions through sharing of the HR
Wall of Value Objective : To attract a skilled and motivated workforce BY communicating knowledge gained through the human and robotic exploration experience to workers currently in and yet to enter the workforce

35. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Science youth and future workforce; Stakeholder Need : to continue to attract a skilled and motivated workforce
Stakeholder's need: inspire and attract present and future workforce to work at commercial technical ventures through sharing of the HR
Wall of Value Objective : To attract a skilled and motivated workforce BY communicating knowledge gained through the human and robotic exploration experience to workers currently in and yet to enter the workforce

36. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : NASA youth and future workforce; Stakeholder Need : to continue to attract a skilled and motivated workforce
Stakeholder's need: inspire and attract present and future workforce to work at NASA through sharing of the HR
Wall of Value Objective : To attract a skilled and motivated workforce BY communicating knowledge gained through the human and robotic exploration experience to workers currently in and yet to enter the workforce

37. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Explorers ; Stakeholder Need : to be inspired to continue to explore further
Stakeholder's need: provide inspiration to explorers to continue exploring through sharing of the HR
Wall of Value Objective : To inspire explorers to aspire to explore new frontiers BY building upon a steady cadence of successful exploration events

38. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : NASA workforce; Stakeholder Need : to be inspired and motivated in their current jobs
Stakeholder's need: inspire present NASA workforce through the sharing of HR
Wall of Value Objective : To inspire a skilled and motivated NASA workforce BY communicating knowledge gained through the human and robotic exploration experience

39. Inspiration - Direct

Loop : Knowledge of the human and robotic experience; Stakeholder : Commercial entrepreneurial; Stakeholder Need : to be inspired to create new companies based on science and technology
Stakeholder's need: inspire commercial entrepreneurs to the application of new technologies and the creation of new companies
Wall of Value Objective : To inspire the creation of new companies and industries BY demonstrating the application of science and new technologies through human and robotic exploration

40. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Public general; Stakeholder Need : national pride
Stakeholder's need: increase national pride by providing / sharing American identification of the mission
Wall of Value Objective : To generate national pride BY promoting American identity during missions

41. Inspiration - Direct
Loop : Knowledge of the human and robotic experience; Stakeholder : Public general; Stakeholder Need : inspiration
Stakeholder's need: inspire the American public by providing / sharing American identification of the mission
Wall of Value Objective : To inspire public BY increasing American identity during mission

42. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : Congress ; Stakeholder Need : Demonstrate stewardship of public interest; common good
Stakeholder's need: increase the political capital of the congress by allowing it to show its stewardship of the public interest
Wall of Value Objective : TO demonstrate effective stewardship of the public interest BY providing in Congressional hearings NASA operating and exploring performance, space budget execution, and stakeholder satisfaction

43. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : Executive ; Stakeholder Need : Demonstrate stewardship of public interest; common good
Stakeholder's need: increase the political capital of the executive branch by operating with efficiency
Wall of Value Objective : TO demonstrate effective stewardship of the public interest BY delivering NASA operating and exploring performance, space budget execution, and stakeholder satisfaction

44. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : Executive ; Stakeholder Need : progress on agenda
Stakeholder's need: increase the executive branch political capital through a steady cadence of successful HVE (high visibility events)
Wall of Value Objective : To demonstrate progress on the space vision agenda BY delivering a steady cadence of successful results

45. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : Executive ; Stakeholder Need : public approval through favorable press coverage
Stakeholder's need: generate positive press coverage about the SE through HVE
Wall of Value Objective : TO increase favorable press coverage BY increasing positive perception through high visibility events

46. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : Commercial Space Tourism; Stakeholder Need : more interest in flying
Stakeholder's need: increase the interest in space tourism through sharing the excitement of SE
Wall of Value Objective : TO increase the attractiveness of space tourism BY demonstrating the safety and excitement of space exploration

47. Knowledge Of Human/Robotic Experience - Indirect

Loop : Knowledge of the human and robotic experience; Stakeholder : public workforce; Stakeholder Need : jobs
Stakeholder's need: generate additional jobs through the creation of new technology based ventures
Wall of Value Objective : TO increase or maintain the number and stability of rewarding jobs BY inspiring new young entrepreneurs to found and grow new technology based companies

48. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : public workforce; Stakeholder Need : jobs
Stakeholder's need: generate additional jobs by stimulating media education and communications
Wall of Value Objective : TO increase or maintain the number and stability of rewarding jobs BY stimulating media, education and communications

49. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : Educators Primary and Secondary Educators; Stakeholder Need : NASA sponsorship of programs
Stakeholder's need: increase interest in math - science through NASA sponsorship of science programs on schools
Wall of Value Objective : To increase availability of science and engineering opportunities for students BY awarding financial and programmatic support for educationally related activities

49. Knowledge Of Human/Robotic Experience - Indirect
Loop : Knowledge of the human and robotic experience; Stakeholder : Educators Primary and Secondary Educators; Stakeholder Need : revenues and profits
Stakeholder's need: enable a timely coverage of interesting events for benefit of commercial media stakeholders
Wall of Value Objective : To increase revenue and profits BY facilitating timely coverage of interesting news events

50. Knowledge Of Human/Robotic Experience - Political
Loop : Knowledge of the human and robotic experience; Stakeholder : Public general; Stakeholder Need : [covered above]
Stakeholder's need: provide easy to access knowledge about the benefits of HUMAN space exploration
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits of human and robotic exploration BY receiving easily accessible information frequently about the exploration experience

51. Knowledge Of Human/Robotic Experience - Political
Loop : Knowledge of the human and robotic experience; Stakeholder : NASA; Stakeholder Need : to inform the public, other stakeholders of the direct, indirect and workforce benefits of the human and robotic experience
Stakeholder's need: increase NASA political capital through the diffusion of information on the HR
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits of human and robotic exploration BY communicating easily accessible information frequently about the exploration experience

52. Knowledge Of Human/Robotic Experience - Political
Loop : Knowledge of the human and robotic experience; Stakeholder : Executive; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from knowledge of the human and robotic experience
Stakeholder's need: increase the executive branch political capital through the diffusion of benefits of the HR
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from knowledge of the human and robotic exploration experience

53. Knowledge Of Human/Robotic Experience - Political
Loop : Knowledge of the human and robotic experience; Stakeholder : Congress; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from knowledge of the human and robotic experience

Stakeholder's need: increase the congress political capital through the diffusion of benefits of the HR
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from knowledge of the human and robotic exploration experience

54. Non-Space / Non-Security Technology - Direct
Loop : Technology outside NASA; Stakeholder : Public consumers; Stakeholder Need : new products and services
Stakeholder's need: enable the creation of new products through the use of dual use innovative technologies
Wall of Value Objective: To increase number of consumer goods and services BY developing dual use (space - nonspace) technologies/capabilities of interest (autonomy, health, communications, sensors, energy, etc.)

55. Non-Space / Non-Security Technology - Direct
Loop : Technology outside NASA; Stakeholder : Commercial consumer service and product providers; Stakeholder Need : new technology, goods and services to promote market creation/growth, profitability
Stakeholder's need: enable the creation of new profitable markets through the application of dual use technologies
Wall of Value Objective: To support the development of consumer goods BY developing dual use (space - nonspace) technologies/capabilities of interest (autonomy, health, communications, sensors, energy, etc.)

56. Non-Space / Non-Security Technology - Direct
Loop : Technology outside NASA; Stakeholder : Other gob agencies (NOAA, DoE, FAA, EPA, HHS) service and technology providers; Stakeholder Need : more effective development of new technologies to advance their agency mission
Stakeholder's need: enable gob civil agencies to fulfill their missions more efficiently through the application of dual use technologies
Wall of Value Objective: To support the development of agency specific technologies for non-space applications BY developing dual use (space - nonspace) technologies/capabilities of interest (autonomy, health, communications, sensors, energy, etc.)

57. Non-Space / Security Related Technology - Direct
Loop : Technology outside NASA; Stakeholder : Security providers (DoD, NRO, etc) operators and developers; Stakeholder Need : More effective, reliable and affordable non-space security systems
Stakeholder's need: enable the creation of more reliable and affordable NON-space security assets through the application of dual use technologies
Wall of Value Objective: To support development of non-space security systems BY developing dual use (space - nonspace security) technologies/capabilities of interest (autonomy, health, communications, sensors, energy, etc.)

58. Non-Space / Security Related Technology - Direct
Loop : Technology outside NASA; Stakeholder : Commercial Defense contractors; Stakeholder Need : Technology to build more effective, reliable and affordable security systems
Stakeholder's need: enable the creation of more reliable and profitable security products through the use of dual use technologies
Wall of Value Objective: To support development of non-space security systems BY developing dual use (space - nonspace security) technologies/capabilities of interest (autonomy, health, communications, sensors, energy, etc.)

