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VALUE BASED ARCHITECTURE SELECTION

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ABSTRACT

In the design of complex systems serving a broad group of stakeholders, it can be difficult to prioritize objectives for the architecture. We postulate that it is possible to make architectural decisions based on consideration of stakeholder value delivery. We introduce the concept of using network models linked to architecture models to investigate value delivery. These models are used to examine the connectivity and sensitivity of a test NASA architecture to value delivery. We conclude that a limited subset of NASA's outputs are available for discriminating between architectures. For the architecturally significant outputs, we show that the value space is broad enough to support architecture discrimination. In this manner, we show how value considerations can be used to structure the design space before critical technical decisions are made to narrow it.

1. Introduction

In the design of complex systems serving a broad group of stakeholders, it can be difficult to prioritize objectives. Government agencies embody this challenge – within a network of other agencies with overlapping purposes, they are held accountable to a variety of different proxy interests by the Executive. Indeed, it is clearly stated in the charters of many agencies that technical success is but one of many success criteria – NASA's charter notes its responsibilities with respect to creation of new markets, encouragement of commercial space activities, and international cooperation[1].

In search of a cogent approach to prioritizing objectives, we define the objective function of NASA as maximizing the sustainability of space exploration. We define sustainability using a four-fold approach: valued benefits to all stakeholders[2], affordability, risk management that communicates residual risks to stakeholders[3], policy robustness to improve the chances of success in a changing political environment[4].

In this paper, we put forth the hypothesis that the first pillar, valued benefits, can be used to discriminate between architectures for space exploration. To test this hypothesis, we created a model of all the generic types of benefits provided to NASA's stakeholders. We then identify six key architecture values, using NASA's Exploration Systems Architecture Study as a baseline. We propose a framework for connecting these architecture values to benefit delivery, and for determining the sensitivity of the connection. If this connection can be made, we postulate that a more deliberate consideration of value delivery to stakeholders will result in an analytical method for prioritizing objectives.

This work draws heavily on stakeholder theory. Rising interest in corporate governance issues has renewed interest in stakeholder theory[5]. However, where for-profit enterprises use a single metric for maximizing stakeholder value, public agencies have to first define a measurable concept of value. We define value as the benefit as perceived by the receiving party, and we showcase a method for capturing this information numerically. Stakeholder analysis provides a number of tools for identifying stakeholders and their needs, but has traditionally been separated from requirements engineering – indeed, the ESAS study only references the importance of consulting and communicating with stakeholders, but does not mention how the result of consultations should be incorporated with the technical analysis[6].

There are several reasons for which requirements analysis has historically been separated from stakeholder analysis. In many cases, the identification of requirements is levied from the customer-specified technical requirements or past technical systems, without examining where needs derive from. Furthermore, there is often a selection bias which tends to highlight technical needs because they can be more easily quantified as requirements. Requirements analysis has therefore not mated well with stakeholder analysis in the past, because there are difficulties translating between the output of stakeholder analysis and the inputs for requirements analysis.

Our method uses a network of value flows to capture the information from stakeholder analysis, namely the flow of benefit delivery between stakeholders. We then propose a series of proximate metrics to connect architectural values to value flows. These connections are evaluated by enumerating a set of possible architectures. Previous work has demonstrated this technique on transportation architecture for NASA's Vision for Space Exploration[7] – a space of 1162 possible architectures was generated using an executable model. Whereas the previous work used technical metrics to reduce the design space to a manageable set of architectures for in-depth study, the approach we demonstrate here investigates non-technical metrics.

2. Value Model

In order to capture the stakeholder context in which NASA operates, we created a executable network model. A brief introduction to the previous modeling efforts[2] is given below.

Stakeholders were identified by asking the question *'who are the beneficiaries of the space exploration system of systems?'*. Eight major groups of stakeholders were identified:

- US People
- Educators
- Media
- US Executive & Congress
- International Partners
- US Security Community
- US Economy
- Science

Each stakeholder was then modeled as an input-output black box. The stakeholder's inputs are derived from consideration of stakeholder needs, while the outputs are the result of the organization using it processes and assets to accomplish its mission. For example, Science Data is a necessary input to the Science community, and 'Stable and Rewarding Employment' is an output of the Economy.