59. Space Technology Outside NASA - Direct
Loop : Technology outside NASA; Stakeholder : Security providers (DoD, NRO, etc) operators and developers; Stakeholder Need : More effective, reliable and affordable space security systems
Stakeholder's need: enable the creation of more reliable and affordable IN-space security assets through the application of SE developed technologies
Wall of Value Objective : To support development of space security systems BY developing technology dual use space technologies (autonomy, guidance, launch, operations, communications, sensors, energy, etc.) and modifying federal regulations to enhance cooperative development

60. Space Technology Outside NASA - Direct
Loop : Technology outside NASA; Stakeholder : Science space asset operators and developers; Stakeholder Need : More effective, reliable and affordable space systems
Stakeholder's need: enable space based science assets to run more reliably and accurately, and be more affordable through the application of SE developed technologies
Wall of Value Objective: To support development of space systems for science BY developing technology dual use space technologies (autonomy, guidance, launch, operations, communications, sensors, energy, etc.)

61. Space Technology Outside NASA - Direct
Loop : Technology outside NASA; Stakeholder : Other gob agencies (NOAA, etc.) space asset operators and developers; Stakeholder Need : More effective, reliable and affordable space systems
Stakeholder's need: allow gob civil agencies to do a more reliable, affordable and effective work through changes on federal regulations that prevent cooperative development
Wall of Value Objective : To support development of space systems for other agencies BY developing technology dual use space technologies (autonomy, guidance, launch, operations, communications, sensors, energy, etc.) and modifying federal regulations to enhance cooperative development

62. Space Technology Outside NASA - Direct
Loop : Technology outside NASA; Stakeholder : Commercial space-based service providers (communications, sensing, tourism, etc); Stakeholder Need : More effective, reliable and affordable space systems
Stakeholder's need: help commercial space based systems to do a more reliable affordable and effective work through the application of Dual Use technologies
Wall of Value Objective : To support development of space systems for other agencies BY developing technology dual use space technologies (autonomy, guidance, launch, operations, communications, sensors, energy, etc.) and modifying federal regulations to enhance cooperative development

63. Space Technology Outside NASA - Direct
Loop : Technology outside NASA; Stakeholder : Commercial Defense/aerospace contractors; Stakeholder Need : More effective, reliable and affordable space systems
Stakeholder's need: share development costs with defense related systems
Wall of Value Objective: To support development of space systems BY developing technology dual use space technologies (autonomy, guidance, launch, operations, communications, sensors, energy, etc.)

64. Space Technology Outside NASA - Direct
Loop : Technology outside NASA; Stakeholder : Commercial Launch service provider; Stakeholder Need : cheaper space transportation
Stakeholder's need: share development and operations costs with commercial launch systems
Wall of Value Objective: To support the development of new launch systems BY developing technology dual use space technologies (autonomy, guidance, launch, operations, etc.)

65. Technology Benefits - Indirect
Loop : Technology outside NASA; Stakeholder : Other gob agencies (DOE) technology developers; Stakeholder Need : to develop advanced energy technology
Stakeholder's need: develop energy technologies of dual use that are of interest to other agencies (nuclear/solar)
Wall of Value Objective : To support development of advanced and nuclear energy technology BY generating demand for technology capabilities (e.g. advanced nuclear reactor technology research) that are of interest of other agencies (e.g. DoE)

66. Technology Benefits - Indirect
Loop : Technology outside NASA; Stakeholder : NASA technology developers; Stakeholder Need : Lower the cost to develop technologies for exploration
Stakeholder's need: use cooperation with other government agencies to lower space exploration costs
Wall of Value Objective : To reduce cost/risk of exploration technology development BY increasing technology commonality and development cooperation with security and other government agencies and modifying federal regulations to allow cooperation

67. Technology Benefits - Indirect
Loop : Technology outside NASA; Stakeholder : Technologist ; Stakeholder Need : Rewarding and stimulating endeavors
Stakeholder's need: improve skills of technology related workforce by providing stimulating challenges
Wall of Value Objective : To increase or maintain the skills of the technology workforce BY developing new technologies

68. Technology Benefits - Indirect
Loop : Technology outside NASA; Stakeholder : public workforce; Stakeholder Need : jobs
Stakeholder's need: generate technology jobs by contracting developments outside NASA
Wall of Value Objective : To increase or maintain the number and stability of rewarding jobs BY developing new technologies

69. Technology Benefits - Political
Loop : Technology outside NASA; Stakeholder : Public general; Stakeholder Need : to understand the direct, indirect and workforce benefits from dual use technology
Stakeholder's need: will build PK by communicating the benefits of dual use technologies
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits of dual use technology BY receiving easily accessible information frequently about the application of exploration-related technologies to other sectors

70. Technology Benefits - Political
Loop : Technology outside NASA; Stakeholder : NASA ; Stakeholder Need : to inform the public, other stakeholders of the direct, indirect and workforce benefits of dual use technology
Stakeholder's need: will build PK by communicating the benefits of dual use technologies
Wall of Value Objective : To increase public understanding of direct and indirect benefits of dual use technology BY communicating easily accessible information frequently about the application of exploration-related technologies to other sectors

71. Technology Benefits - Political
Loop : Technology outside NASA; Stakeholder : Executive ; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from dual use technology
Stakeholder's need: will build PK by communicating the benefits of dual use technologies
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from the application of exploration-related technologies to other sectors

72. Technology Benefits - Political
Loop : Technology outside NASA; Stakeholder : Congress ; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from dual use technology
Stakeholder's need: will build PK by communicating the benefits of dual use technologies
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from the application of exploration-related technologies to other sectors

73. Technology Benefits - Political
Loop : Technology outside NASA; Stakeholder : Congress; Stakeholder Need : Economic leadership
Stakeholder's need: enable US economic leadership by developing technological capabilities
Wall of Value Objective : To enable economic leadership BY funding R&D to develop new technologies and industrial capabilities

74. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Commercial Space resource exploration and development; Stakeholder Need : Cheaper Space Transportation and operational Infrastructure
Stakeholder's need: promote a low cost access to LEO with an acceptable reliability/safety

Wall of Value Objective : To enable the development of commercial space resource BY building Space operational infrastructure and contributing to the development of low cost reliable launch to LEO

75. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Commercial Space Tourism; Stakeholder Need : Cheaper Space Transportation Infrastructure
Stakeholder's need: will build PK by communicating the benefits of dual use technologies
Wall of Value Objective : To support the development of space tourism BY contributing to the development of low cost reliable launch to LEO

76. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Commercial space communications and other commercial information services; Stakeholder Need : Cheaper Space Transportation Infrastructure
Stakeholder's need: will build PK by communicating the benefits of dual use technologies
Wall of Value Objective : TO support the development of space communications and other information services BY contributing to the development of low cost reliable launch to LEO, MEO and GEO

77. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Commercial Space Tourism; Stakeholder Need : [market accessibility, government deregulation], safety improvements
Stakeholder's need: lower the barriers of entry for the access to LEO market to promote space tourism
Wall of Value Objective : TO support the development of space tourism BY developing high reliability/safe launch capability

78. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Commercial Space Communications and other commercial information services; Stakeholder Need : risk reduction in launch phase
Stakeholder's need:
Wall of Value Objective : TO support the development of space communications and other information services BY developing high reliability launch capability

79. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Security providers (DoD, NRO, etc) launch service users; Stakeholder Need : Cheaper Space Transportation Infrastructure
Stakeholder's need:
Wall of Value Objective : To support the development of space based security assets BY contributing to the development of low cost reliable launch to LEO, MEO and GEO, modifying federal regulations and NASA launch policy

80. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Other gob agencies (NOAA, etc) launch service users; Stakeholder Need : Cheaper Space Transportation Infrastructure
Stakeholder's need:
Wall of Value Objective : To support the development of space based assets of those agencies BY contributing to the development of low cost reliable launch to LEO, MEO and GEO, modifying federal regulations and NASA launch policy

81. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Security providers (DoD, NRO, etc) launch service users; Stakeholder Need : Responsive Space Transportation Infrastructure
Stakeholder's need: decrease the lag time to launch for non-programmed launches
Wall of Value Objective : To support the development of responsive space based security assets BY contributing to the development of launch infrastructure capable of responsive launch

82. Benefits To Users Of Launch Systems - Direct
Loop : Launch and space infrastructure; Stakeholder : Security providers (DoD, NRO, etc) information services community; Stakeholder Need : Preserve the possibility of using space communication and information networks for defense applications

Stakeholder's need: be able to share communication infrastructure with defense agencies

Wall of Value Objective : TO support a robust security observation and communication infrastructure BY providing information and communications infrastructure accessible for contingency security operations and modifying federal policy

83. Benefits To Users Of Launch Systems - Direct

Loop : Launch and space infrastructure; Stakeholder : Science launch service users; Stakeholder Need : Cheaper Space Transportation Infrastructure

Stakeholder's need:

Wall of Value Objective : To support the development of space based scientific assets BY contributing to the development of low cost reliable launch to LEO, MEO and GEO

84. Benefits To Users Of Launch Systems - Direct

Loop : Launch and space infrastructure; Stakeholder : International Partners* launch service users; Stakeholder Need : Cheaper Space Transportation Infrastructure

Stakeholder's need: promote participation of international partners by using a launcher open architecture

Wall of Value Objective : To support the development of scientific, economic and security space assets BY contributing to the development of international/open space transportation infrastructure

85. Benefits To Users Of Launch Systems - Direct

Loop : Launch and space infrastructure; Stakeholder : public ; Stakeholder Need : Contribute to the protection of the planet from extraterrestrial threats to existence

Stakeholder's need: help to protect the planet from Extraterrestrial threats by increasing near earth objects detection capabilities

Wall of Value Objective : TO contribute to planetary protection from extraterrestrial threats BY developing approaches to detecting and deflecting near earth objects using exploration infrastructure

86. Benefits To Launch Service Providers - Direct

Loop : Launch and space infrastructure; Stakeholder : Commercial Established US Launch service provider; Stakeholder Need : provide launch services to NASA

Stakeholder's need: promote the creation of a launch service market

Wall of Value Objective : To support robust commercial launch service industry BY creating a market for commercial launch services

87. Benefits To Launch Service Providers - Direct

Loop : Launch and space infrastructure; Stakeholder : Commercial US emerging launch service provider; Stakeholder Need : provide launch services to NASA

Stakeholder's need: lower the barriers of entry for the access to LEO market nationally

Wall of Value Objective : To support the development of an emerging commercial launch service industry BY creating a reliable market for launch services with low barriers to entry

88. Benefits To Launch Service Providers - Direct

Loop : Launch and space infrastructure; Stakeholder : International Partners* launch service providers; Stakeholder Need : provide launch services to NASA

Wall of Value Objective : To increase international participation in NASA launches BY modifying federal regulations and NASA launch policy

89. Benefits To Launch Service Providers - Direct

Loop : Launch and space infrastructure; Stakeholder : NASA launch providers; Stakeholder Need : provide launch services to NASA (a reliable source of revenue)

Stakeholder's need: provide a stable demand for launch service for benefit of launch operators

Wall of Value Objective : To maintain national launch capability BY identifying and funding government unique launch requirements

90. Benefits From Launch Systems - Indirect

Loop : Launch and space infrastructure; Stakeholder : Commercial launch service providers; Stakeholder Need : attract business from foreign markets

Stakeholder's need: increase the competitiveness of the US launch and space infrastructure (LSI) by exposing them gradually to international competition
Wall of Value Objective : To develop new business from foreign sources BY developing an internationally competitive launch service and space system and services sector

91. Benefits From Launch Systems - Indirect
Loop : Launch and space infrastructure; Stakeholder : public workforce; Stakeholder Need : jobs
Stakeholder's need: create jobs in the US LSI by increasing its competitiveness
Wall of Value Objective : To increase or maintain the number and stability of rewarding jobs BY developing a competitive launch service and space system and services sector

92. Benefits From Launch Systems - Indirect
Loop : Launch and space infrastructure; Stakeholder : public workforce; Stakeholder Need : jobs
Stakeholder's need: promote the creation of jobs through new companies that operate on the SLI market
Wall of Value Objective : To increase or maintain the number and stability of rewarding jobs BY enabling creation of new companies that produce space-related goods and services

93. Benefits From Launch Systems - Political
Loop : Launch and space infrastructure; Stakeholder : Public general; Stakeholder Need : to understand the direct, indirect and workforce benefits from launch and space infrastructure
Stakeholder's need: build PK by communicating the benefits of a successful SLI
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits from launch and space infrastructure BY receiving easily accessible information frequently about the applications of an advanced and thriving launch and space infrastructure

94. Benefits From Launch Systems - Political
Loop : Launch and space infrastructure; Stakeholder : NASA ; Stakeholder Need : to inform the public, other stakeholders of the direct, indirect and workforce benefits of launch and space infrastructure
Stakeholder's need:
Wall of Value Objective : To increase public understanding of direct and indirect benefits from launch and space infrastructure BY communicating easily accessible information frequently about the applications of an advanced and thriving launch and space infrastructure

95. Benefits From Launch Systems - Political
Loop : Launch and space infrastructure; Stakeholder : Executive ; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from launch and space infrastructure
Stakeholder's need: build PK by communicating the benefits of a successful SLI
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from an advanced and thriving launch and space infrastructure

96. Benefits From Launch Systems - Political
Loop : Launch and space infrastructure; Stakeholder : Congress ; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from launch and space infrastructure
Stakeholder's need: build PK by communicating the benefits of a successful SLI
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from an advanced and thriving launch and space infrastructure

97. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Engineers Architects; Stakeholder Need : ability to architect missions
Stakeholder's need: provide information about the technology needs that impact the architecture to allow effective architecture design
Wall of Value Objective : To increase confidence in architectural plans BY identifying technology needs that drive architectural decisions

98. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Engineers Architects; Stakeholder Need : ability to architect missions
Stakeholder's need: identify requirements of the Human and Robotic Systems (H&RS) to allow an effective architecture design (EAD)
Wall of Value Objective : To increase confidence in architectural plans BY defining requirements for the human and robotic system

99. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Engineers Technologist; Stakeholder Need : develop technologies
Stakeholder's need: improve tech readiness of H&RS by testing to allow EAD
Wall of Value Objective : To increase technology readiness level BY developing and testing innovative technology

100. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Engineers Technologists; Stakeholder Need : technology validation

Wall of Value Objective : To increase technology readiness level BY validating technology through mission completion

101. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Engineers Developers; Stakeholder Need : validate human and robotic systems and infrastructure

Wall of Value Objective : To demonstrate the operational status BY testing on earth, in LEO and on the moon operational human and robotic systems

102. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Explorers Crew; Stakeholder Need : Operations knowledge
Stakeholder's need: improve operations tech readiness by testing operations in intermediate destinations or surrogates (test on the moon)
Wall of Value Objective : TO increase operations knowledge for the next destination (e.g. Mars) BY performing operations on intermediate surrogate destinations (e.g. Moon)

103. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Engineers Developers; Stakeholder Need : develop human and robotic systems and infrastructure
Stakeholder's need: improve operational status of the H&RS by designing and building a H&RS
Wall of Value Objective : To increase developmental status of the human and robotic systems and infrastructure BY designing and building operational human and robotic systems

104. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Engineers Developers; Stakeholder Need : improve human and robotic systems and infrastructure
Stakeholder's need: provide effective feedback channels from H&RS implementations to design the new H&RS generations
Wall of Value Objective : To improve the operational status BY feeding back developmental and operational knowledge to the design and upgrading of operational human and robotic systems

105. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : NASA; Stakeholder Need : Lower risk of space exploration
Stakeholder's need: improve incrementally the H&RS to reduce risks
Wall of Value Objective : To lower risk of adverse outcomes in space exploration BY developing experience and technical capabilities incrementally

106. Developmental Knowledge For Space Exploration - Direct
Loop : Developmental knowledge; Stakeholder : Commercial enterprises New; Stakeholder Need : contracts
Stakeholder's need: promote the use of new technologies by reducing the scope of modules of the SES
Wall of Value Objective : To increase use of innovative new technologies and concepts BY lowering the work scope/cost of modules in the space exploration system architecture

107. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : NASA ; Stakeholder Need : High-performance workforce
Stakeholder's need: attract a high performance workforce by providing interesting jobs
Wall of Value Objective : TO attract top scientists and engineers BY creating stimulating and rewarding jobs

108. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : Engineers Technologists; Stakeholder Need : Jobs
Stakeholder's need: increase the demand for technology jobs by creating technology development projects
Wall of Value Objective : To increase number of engineering jobs created BY creating technology and development programs

109. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : Engineers Developers; Stakeholder Need : Jobs
Stakeholder's need:
Wall of Value Objective : To increase number of product developer jobs created BY creating technology and development programs

110. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : Engineers Developers; Stakeholder Need : Job Stability
Stakeholder's need: provide job stability by developing programs with a steady cadence
Wall of Value Objective : To increase stability of engineering jobs created BY developing programs progressively over time

111. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : Commercial Developers; Stakeholder Need : revenues and profits
Stakeholder's need: promote broad commercial participation by awarding development contracts outside NASA
Wall of Value Objective : To increase commercial revenue and profit BY awarding development contracts outside of NASA

112. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : Commercial developers; Stakeholder Need : contracts
Stakeholder's need: promote broad commercial participation by lowering the cost of adapting COTS to SE
Wall of Value Objective : To increase participation of a broad base of commercial enterprises BY lowering the cost of adapting commercial products to space exploration use

113. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : Educators University developers; Stakeholder Need : Research grants
Stakeholder's need: increase student participation in the SE by awarding development grants to universities
Wall of Value Objective : To increase participation of students BY awarding technology development grants to universities