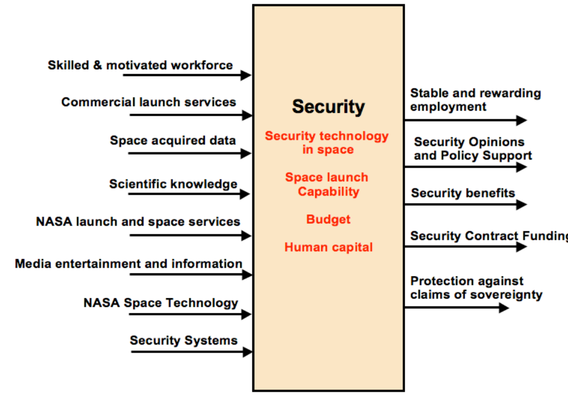
The network model was then created by connecting the stakeholder outputs to the relevant inputs, forming a closed-circuit. The term value flow is used to refer to edges in the model. We classed these value flows into 6 categories:

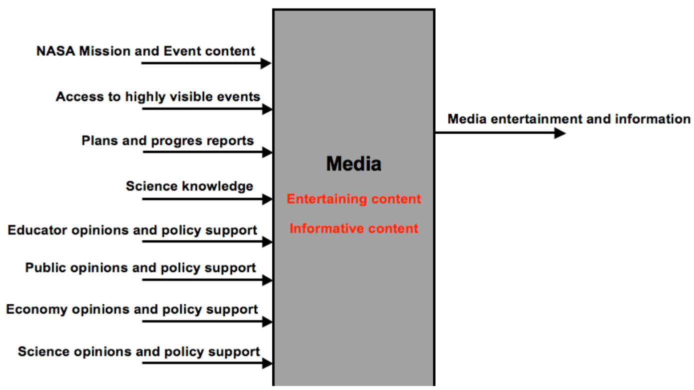
1) Policy – Flows that relate to the motivation or transaction of policy decision. Ex. Political Support, International Agreements.
2) Money – Flows that provide primarily funds. Ex. Corporate Taxes, NASA Market Funding.
3) Workforce – The flow of employment and job-related expertise between different stakeholders. Ex. Skilled Workforce, Stable and Rewarding Employment.
4) Technology – Sharing of technology between stakeholders. Ex. Space Technology flowing from NASA to the Economy.
5) Systems – The transaction of actual systems, both hardware, software, and processes. Ex. International Space Systems.
6) Knowledge – The transmission of knowledge from one stakeholder to another. Ex. NASA provides Space Resource Knowledge to the Economy.

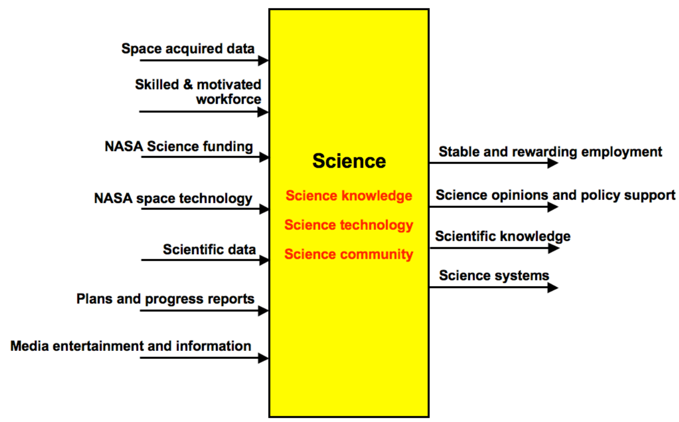
The use of flows signals our intention to use stocks to represent the key attributes with which each stakeholder is concerned. The names of the stocks are inscribed in the stakeholder input-output diagrams of Figure 1. The connectivity of flows to individual stocks is not illustrated in the diagram to minimize the visual complexity – however, each input and output flow is connected to a minimum of one stock.

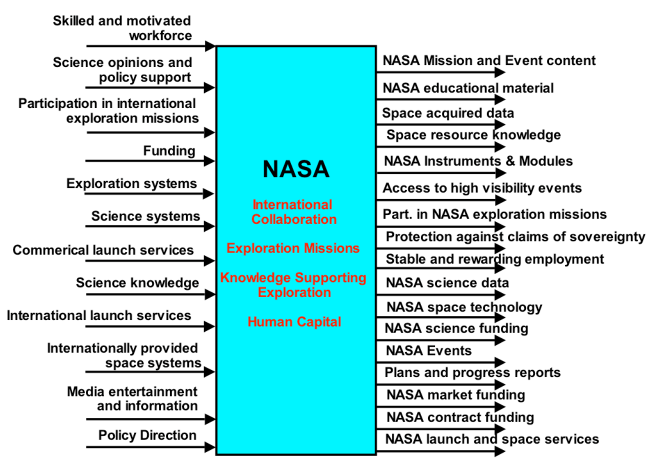
Our aim in modeling the value context around NASA is to capture the steady-state conditions which represent the space of reasonable value delivery mechanisms. In this manner, we avoid the complexity of event-driven simulations (which would, for example, capture an the individual spike in media coverage associated with a given Shuttle launch). Given that the eventual goal is to link the value model to an architectural model, the space of flows should enable the full space of an exploration architecture to be captured in. This is addressed in depth in Section 5: The Link to Architecture.