114. Developmental Space Exploration Knowledge - Indirect
Loop : Developmental knowledge; Stakeholder : International partners; Stakeholder Need : contracts, revenue and profit
Stakeholder's need: promote international partners participation in development by contracting with them

Wall of Value Objective : To increase international collaboration and partnerships BY awarding contracts to provide products for space exploration

115. Developmental Knowledge For Space Exploration - Indirect
Loop : Developmental knowledge; Stakeholder : NASA HQ; Stakeholder Need : Demonstrate progress on space vision
Stakeholder's need: increase NASA PK by leveraging international partners development collaboration
Wall of Value Objective : To achieve progress in space exploration BY leveraging international partner capabilities

116. Developmental Knowledge For Space Exploration - Political
Loop : Developmental knowledge; Stakeholder : Public general; Stakeholder Need : to understand the direct, indirect and workforce benefits from developmental knowledge
Stakeholder's need: improve NASA PK by communicating the benefits of the development of technologies for use in exploration
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits from developmental knowledge BY receiving easily accessible information frequently about the creation of advanced technologies for application in exploration

117. Developmental Knowledge For Space Exploration - Political
Loop : Developmental knowledge; Stakeholder : NASA ; Stakeholder Need : to inform the public, other stakeholders of the direct, indirect and workforce benefits of developmental knowledge
Stakeholder's need:
Wall of Value Objective : To increase public understanding of direct and indirect benefits from developmental knowledge BY communicating easily accessible information frequently about the creation of advanced technologies for application in exploration

118. Developmental Knowledge For Space Exploration - Political
Loop : Developmental knowledge; Stakeholder : Executive ; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from developmental knowledge
Stakeholder's need:
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from the creation of advanced technologies for application in exploration

119. Developmental Knowledge For Space Exploration - Political
Loop : Developmental knowledge; Stakeholder : Congress ; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from developmental knowledge
Stakeholder's need:
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from the creation of advanced technologies for application in exploration

120. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Crew; Stakeholder Need : Physical health
Stakeholder's need: maintain crew physical health by developing health risk mitigation strategies
Wall of Value Objective : TO maintain health (physical) BY developing operational mitigation strategies (for health risk)

121. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Crew; Stakeholder Need : Psychological health
Stakeholder's need: maintain crew psychological health by developing health risk mitigation strategies
Wall of Value Objective : TO maintain health (psychological) BY developing operational mitigation strategies (for health risk)

122. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Crew; Stakeholder Need : Safety

Stakeholder's need: maintain crew safety by developing risk mitigation strategies
Wall of Value Objective : TO increase safety (human) BY developing operational mitigation strategies (for safety improvement)

123. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : security providers DoD; Stakeholder Need : knowledge about effects (e.g. space habitat, low gravity) on human health
Stakeholder's need: improve knowledge about low gravity and radiation effects on humans for benefit of the DoD
Wall of Value Objective : TO increase knowledge about effects (e.g. space habitat, low gravity) on human health BY running experiments, observations and measurements

124. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Other Government Agencies DoE, HHS; Stakeholder Need : knowledge about effects (e.g. radiation) on human health
Stakeholder's need: improve knowledge about radiation effects on humans for benefit of the DoE
Wall of Value Objective : TO increase knowledge about effects (e.g. radiation) on human health BY running experiments, observations and measurements

125. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Crew; Stakeholder Need : Empowerment to explore
Stakeholder's need: provide explorers freedom to replan for psychological benefits
Wall of Value Objective : TO increase degree of explorer freedom to explore BY developing the ability to plan under uncertainty

126. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Space resource exploration and development; Stakeholder Need : gather more knowledge per mission
Stakeholder's need: provide explorers freedom to replan to maximize the number of mission objectives achieved per mission
Wall of Value Objective : TO increase number of mission objectives per explorer BY developing the ability to plan under uncertainty

127. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Science ; Stakeholder Need : gather more knowledge per mission
Stakeholder's need: provide explorers freedom to replan to maximize the number of science objectives achieved per mission
Wall of Value Objective : TO increase number of science objectives per explorer BY developing the ability to plan under uncertainty

128. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Earth Operators; Stakeholder Need : gather more knowledge per mission

Wall of Value Objective : TO increase number of mission objectives per explorer BY developing the ability to plan under uncertainty

129. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Space resource exploration and development; Stakeholder Need : training of crew
Stakeholder's need: train explorers to maximize the number of objectives achieved per mission
Wall of Value Objective : TO increase number of mission objectives per explorer BY training explorers

130. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Scientists ; Stakeholder Need : Training of crew
Stakeholder's need: train explorers to maximize the number of science objectives achieved per mission
Wall of Value Objective : TO increase number of mission objectives per explorer BY training explorers

131. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Space resource exploration and development; Stakeholder Need : gather more knowledge per mission
Stakeholder's need: provide effective communication between explorers maximize the number of objectives achieved per mission
Wall of Value Objective : TO increase number of mission objectives per explorer BY increasing interaction communication with explorers

132. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Science ; Stakeholder Need : gather more knowledge per mission
Stakeholder's need: provide effective communication with scientists to maximize the number of science objectives achieved per mission
Wall of Value Objective : TO increase number of mission objectives per explorer BY increasing interaction communication with explorers

133. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Explorers Earth Operators; Stakeholder Need : gather more knowledge per mission
Stakeholder's need: provide effective communication with earth operators to maximize the number of objectives achieved per mission
Wall of Value Objective : TO increase number of mission objectives per explorer BY increasing interaction communication with explorers

134. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : NASA; Stakeholder Need : Lower risk of space exploration
Stakeholder's need: lower the risks of the SES by developing capabilities incrementally
Wall of Value Objective : TO lower risk of adverse outcomes in space exploration BY developing experience and operational capabilities incrementally

135. Operational Space Exploration Knowledge - Direct
Loop : Operational Knowledge; Stakeholder : Other Government Agencies FAA; Stakeholder Need : Air and space safety
Stakeholder's need: improve air and space safety by promoting safe space access systems
Wall of Value Objective : TO increase air and space safety BY promoting development of safety systems for commercial access to space

136. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : NASA ; Stakeholder Need : Crew Health & Safety

Wall of Value Objective : TO increase safety (human) BY developing mitigation strategy (for safety improvement)

137. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : NASA; Stakeholder Need : High-performance workforce

Wall of Value Objective : To attracting top scientists and engineers BY creating stimulating and rewarding jobs

138. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : Engineers Technologists; Stakeholder Need : Jobs

Wall of Value Objective : To increase number of engineering jobs created BY creating technology and development programs

139. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : Commercial Developers; Stakeholder Need : revenues and profits

Wall of Value Objective : To increase commercial revenue and profit BY awarding operational contracts outside of NASA

140. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : International partners commercial; Stakeholder Need : contracts, revenue and profit

Wall of Value Objective : TO increase international collaboration and partnerships, revenue and profit BY awarding contracts to provide services for space exploration

141. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : International partners; Stakeholder Need : Develop space-related operational, technical, and industrial capabilities
Stakeholder's need: increase the space operations knowledge by collaborating with intl' partners
Wall of Value Objective : To increase space operational experience BY increasing the number of joint exploration activities

142. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : International partners; Stakeholder Need : Develop space-related operational, technical, and industrial capabilities

Wall of Value Objective : To increase space operational experience BY increasing the number of joint exploration activities

143. Operational Space Exploration Knowledge - Indirect
Loop : Operational Knowledge; Stakeholder : NASA HQ; Stakeholder Need : Demonstrate progress on space vision

Wall of Value Objective : To achieve progress in space exploration BY leveraging international partner capabilities

144. Operational Space Exploration Knowledge - Political
Loop : Operational Knowledge; Stakeholder : Public general; Stakeholder Need : to understand the direct, indirect and workforce benefits from operation knowledge
Stakeholder's need: build PK for NASA by communicating the benefits of operational knowledge
Wall of Value Objective : To increase understanding of direct, indirect, and workforce benefits from operational knowledge BY receiving easily accessible information frequently about the development of new operating concepts and technologies for application in exploration

145. Operational Space Exploration Knowledge - Political
Loop : Operational Knowledge; Stakeholder : NASA; Stakeholder Need : to inform the public, other stakeholders of the direct, indirect and workforce benefits of operational knowledge

Wall of Value Objective : To increase public understanding of direct and indirect benefits from operational knowledge BY communicating easily accessible information frequently about the development of new operating concepts and technologies for application in exploration

146. Operational Space Exploration Knowledge - Political
Loop : Operational Knowledge; Stakeholder : Executive; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from operational knowledge
Stakeholder's need: build PK by communicating the benefits of operational knowledge
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from the development of new operating concepts and technologies for application in exploration

147. Operational Space Exploration Knowledge - Political

Loop : Operational Knowledge; Stakeholder : Congress; Stakeholder Need : to understand and see reflected in public and stakeholder opinion the direct, indirect and workforce benefits from operational knowledge
Stakeholder's need: build PK by communicating the benefits of operational knowledge
Wall of Value Objective : To develop political capital BY appropriating benefits from positive public opinion about the direct, indirect, and workforce benefits from the development of new operating concepts and technologies for application in exploration

148. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive President; Stakeholder Need : Show Progress on space vision
Stakeholder's need: support funding requirements adequately to show progress and build exec branch PK
Wall of Value Objective : TO maintain progress in executing the space vision BY providing appropriate funding levels for space exploration

149. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive President; Stakeholder Need : Show Progress on space vision
Stakeholder's need: propose adequate regulation and policy to show progress and build PK
Wall of Value Objective : TO enable progress in executing the space vision BY defining appropriate US space policy and regulatory priorities

150. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive President; Stakeholder Need : demonstration of US economic, scientific, technological and security leadership
Stakeholder's need: improve economic, scientific, technological and security leadership by ensuring appropriate funding levels
Wall of Value Objective : TO enable US economic, scientific, technological and security leadership BY providing appropriate funding levels for space exploration and ensuring synergistic outcomes in economic, science, etc.

151. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive office of the President; Stakeholder Need : Stewardship of public interest ; common good
Stakeholder's need: enable the exec branch to show stewardship of public good
Wall of Value Objective : TO demonstrate effective stewardship of the public interest BY reviewing NASA operating and exploring performance, space budget execution

152. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive President; Stakeholder Need : Show Progress on space vision
Stakeholder's need: build PK by providing a steady cadence of success
Wall of Value Objective : TO show progress in executing the space vision BY executing a steady cadence of successful results

153. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive ; Stakeholder Need : More effective Constituency representation
Stakeholder's need: build PK by following fiscal and policy priorities determined by the exec branch
Wall of Value Objective : TO represent constituency effectively BY setting policy and fiscal priorities consistent with the good of the nation and the represented desires of the stakeholders

154. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive President; Stakeholder Need : Develop political capital for positive election outcomes
Stakeholder's need: build PK by inspiring the US public
Wall of Value Objective : TO generate favorable election outcomes BY providing inspiration and communicated benefit to the US public

155. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive President; Stakeholder Need : Demonstrate Global Leadership and create Foreign Policy capital
Stakeholder's need: build international PK by implementing a successful SE with international partners collaboration
Wall of Value Objective : To expand global leadership and foreign policy capital BY leading and executing successful international space exploration

156. Executive Branch - Direct
Loop : Political process; Stakeholder : Executive President; Stakeholder Need : Good stewardship of US interests regarding sovereignty issues in space
Stakeholder's need: propose adequate international treaties to enable freedom of action in space
Wall of Value Objective : To maintain freedom of action in space BY developing and negotiating international space treaties and policies of international governing bodies

157. Congress - Direct
Loop : Political process; Stakeholder : Congress ; Stakeholder Need : demonstrate support for space exploration
Stakeholder's need: support funding requirements adequately to show progress and build congress branch PK
Wall of Value Objective : TO maintain progress in executing the space vision BY providing appropriate levels funding for space exploration

158. Congress - Direct
Loop : Political process; Stakeholder : Congress ; Stakeholder Need : demonstrate support for space exploration
Stakeholder's need:
Wall of Value Objective : TO maintain progress in executing the space vision BY concurring and supporting appropriate US space policy and regulatory priorities

159. Congress - Direct
Loop : Political process; Stakeholder : Congress ; Stakeholder Need : Stewardship of public interest ; common good

Wall of Value Objective : TO demonstrate effective stewardship of the public interest BY reviewing NASA operating and exploring performance, space budget execution, and constituency satisfaction

160. Congress - Direct
Loop : Political process; Stakeholder : Congress ; Stakeholder Need : demonstration of US economic, scientific, technological and security leadership

Wall of Value Objective : TO enable US economic, scientific, technological and security leadership BY providing appropriate levels funding for space exploration and ensuring synergistic outcomes in economic, science, etc.

161. Congress - Direct
Loop : Political process; Stakeholder : Congress; Stakeholder Need : More effective Constituency representation
Stakeholder's need: use its budget according to priorities at the nation, state, district and stakeholder level of different representatives
Wall of Value Objective : To represent constituency effectively BY setting fiscal priorities consistent with the good of the nation and the state or district, and the represented desires of the stakeholders

162. Congress - Direct
Loop : Political process; Stakeholder : Congress ; Stakeholder Need : Develop political capital for positive election outcomes
Stakeholder's need: build PK for congressmen by providing tangible benefits to representatives states and districts

Wall of Value Objective : TO promote reelection BY facilitating communicated and tangible benefit to the state or district

163. Congress - Direct
Loop : Political process; Stakeholder : Congress; Stakeholder Need : Good stewardship of US interests regarding sovereignty issues in space
Stakeholder's need: propose adequate treaties that help maintain US sovereignty in space
Wall of Value Objective: To maintain US sovereignty in space BY ratifying treaties and overseeing international space policy relevant to sovereignty of extraterrestrial territory.

164. International Partners - Direct
Loop : Political process; Stakeholder : International Partners* ; Stakeholder Need : Political influence in the international arena
Stakeholder's need: increase the influence of US foreign policy by increasing the participation of international partners
Wall of Value Objective : To increase political influence in the international arena BY increasing international partners' ability to collaborate in space exploration

165. NASA - Direct
Loop : Political process; Stakeholder : NASA HQ; Stakeholder Need : consistent policy, budgetary support
Stakeholder's need: build PK for NASA by a consistent execution of budget
Wall of Value Objective : To maintain or increase policy support and funding for NASA BY demonstrating consistent successful execution of obligated funds

166. NASA - Direct
Loop : Political process; Stakeholder : NASA HQ; Stakeholder Need : consistent policy, budgetary support
Stakeholder's need: build PK for NASA by communicating effectively the benefits of SE to congress and exec branch
Wall of Value Objective : TO maintain or increase policy support and funding for NASA BY conveying effectively to the Congress and Executive the benefits of exploration

167. NASA - Direct
Loop : Political process; Stakeholder : NASA HQ; Stakeholder Need : other internal NASA processes: strategy/planning
Stakeholder's need: build NASA PK by designing and implementing a successful strategic SE plan
Wall of Value Objective : TO enable successful achievement of the space vision and strategy BY executing effective strategic and operational planning

168. NASA - Direct
Loop : Political process; Stakeholder : NASA directorates; Stakeholder Need : other internal NASA processes: execution
Stakeholder's need: build NASA PK by aligning directorate interest/capabilities with NASA's SE strategy
Wall of Value Objective : TO enable successful exploration BY aligning directorate interests and capabilities with the agency's exploration vision and strategy

169. NASA - Direct
Loop : Political process; Stakeholder : NASA Institutions; Stakeholder Need : other internal NASA processes: institutions
Stakeholder's need: build NASA PK by aligning internal institutions processes with NASA's SE strategy
Wall of Value Objective : TO enable successful exploration BY aligning internal institutions and processes with the agency's exploration vision and strategy

170. NASA - Direct
Loop : Political process; Stakeholder : NASA workforce; Stakeholder Need : other internal NASA processes: workforce
Stakeholder's need: build NASA PK by aligning workforce priorities with NASA's SE strategy

Wall of Value Objective : TO enable successful exploration BY aligning NASA workforce competencies and priorities with the agency's exploration vision and strategy

8.2. Survey Questions – Main body Kano Questionnaire

What follows is the complete list of 23 groups of 3 questions each group that was posed to the Stakeholder representatives. As stated on section 6.5not every surveyees were presented with a maximum of 12 groups of 3 questions, extracted from this list, according to a table presented in the previously mentioned section.