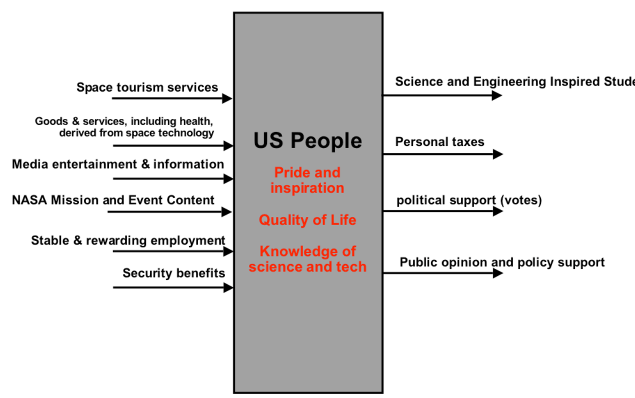
While a Systems Dynamics approach is suggested by the use of the terms Stocks and Flows, we do not explicitly compute the accumulation of Stocks, nor do we make efforts to explicitly differentiate between positive and negative feedback structures. However, we are interested in the role that Structure plays in determining the inputs to NASA. Given the number of connections in our model, we focus on enumerating all of the possible feedback

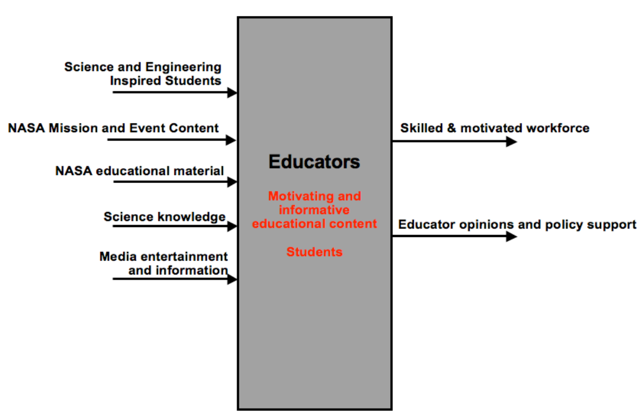


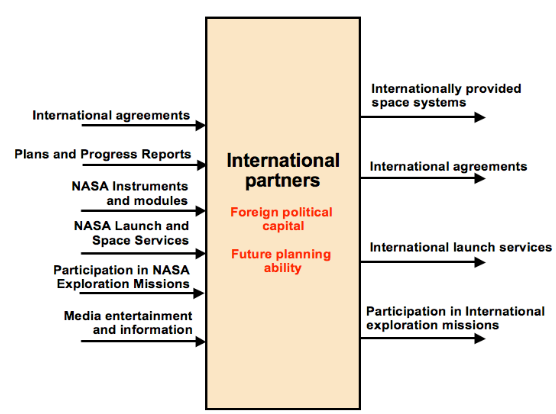












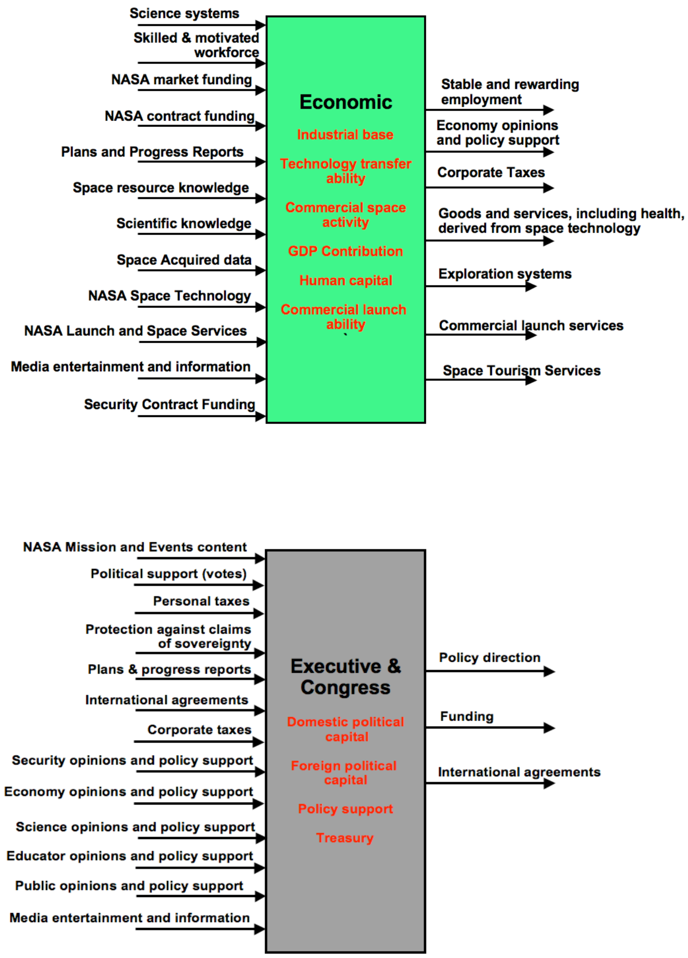


Figure 1 Stakeholder input-output models

loops that create the Structure, and methods for selecting the loops than are likely to dominate behavior.

3. Value Loops

This section describes how the value model was implemented in an executable environment, and what type of data was overlaid in order to compute which loops will dominate the behavior.

It is useful to define precisely what we mean by the term 'value loop': a set of connected value flows forming a chain that begins and ends at the same node (stakeholder). In this manner, a loop could be a reciprocal transaction between two stakeholder, or a network 10 edges long. In this paper, we focus exclusively on loops that begin and end with NASA. One of the key observations from our previous modeling work was that the majority of the important loops are circuitous at best, and pass through a number of stakeholders. For example, the loop that describes how NASA inspires students to study and work in technical fields, which in turn returns positive feedback about NASA to the Executive, is 7 edges long. If stakeholders in this system don't operate on a transaction basis, then how can the decisions related to outputs be reasonably modeled?

Understanding how value loops operate is key to creating the link to architecture. Presuming that an exploration architecture creates outputs that flow from NASA to stakeholder, we could create a limited 'stakeholder impact' model based only on the direct effects of NASA outputs. However, in consideration of the long value loops mentioned above, this would result in a grossly incomplete model of the value delivered to each stakeholder.

We then take the rationale a further step forward. Presuming that we had a method for capturing the indirect value delivery to stakeholders, we could begin to consider the indirect value paths that lead back to NASA. Given that value delivery to NASA will necessarily be result of satisfied stakeholders, this might potentially offer a point function about which we could optimize architectural decisions – maximizing the value delivery to NASA[8]. This idea will be investigated further when we examine the link to architecture in Section 5.

In search of a valuation methods for loops, we had several requirements:

1) Valuation of individual flows, rather than loops as a whole. Given that our aim was to discover which loops dominate, it would not be appropriate to specify those loops up front.
2) Easy computation of loop value based on combination of flow values.
3) Method should enable the valuation of loops having different flow types. For example, how should one value the input of policy direction against the input of funding ?
4) Loop valuation should be independent of loop length. This suggests that a product rule would be favorable over an addition rule.

We selected a modified Kano analysis[9] to value each edge. The Kano methodology was originally used to classify product attributes from the consumer's perspective. The three Kano categories are:

1) Must Have: Stakeholder is discontent if the flow is not present, and neutral if it is satisfied. For example, *Funding* for NASA is a Must Have flow.
2) One Dimensional: Stakeholder is linearly more content the more of the attribute is present. For example, gas mileage in a car. In our model, *Science Knowledge*, flowing from Science to Educators, is a one dimensional attribute.
3) Exciter: Stakeholder is neutral if the attribute is not present, but is non-linearly satisfied if the attribute is present. For example, an LCD monitor on a fridge falls in this category. In our model, the provision of *Space Tourism Services* from the US Economy to the US People is an exciter attribute.

By using the Kano methodology, we circumvent the problem trading between different value flows by specifying all inputs in terms of their criticality to the stakeholder in question.

We augment the Kano methodology by specifying an 'Importance' rating for each flow. While the Kano categories classify the shape of the attribute's satisfaction curve, the Importance rating specifies where on the curve. For example, a CD Player could be classified as an Exciter attribute for a car, but the user might specify that attribute at 'Low Importance' in light of budget constraints. We used an anchored scale for importance, varying linearly between 'Not At All Important' to 'Extremely Important', shown below in Figure 2.

The next step is then to create numerical equivalents for these two scales. We accomplished by defining two numbers:

1) Kano Multiplier: At equivalent importance ratings, how many of each Exciter flows are equivalent to a One Dimensional flow, or equivalently, how many One Dimensional flows represent the same value delivery as a Must Have flow. This could be determined using Conjoint Analysis with each stakeholder, but for our purposes here, the Multiplier was set at 3, after consulting several test cases.
2) Importance Equivalence: For two flows having adjacent Kano categories, what spread in importance rating will cause the same value delivery to the stakeholder? We set our scale such that the maximum on the Importance scale ('Extremely Important') is equivalent to the next Kano category up, but having the second lowest Importance rating ('Somewhat Important'). This is graphically represented below.

In addition to these two parameters, we enforced that the valuation should be normalized. We then have the property that a chain of value flows can be multiplied together and retain the same scale, which satisfies loop requirements #2 and #4.