1 The Space Exploration System DOES increase the development of long term strategic plans and planning knowledge for the space exploration
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the development of long term plans
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the development of long term strategic plans and planning knowledge for the space exploration
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

2 The Space Exploration System DOES increase the development and planning knowledge for the space exploration for short-term attainable results
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the development focused on short term results objectives
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the development and planning knowledge for the space exploration for short-term attainable results
1 = Not important at all

3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

3 The Space Exploration System DOES increase the positive perception about the congress and executive branch by associating them with successful exploration events
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the positive perception about the congress and executive branch
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the positive perception about the congress and executive branch by associating them with successful exploration events
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

4 The Space Exploration System DOES increase the positive perception about NASA by associating it with successful exploration events
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the positive perception about NASA
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the positive perception about NASA by associating it with successful exploration events
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important

9 = Extremely important

5 The Space Exploration System DOES increase its efforts to make the Space Exploration results understandable outside the technical community, relative to the current effort?
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase its efforts to make the Space Exploration results understandable
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase its efforts to make the Space Exploration results understandable outside the technical community, relative to the current effort?
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

6 The Space Exploration System DOES promote the positive perception of the technical workforce by showing the results of its work
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT promote the positive perception of the technical workforce
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System promote the positive perception of the technical workforce by showing the results of its work
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

7 The Space Exploration System DOES increase the foreign influence of US through an

increased cooperation with exploration partners and through adequate freedom of access to space treaties
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the foreign influence of US through
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the foreign influence of US through an increased cooperation with exploration partners and through adequate freedom of access to space treaties
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

8 The Space Exploration System DOES increase foreign citizens positive perception about their governments by allowing their participation in the Space Exploration System
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase foreign citizens positive perception about their governments
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase foreign citizens positive perception about their governments by allowing their participation in the Space Exploration System
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

9 The Space Exploration System DOES increase its efforts to make the Space Exploration funding adequate, steady and manageable without external intervention

A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase its efforts to make the Space Exploration funding adequate
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase its efforts to make the Space Exploration funding adequate, steady and manageable without external intervention
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

10 The Space Exploration System DOES promote sharing of asset ownership (including development costs) with other parties (civil or military agencies, foreign governments)
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT promote sharing of asset ownership with other parties
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System promote sharing of asset ownership (including development costs) with other parties (civil or military agencies, foreign governments)
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

11 The Space Exploration System DOES re-align NASA's funding priorities by reducing other programs' funding to acquire funds for space exploration
A=This would be very helpful for us.
B=This is a basic requirement for us

C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT re-align NASA's funding priorities
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System re-align NASA's funding priorities by reducing other programs' funding to acquire funds for space exploration
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

12 The Space Exploration System DOES create interesting and inspiring content for educational use
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT create content for educational use
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System create interesting and inspiring content for educational use
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

13 The Space Exploration System DOES increase the production of interesting media content, for use by news, entertainment, and popular science media distributors
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the production media content

A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the production of interesting media content, for use by news, entertainment, and popular science media distributors
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

14 The Space Exploration System DOES provide scientific data, which is as easily and quickly accessible
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT provide scientific data
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System provide scientific data, which is as easily and quickly accessible
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

15 The Space Exploration System DOES promote SECURITY related dual use technologies
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT promote SECURITY related dual use technologies
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us

E=This would be a major problem for us

How important is that the Space Exploration System promote SECURITY related dual use technologies
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

16 The Space Exploration System DOES develops SECURITY qualified space access
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT develops SECURITY qualified space access
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System develops SECURITY qualified space access
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

17 The Space Exploration System DOES increase presence and freedom of action in space
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase presence and freedom of action in space
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase presence and freedom of action in space
1 = Not important at all
3 = Somewhat important
5 = Important

7 = Very important
9 = Extremely important

18 The Space Exploration System DOES provide earth security relevant data acquired from space
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT provide earth security relevant data
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System provide earth security relevant data acquired from space
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

19 The Space Exploration System DOES increase launch capabilities, measured as a lower cost per kg, and failure rate
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase launch capabilities
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase launch capabilities, measured as a lower cost per kg, and failure rate
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

20 The Space Exploration System DOES promote space related commercial activities, including communications, tourism, and resource extraction

A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT promote space related commercial activities
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System promote space related commercial activities, including communications, tourism, and resource extraction
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

21 The Space Exploration System DOES increase the acquisition of commercially developed, commercially contracted and COTS space infrastructure for use on exploration goals
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the acquisition of commercial space infrastructure
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the acquisition of commercially developed, commercially contracted and COTS space infrastructure for use on exploration goals
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

22 The Space Exploration System DOES increase the developmental and operational knowledge about space exploration
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us

D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT increase the developmental and operational knowledge
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System increase the developmental and operational knowledge about space exploration
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

23 The Space Exploration System DOES promote NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to non-space uses).
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

What if it DOES NOT promote NON SECURITY related dual use technologies
A=This would be very helpful for us.
B=This is a basic requirement for us
C=This would not affect us
D=This would be a minor inconvenience for us
E=This would be a major problem for us

How important is that the Space Exploration System promotes NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to non-space uses).
1 = Not important at all
3 = Somewhat important
5 = Important
7 = Very important
9 = Extremely important

8.3. Values of the Objectives to Stakeholders matrix used in the Space Exploration example.

Table 39, Table 40, Table 41, Table 42, Table 43, and Table 44 present the information used to generate Matrix J.

		X												
Sv Q	**JD**	**Objective**	**Exp**	**Cong**	**Exec**	**Intl**	**Sec**	**Econ**	**Sci**	**Tech**	**NASA**	**Media**	**Educ**	**Vot**
1	1.1	Develop strategic long term planning for the Space Exploration System	-0.929	-0.844	-0.955	-0.645	-0.741	0.000	-0.896	-0.659	-0.793	0.000	0.000	-0.782
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	-0.711	-0.847	-0.955	-0.912	-0.980	0.000	0.617	-0.807	-0.587	-0.948	-0.629	-0.810
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.000	-0.924	-0.779	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	2.2	Increase positive perception about NASA (political capital)	-0.621	0.000	0.000	0.000	0.000	0.000	0.000	-0.888	-0.845	0.000	0.000	0.000
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	-0.714	0.000	0.000	-0.997	0.000	-0.833	-0.768	-0.864	-0.798	-0.798	-0.964	0.000
6	2.4	Motivate-recognize technical workforce	-0.942	0.000	0.000	-0.888	0.000	0.000	-0.858	-0.892	-0.664	0.000	0.000	0.000
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.000	-0.854	-0.913	1.072	-0.933	0.000	0.000	0.000	0.000	0.000	0.000	-0.832
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.000	0.000	0.000	-0.784	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	-0.775	0.000	0.000	0.000	0.000	-0.567	-0.819	-0.741	-0.915	0.000	-0.826	0.000
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	-0.790	-0.924	0.000	0.000	-1.020	0.000	-0.944	0.000	-0.788	0.000	0.000	0.000
11	3.3	Align NASA funding priorities towards space exploration	-0.552	-1.000	-1.016	0.000	0.147	0.000	0.565	-0.879	0.904	0.000	0.000	0.000
12	4.1	Create interesting and inspiring content for educational use	0.000	-0.574	-0.763	0.000	0.000	0.000	-0.746	-0.879	0.000	-0.787	-0.700	-0.769
13	4.2	Create entertaining and inspiring content for media	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.853	-0.667	-0.845
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.000	0.000	0.000	-0.812	0.000	0.000	-0.844	0.000	0.000	-0.911	-0.669	0.000
15	6.11	Create security related dual use technologies	0.000	0.000	-0.851	0.810	-0.831	0.000	0.000	0.000	0.000	0.000	0.000	-0.827
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.000	-0.703	-0.684	0.223	-0.664	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	6.13	Provide space presence and freedom of action	0.000	-0.867	-0.804	0.676	-0.656	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	6.14	Provide space acquired earth relevant security data	0.000	0.000	-0.897	0.000	-0.950	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	-0.842	0.000	0.000	0.000	-0.911	-0.879	-0.740	-0.748	-0.845	0.000	0.000	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	-0.817	-1.012	-0.835	0.000	-0.700	-0.739	0.000	0.000	-1.043	-0.209	-0.821	-0.839
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	-0.605	0.000	0.000	-0.761	0.000	-0.731	0.000	-0.908	0.780	0.000	0.000	0.224
22	6.5	Develop space infrastucture development and operational knowledge	-0.975	0.000	0.000	0.000	-0.800	-0.920	0.000	-1.005	-0.826	0.000	0.000	0.000
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.000	-0.782	-0.836	0.000	0.000	-0.889	-0.948	-0.649	0.000	0.000	0.000	-0.850

Table 39. Shows precursor data to build Matrix J. These are the answers to the dysfunctional question posed to the stakeholder groups or variable X. The table is structured as the transpose of the actual Matrix J, for a better graphical format. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research.

Sv Q	JD	Importance Objective	Exp	Cong	Exec	Intl	Sec	Econ	Sci	Tech	NASA	Media	Educ	Vot
1	1.1	Develop strategic long term planning for the Space Exploration System	0.900	0.250	0.250	0.900	0.500	0.000	0.900	0.750	0.900	0.900	0.900	0.750
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.750	0.750	0.750	0.500	0.500	0.000	0.900	0.900	0.500	0.500	0.500	0.500
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.000	0.750	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	2.2	Increase positive perception about NASA (political capital)	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.900	0.900	0.000	0.000	0.000
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.900	0.000	0.000	0.500	0.000	0.500	0.500	0.750	0.900	0.900	0.900	0.000
6	2.4	Motivate-recognize technical workforce	0.900	0.000	0.000	0.900	0.000	0.000	0.900	0.500	0.500	0.000	0.000	0.000
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.000	0.900	0.500	0.500	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.500
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.000	0.000	0.000	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.900	0.000	0.000	0.000	0.000	0.500	0.900	0.900	0.750	0.000	0.900	0.000
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.750	0.900	0.000	0.000	0.900	0.000	0.750	0.000	0.900	0.000	0.000	0.000
11	3.3	Align NASA funding priorities towards space exploration	0.750	0.900	0.900	0.000	0.500	0.000	0.900	0.900	0.750	0.000	0.500	0.000
12	4.1	Create interesting and inspiring content for educational use	0.000	0.500	0.750	0.000	0.000	0.000	0.750	0.900	0.000	0.900	0.900	0.750
13	4.2	Create entertaining and inspiring content for media	0.000	0.000	0.000	0.000	0.000	0.750	0.000	0.000	0.000	0.750	0.900	0.900
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.000	0.000	0.000	0.900	0.000	0.000	0.900	0.500	0.000	0.750	0.500	0.000
15	6.11	Create security related dual use technologies	0.000	0.000	0.500	0.500	0.900	0.000	0.000	0.000	0.000	0.000	0.000	0.900
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.000	0.900	0.900	0.750	0.750	0.000	0.500	0.000	0.000	0.000	0.000	0.000
17	6.13	Provide space presence and freedom of action	0.000	0.500	0.500	0.900	0.750	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	6.14	Provide space acquired earth relevant security data	0.000	0.000	0.500	0.000	0.500	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.900	0.000	0.000	0.000	0.900	0.900	0.750	0.900	0.750	0.000	0.000	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.750	0.750	0.500	0.000	0.900	0.750	0.000	0.000	0.750	0.750	0.500	0.900
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.900	0.000	0.000	0.500	0.000	0.750	0.000	0.500	0.900	0.750	0.000	0.900
22	6.5	Develop space infrastucture development and operational knowledge	0.900	0.000	0.000	0.000	0.900	0.500	0.000	0.900	0.900	0.000	0.000	0.000
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.000	0.750	0.900	0.000	0.000	0.900	0.900	0.500	0.000	0.000	0.000	0.500

Table 40. Shows precursor data to build Matrix J. These are the answers to the importance question posed to the stakeholder groups or variable W. The table is structured as the transpose of the actual Matrix J, for a better graphical format. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research.

		X . Imp – expected value												
Sv Q	**JD**	**Objective**	**Exp**	**Cong**	**Exec**	**Intl**	**Sec**	**Econ**	**Sci**	**Tech**	**NASA**	**Media**	**Educ**	**Vot**
1	1.1	Develop strategic long term planning for the Space Exploration System	-0.836	-0.211	-0.239	-0.581	-0.370	0.000	-0.807	-0.494	-0.713	0.000	0.000	-0.587
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	-0.533	-0.635	-0.717	-0.456	-0.490	0.000	0.555	-0.727	-0.294	-0.474	-0.314	-0.405
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.000	-0.693	-0.584	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	2.2	Increase positive perception about NASA (political capital)	-0.559	0.000	0.000	0.000	0.000	0.000	0.000	-0.800	-0.760	0.000	0.000	0.000
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	-0.642	0.000	0.000	-0.499	0.000	-0.416	-0.384	-0.648	-0.718	-0.718	-0.868	0.000
6	2.4	Motivate-recognize technical workforce	-0.848	0.000	0.000	-0.800	0.000	0.000	-0.772	-0.446	-0.332	0.000	0.000	0.000
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.000	-0.768	-0.456	0.536	-0.467	0.000	0.000	0.000	0.000	0.000	0.000	-0.416
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.000	0.000	0.000	-0.705	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	-0.698	0.000	0.000	0.000	0.000	-0.283	-0.737	-0.667	-0.686	0.000	-0.743	0.000
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	-0.593	-0.832	0.000	0.000	-0.918	0.000	-0.708	0.000	-0.709	0.000	0.000	0.000
11	3.3	Align NASA funding priorities towards space exploration	-0.414	-0.900	-0.914	0.000	0.073	0.000	0.509	-0.791	0.678	0.000	0.000	0.000
12	4.1	Create interesting and inspiring content for educational use	0.000	-0.287	-0.572	0.000	0.000	0.000	-0.560	-0.791	0.000	-0.708	-0.630	-0.577
13	4.2	Create entertaining and inspiring content for media	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	-0.640	-0.600	-0.761
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.000	0.000	0.000	-0.730	0.000	0.000	-0.760	0.000	0.000	-0.683	-0.335	0.000
15	6.11	Create security related dual use technologies	0.000	0.000	-0.425	0.405	-0.748	0.000	0.000	0.000	0.000	0.000	0.000	-0.744
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.000	-0.632	-0.616	0.168	-0.498	0.000	0.000	0.000	0.000	0.000	0.000	0.000
17	6.13	Provide space presence and freedom of action	0.000	-0.434	-0.402	0.608	-0.492	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	6.14	Provide space acquired earth relevant security data	0.000	0.000	-0.448	0.000	-0.475	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	-0.758	0.000	0.000	0.000	-0.820	-0.791	-0.555	-0.673	-0.633	0.000	0.000	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	-0.613	-0.759	-0.418	0.000	-0.630	-0.555	0.000	0.000	-0.782	-0.157	-0.411	-0.755
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	-0.545	0.000	0.000	-0.380	0.000	-0.548	0.000	-0.454	0.702	0.000	0.000	0.202
22	6.5	Develop space infrastucture development and operational knowledge	-0.877	0.000	0.000	0.000	-0.720	-0.460	0.000	-0.904	-0.744	0.000	0.000	0.000
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.000	-0.586	-0.752	0.000	0.000	-0.800	-0.853	-0.325	0.000	0.000	0.000	-0.425

Table 41. Shows precursor data to build Matrix J. These are the expected values of the answers to the dysfunctional question compounded by their importance posed to the stakeholder groups. The table is structured as the transpose of the actual Matrix J, for a better graphical format. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research.

		X . imp – standard deviation												
Sv Q	**JD**	**Objective**	**Exp**	**Cong**	**Exec**	**Intl**	**Sec**	**Econ**	**Sci**	**Tech**	**NASA**	**Media**	**Educ**	**Vot**
1	1.1	Develop strategic long term planning for the Space Exploration System	0.116	0.003	0.018	0.005	0.021	0.012	0.015	0.009	0.017	0.005	0.003	0.011
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.014	0.012	0.011	0.026	0.037	0.006	0.000	0.038	0.004	0.029	0.026	0.026
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.002	0.029	0.009	0.008	0.006	0.012	0.010	0.003	0.010	0.001	0.003	0.002
4	2.2	Increase positive perception about NASA (political capital)	0.000	0.004	0.002	0.009	0.004	0.007	0.002	0.015	0.052	0.007	0.001	0.004
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.031	0.001	0.006	0.037	0.002	0.007	0.012	0.023	0.002	0.009	0.024	0.001
6	2.4	Motivate-recognize technical workforce	0.037	0.006	0.004	0.007	0.004	0.008	0.006	0.013	0.001	0.002	0.006	0.000
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.005	0.005	0.006	0.021	0.017	0.001	0.003	0.006	0.004	0.003	0.007	0.036
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.008	0.000	0.001	0.003	0.001	0.000	0.010	0.004	0.007	0.003	0.007	0.003
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.003	0.000	0.009	0.002	0.003	0.001	0.060	0.009	0.004	0.003	0.043	0.005
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.005	0.007	0.001	0.005	0.037	0.000	0.013	0.003	0.052	0.000	0.001	0.002
11	3.3	Align NASA funding priorities towards space exploration	0.010	0.005	0.012	0.001	0.006	0.012	0.044	0.019	0.057	0.004	0.003	0.005
12	4.1	Create interesting and inspiring content for educational use	0.004	0.003	0.020	0.005	0.004	0.003	0.022	0.002	0.006	0.043	0.005	0.044
13	4.2	Create entertaining and inspiring content for media	0.002	0.002	0.007	0.001	0.003	0.007	0.012	0.001	0.012	0.062	0.060	0.005
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.002	0.001	0.007	0.013	0.008	0.011	0.023	0.002	0.006	0.010	0.009	0.007
15	6.11	Create security related dual use technologies	0.004	0.004	0.023	0.010	0.050	0.000	0.005	0.003	0.004	0.005	0.002	0.014
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.009	0.031	0.028	0.011	0.001	0.007	0.000	0.000	0.000	0.003	0.000	0.003
17	6.13	Provide space presence and freedom of action	0.003	0.007	0.003	0.046	0.007	0.002	0.008	0.006	0.000	0.002	0.001	0.005
18	6.14	Provide space acquired earth relevant security data	0.000	0.001	0.018	0.002	0.015	0.001	0.000	0.009	0.001	0.002	0.001	0.009
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.015	0.000	0.001	0.004	0.015	0.035	0.014	0.018	0.001	0.003	0.004	0.002
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.037	0.010	0.014	0.007	0.003	0.034	0.001	0.005	0.030	0.001	0.041	0.077
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.002	0.000	0.011	0.001	0.009	0.022	0.004	0.015	0.033	0.001	0.003	0.002
22	6.5	Develop space infrastucture development and operational knowledge	0.056	0.008	0.006	0.004	0.004	0.026	0.012	0.061	0.018	0.001	0.002	0.005
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.002	0.037	0.005	0.010	0.007	0.027	0.002	0.008	0.002	0.007	0.005	0.009

Table 42. Shows precursor data to build Matrix J. These are the standard deviations of the answers to the dysfunctional question compounded by their importance posed to the stakeholder groups. The table is structured as the transpose of the actual Matrix J, for a better graphical format. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research.