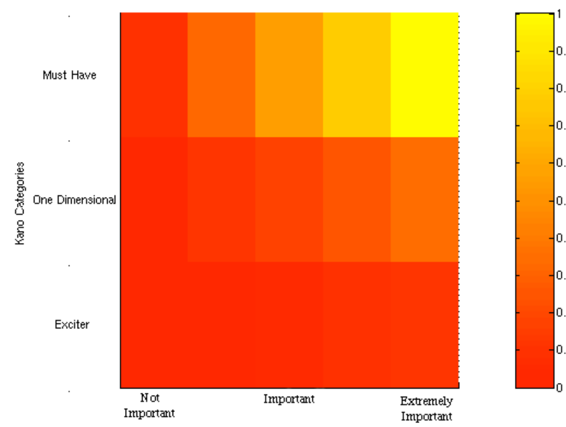


Figure 2 Value Flow Weighting Scale Equivalencies

Using this methodology, we created data for each edge in the model in-house. In ideal situation, this data would come directly from stakeholder interviews, or from surrogate stakeholders. However, our interest was to test the methodology, and to determine the dominant trends of behavior, rather than to produce exact data.

We used an Object Process Network (OPN)[10] to capture the value flow network and the associated Kano data. OPN is a graphical programming language for generating architectures – it enables us to create a network, with information recorded at each of the nodes (stakeholders), and logic on each edge of the model. The net result is that we can enumerate all of the possible value loops in the model, by creating all of the possible input-output pairings at stock sub-nodes.

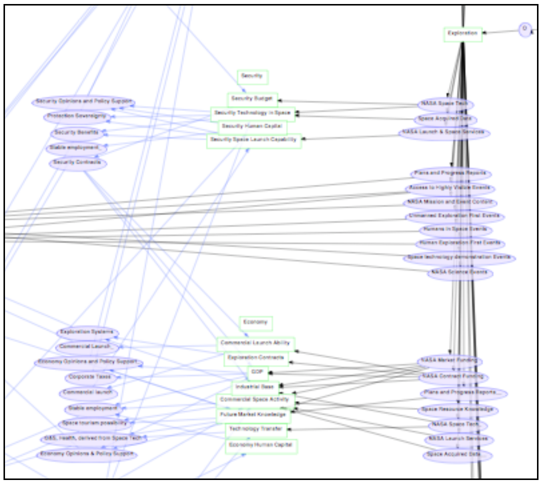


Figure 3 Subsection of the OPN network model showing value flow from NASA to the Security and Economy stakeholders

Some of the more interesting results from the loop analysis are presented briefly in Section 4: Loop Results.

4. Loop Results

Analysis of the results from the model provide something of a sanity-check for the data inputted to the model. Additionally, future computations relating to the link to architecture will be based on a sub-network of the current model, pruned using information contained in the existing data.

The top ranked value loops are shown in Figure 6.

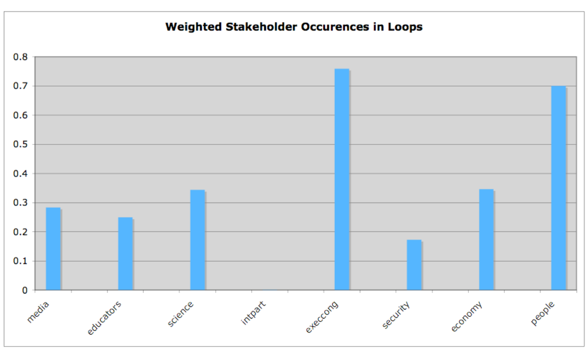


Figure 4 Weighted Stakeholder Occurrences in Loops

We also computed statistics on the most common nodes in the system (Figure 4). A weighted average of the frequency at which a node appears in a given value loop (regardless of where in the loop it occurred) was used, where the rankings of the loops was used as the weighting.

With respect to NASA the Executive and the US People are clearly the most important stakeholders. International partners are noticeably absent (although non-zero), primarily because the valuation data assumes that international participation is not necessary but desirable, which makes all of its outputs Exciters, significantly decreasing their rankings.

A similar weighted average was computed for the outputs from NASA, as well as for the inputs to NASA, shown in Figure 5.

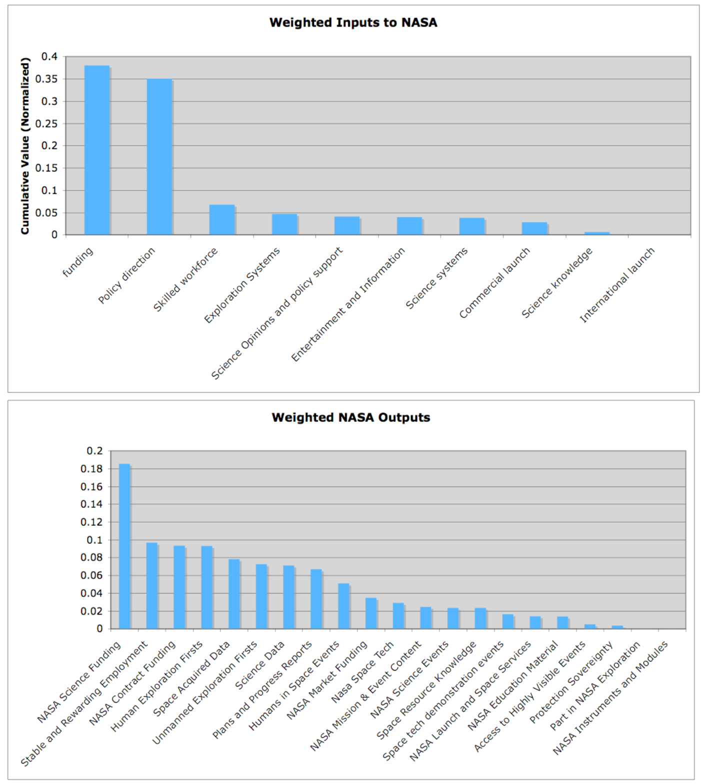


Figure 5 Weighted Inputs and Outputs of the Value Model

It is interesting to note that Science Funding figures so prominently in NASA's outputs, and yet Science is at best an average stakeholder. First, we note that in this model, the Science community, even that within NASA, has been abstracted to a group outside NASA. Therefore, Science Funding is one of the key methods by which Science Knowledge, on the most popular intermediate flows, is stimulated. Second, Science Funding is more powerful than the other major NASA input to Science – Science Data – because Science Funding

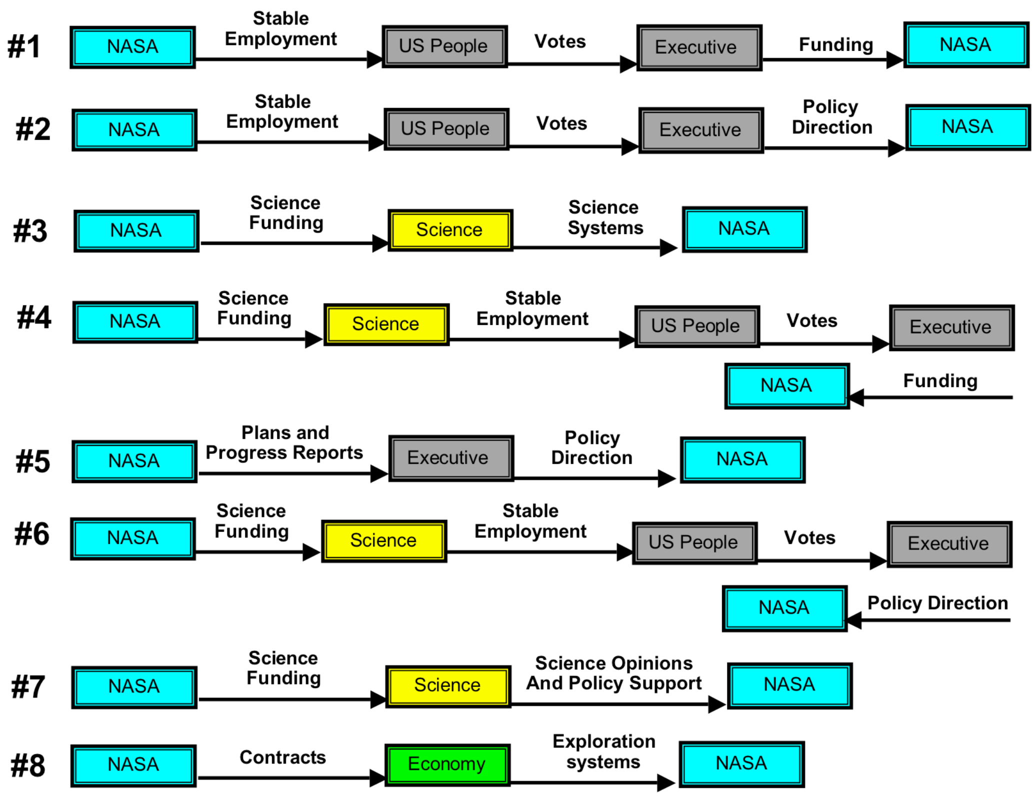


Figure 6 Top Ranked Value Loops

stimulates all three Science stocks (Community, Technology, and Knowledge), whereas Science Data stimulates only one.

The model's ranking of NASA's inputs is relatively straightforward. It is interesting that in the aggregate, the model indicates NASA's values Science Knowledge at a relatively low level, despite Science Knowledge's impressive role an enabler for other stakeholders in the model. It is worth reminding the reader that this model does not incorporate an internal model of NASA. The likelihood is that the external inputs which serve to provide both outputs as well as foster internal capabilities (like Science Knowledge) would see their rankings improve dramatically.

5. Link to Architecture

Now we begin to address the fundamental hypothesis of this paper: will architecture variables differentiate between value flows?