		Y . Imp – expected value												
Sv Q	**JD**	**Objective**	**Exp**	**Cong**	**Exec**	**Intl**	**Sec**	**Econ**	**Sci**	**Tech**	**NASA**	**Media**	**Educ**	**Vot**
1	1.1	Develop strategic long term planning for the Space Exploration System	-0.168	0.189	0.168	0.193	0.456	0.000	0.986	0.721	-0.228	0.779	0.702	0.619
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.000	0.162	-0.155	0.453	0.412	0.000	-0.741	0.866	0.107	0.433	0.446	0.506
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.000	-0.165	-0.137	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
4	2.2	Increase positive perception about NASA (political capital)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.691	-0.171	0.000	0.000	0.000
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.970	0.000	0.000	0.453	0.000	0.425	0.548	0.686	-0.171	-0.162	0.000	0.000
6	2.4	Motivate-recognize technical workforce	-0.169	0.000	0.000	0.777	0.000	0.000	0.789	0.000	0.347	0.000	0.000	0.000
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.000	0.735	-0.118	-0.395	0.421	0.000	0.000	0.000	0.000	0.000	0.000	0.394
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.000	0.000	0.000	0.197	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	-0.186	0.000	0.000	0.000	0.000	0.407	0.166	0.886	0.130	0.000	0.735	0.000
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.435	0.742	0.000	0.000	0.604	0.000	0.000	0.000	0.732	0.000	0.000	0.000
11	3.3	Align NASA funding priorities towards space exploration	0.156	0.742	0.199	0.000	0.384	0.000	-0.506	0.589	-0.496	0.000	0.403	0.000
12	4.1	Create interesting and inspiring content for educational use	0.000	0.384	0.541	0.000	0.000	0.000	0.130	0.522	0.000	0.584	-0.212	0.000
13	4.2	Create entertaining and inspiring content for media	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.599	-0.182
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.000	0.000	0.000	0.000	0.000	0.000	-0.214	0.330	0.000	0.699	0.420	0.000
15	6.11	Create security related dual use technologies	0.000	0.000	0.373	-0.434	0.188	0.000	0.000	0.000	0.000	0.000	0.000	0.727
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.000	0.671	0.671	-0.380	0.176	0.000	-0.381	0.000	0.000	0.000	0.000	0.000
17	6.13	Provide space presence and freedom of action	0.000	0.000	0.438	-0.836	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000
18	6.14	Provide space acquired earth relevant security data	0.000	0.000	0.438	0.000	-0.110	0.000	0.000	0.000	0.000	0.000	0.000	0.000
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	-0.179	0.000	0.000	0.000	0.186	-0.216	0.657	-0.163	0.550	0.000	0.000	0.000
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	-0.159	0.675	0.000	0.000	0.653	0.420	0.000	0.000	-0.128	0.645	0.443	0.765
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	-0.126	0.000	0.000	0.439	0.000	0.149	0.000	0.474	-0.539	0.703	0.000	0.645
22	6.5	Develop space infrastucture development and operational knowledge	-0.203	0.000	0.000	0.000	0.654	0.379	0.000	-0.180	-0.192	0.000	0.000	0.000
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.000	0.528	0.726	0.000	0.000	0.770	0.574	0.000	0.000	0.000	0.000	0.444

Table 43. Shows precursor data to build Matrix J. These are the expected values of the answers to the functional question compounded by their importance posed to the stakeholder groups. The table is structured as the transpose of the actual Matrix J, for a better graphical format. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research.

Sv Q	JD	Y . imp – standard deviation Objective	Exp	Cong	Exec	Intl	Sec	Econ	Sci	Tech	NASA	Media	Educ	Vot
1	1.1	Develop strategic long term planning for the Space Exploration System	0.006	0.049	0.029	0.018	0.015	0.003	0.000	0.087	0.003	0.013	0.051	0.032
2	1.2	Develop strategies for short-term attainable results for the Space Exploration System	0.002	0.005	0.000	0.051	0.009	0.001	0.024	0.028	0.002	0.000	0.068	0.031
3	2.1	Increase domestic positive perception about the Congress and Executive Branch (political capital)	0.006	0.001	0.004	0.006	0.005	0.004	0.005	0.001	0.001	0.004	0.007	0.003
4	2.2	Increase positive perception about NASA (political capital)	0.003	0.003	0.008	0.002	0.005	0.002	0.005	0.031	0.001	0.007	0.000	0.001
5	2.3	Increase understanding of the Space Exploration System and technology in general to non-technical groups	0.017	0.001	0.007	0.003	0.001	0.012	0.018	0.003	0.003	0.001	0.001	0.003
6	2.4	Motivate-recognize technical workforce	0.003	0.010	0.001	0.069	0.004	0.005	0.001	0.014	0.001	0.002	0.002	0.000
7	2.5	Increase US foreign policy influence (international political capital) on earth and space (sovereignty) issues	0.000	0.033	0.001	0.009	0.012	0.009	0.007	0.001	0.011	0.005	0.002	0.013
8	2.6	Increase foreign citizens posive perception about their governments by promoting their participation in the Space Exploration	0.000	0.006	0.003	0.016	0.001	0.006	0.002	0.006	0.004	0.002	0.002	0.003
9	3.1	Promote funding for the Space Exploration System that is adequate, steady and manageable without external intervention	0.000	0.005	0.001	0.011	0.006	0.015	0.027	0.101	0.012	0.000	0.007	0.004
10	3.2	Promote funding efficiencies through sharing of investments and asset ownership	0.039	0.001	0.002	0.010	0.031	0.010	0.003	0.006	0.013	0.003	0.002	0.002
11	3.3	Align NASA funding priorities towards space exploration	0.009	0.017	0.019	0.006	0.007	0.003	0.021	0.022	0.032	0.006	0.024	0.008
12	4.1	Create interesting and inspiring content for educational use	0.001	0.030	0.024	0.004	0.001	0.013	0.002	0.004	0.009	0.043	0.004	0.009
13	4.2	Create entertaining and inspiring content for media	0.003	0.004	0.006	0.003	0.002	0.008	0.002	0.003	0.003	0.002	0.014	0.006
14	5.1	Provide easily and quickly accesible data for use on science knowledge	0.000	0.000	0.003	0.004	0.003	0.002	0.006	0.031	0.000	0.054	0.001	0.001
15	6.11	Create security related dual use technologies	0.000	0.003	0.002	0.002	0.031	0.001	0.003	0.006	0.002	0.002	0.010	0.117
16	6.12	Improve security qualified space access and infrastructure (US independent and clearence protected)	0.002	0.004	0.006	0.023	0.006	0.004	0.000	0.001	0.005	0.003	0.007	0.003
17	6.13	Provide space presence and freedom of action	0.011	0.004	0.024	0.007	0.000	0.004	0.001	0.002	0.003	0.001	0.005	0.001
18	6.14	Provide space acquired earth relevant security data	0.000	0.007	0.009	0.000	0.001	0.001	0.000	0.000	0.008	0.013	0.002	0.011
19	6.2	Improve space access measured as cost and risk reductions (commercial and exploration but not security)	0.000	0.004	0.002	0.009	0.000	0.003	0.005	0.009	0.020	0.003	0.008	0.005
20	6.3	Promote space related commercial activities, including communications, tourism, and resource extraction	0.003	0.077	0.002	0.009	0.047	0.019	0.006	0.000	0.003	0.066	0.015	0.035
21	6.4	Promote commercial acqusition of space good & service (includes COTS and entrepreneurial except space tourism)	0.001	0.007	0.007	0.016	0.009	0.018	0.005	0.025	0.020	0.014	0.004	0.057
22	6.5	Develop space infrastucture development and operational knowledge	0.005	0.001	0.001	0.003	0.055	0.032	0.003	0.002	0.002	0.003	0.004	0.006
23	6.6	Create NON SECURITY related dual use technologies (technologies developed for space exploration that can be applied to other non-security uses)	0.006	0.022	0.023	0.005	0.009	0.025	0.013	0.001	0.006	0.005	0.006	0.009

Table 44. Shows precursor data to build Matrix J. These are the standard deviations of the answers to the functional question compounded by their importance posed to the stakeholder groups. The table is structured as the transpose of the actual Matrix J, for a better graphical format. The data on this table is conceptual, used to illustrate the example of space exploration. While it has been extracted from an internal survey at the MIT-Draper Concept Evaluation and Refinement Research group, it is not result of extensive surveys, as adviced by our research.

9. Table of figures

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11. Bibliography

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