In order to test this hypothesis, we have chosen 6 key architecture variables from the ESAS report, and created a framework for evaluating their impact on value delivery.

The link to architecture is divided into three sections:

1) Architecture Variables
2) Proximate Metrics
3) Propagation in the Value Model

5.1 Architecture Variables

The six variables chosen were:

Heavy Lifter Launch Capability : The LEO injection mass (in MT) capability of the heavy lift launch vehicle.

Global Access : Whether or not the architecture caries a requirement to be able to land anywhere on the moon. While all landing sites are accessible on entry, the propulsive cost / time required to perform ascent varies between landing latitudes.

Crew Size : The number of crew members landed on the moon.

Duration of Stay : The number of days the crew is on the lunar surface, during a sortie mission.

For a campaign schedule with varying sortie durations, the average duration would be used.

Science Mass : The cargo mass in kilograms dedicated to science instruments per sortie mission. This does not include rover or spacesuit mass. It is recognized that the actual boundary between science systems and the remainder of the vehicle will be fuzzy (for example, in the case where an instrument draws its power from the lander, does one consider the fractional battery use as science mass?), but at the current level of abstraction, this is a reasonable approximation

Rover Range : The one day maximum distance from the base that the rover can drive, including battery considerations and estimated part lifetimes. Note that the total distance traveled by the rover on a straight out-and-back mission would be double the Rover Range, as we have defined it.

Using these 6 variables, we first took a holistic look at the model, and asked which value flows we would expect the variables to affect. A tree diagram of those connections is showm in Figure 7.

In Figure 7, we note that the architecture variables do not span the space of network flows. Only 7/21 possible flows are affected by our subset of test architecture variables. We observe that NASA's output flows fall into three categories: Architecturally- determined Flows, Schedule-determined Flows, and Organizational Decisions. For example, NASA's ability to provide Plans and Progress Reports is primarily driven by the schedule set for the campaign, whereas the amount of Educational Material is almost purely an organizational decision, made irrespective of the architecture. Of the 21 flows we've identified, we label 14 as Architecturally-determined Flows, implying that 1/3 of the value space will not discriminate between architectures.

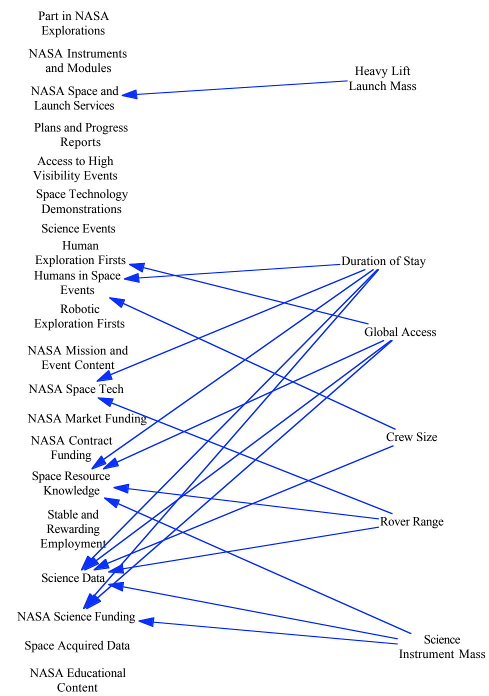


Figure 7 Connectivity of architecture variables (at right) to NASA output value flows (at left)

The 7 flows which we postulate will not be affected by the architecture are:

- Stable and Rewarding Employment
- NASA Mission and Event Content
- Protection against claims of sovereignty over planetary bodies by other nations
- NASA Educational Content
- Access to High Visibility Events
- NASA Instruments and Modules to International Partners
- Plans and Progress Reports

The proximate metrics outlined in the following sections will define how widely the remaining 2/3 do discriminate.

5.2 Proximate Metrics

Proximate metrics are used to connect the architecture variables to the value flow delivered. We first highlight some of the desirable qualities of such metrics, and we then describe the metrics that were created.

The function of a metric is to bring together a number of different types of information into a single value, on which useful decisions can be made.

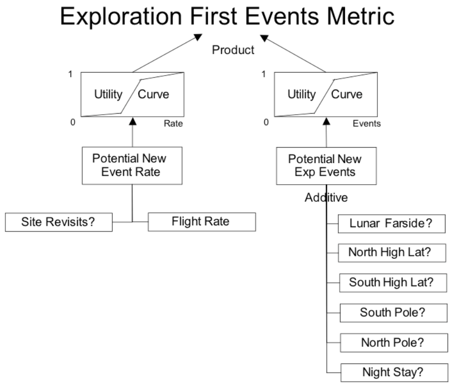
In order to make decisions, we enforce that each metric should condense the inputs to a single value, for ease of later computation. While we do intend to propagate this scheme through all values flows in the model, and have constrained each flow to be a uni-dimensional quantity, we do not intend to further condense multiple flows into aggregate 'Total Stakeholder Satisfaction' values. The intent is that the architect's decision space should act at the same level of complexity as the original value flow model.

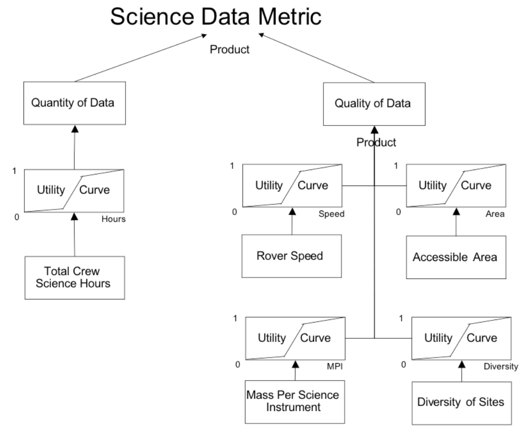
In order to examine different ways of combining these different types of information, we first delineate between additive versus multiplicative metrics. Additive metrics suggest the component inputs are all tradable, or in other words, each have the same potential to deliver value. Product metrics, particularly normalized ones (defined on [0,1]), suggests co-dependency of components, in that the product cannot be maximized unless all components are active. Product metrics have the unique quantity that doubling a component's contribution doubles the output. Both additive and multiplicative metrics are employed in our process, depending on the situation.

Finally, with a view to enabling 'useful' decisions, we submit that some form of stakeholder input is required. Ideally, the metric used coincides with a physical value of interest to the stakeholder, on which the stakeholder can then offer an anchored opinion of value. For example, for NASA Launch and Space Services, the key concern for receiving parties is the launch mass the lifter is capable of. If the value flow is insufficiently concrete to enable this, then stakeholder information needs to be captured at the input component level. We use the concept of the utility curve to encapsulate both types of stakeholder input. The utility curve maps the input value (as the independent variable) to the perceived value to the stakeholder. Monotonically increasing utility curves are used, defined by the 0%, 10%, 90% and 100% value levels, with linear interpolation in between. In this manner, we can represent value delivery with clear thresholds (such as Humans in Space Events, which saturate media coverage above certain frequencies of events) by defining the 100% value mark at the threshold, as well as representing open-ended value delivery flows (such as 'Science Data'), where a marginal increase will continue to deliver marginal value, by setting the 90% or 100% levels to unachievable levels. Given that the purpose here is to enable relative comparisons between architectures, we are more concerned that the metric captures the full space of input ranges (and therefore all architecture value movements with relevant value impacts are captured) than we are with defining the precise upper bound at which a stakeholder can be said to be 100% satisfied with the value delivered.

The two examples we use to illustrate our methodology are the metrics for Human Exploration First Events and for Science Data.

Our Exploration First Events metric captures the two most basic aspects, the number of exploration events, and the frequency. Given that the test architecture we chose is limited to the sortie phase, we use destinations and night stays as simple proxies for exploration events. The number of events is then passed through a utility curve, which represents the number of events within a campaign which the public would perceive as 'exploration', before the mission type would become routinized to the extent that further missions would represent 'Humans in Space Events', rather than 'Exploration First Events'. The 90% threshold for this curve was set at 3 events for this phase of the campaign. The campaign's ability to provide these events depends on the global access architecture variable, as well as the duration variable. The events are totaled, and then passed through the utility curve. We calculate the frequency of new destination visits based on a flight rate and the extent to which the architecture builds in site revisit requirements / assumptions. Given that neither of these is trades in our test architecture space, both are set to reasonable maximum values. The frequency and quantity aspects of this metric are modeled as a product, in that flight frequency and the capability to go to new places are required to produce Exploration Firsts.





The Science Data metric abstracts across all types of data (visual survey, sample return, imaging, etc.) by capturing a Quality and a Quantity aspect. We make the simplifying assumption that the Quantity of Data is proportional to the available crew science hours, which in turn is influenced by crew number and , mission duration. The bounds on Quantity of Data are determined using a 'operating hours per instrument' guideline, where the 90% threshold is set at 10h/instrument (well in excess of the Apollo computed average of 1.23h/experiment, assuming a 60% science & experiment time fraction [11,12]). This calculation does not yet incorporate planned autonomous operation - for example, some of the Apollo experiments operated for 45h or longer. Quality of data is a multiplicative composition of the accessible area (defined by rover range), rover speed (which enhances choice and flexibility in the areas to study), diversity of landing sites (defined by the Global Access variable), and Mass Per Science Instrument (MPI). Each of these components has an individual utility curve, given that a generalized metric for the quality of science data (like Signal to Noise Ratio) is not available. For example, the MPI 90% value was set to 100kg, double the Apollo 16 average of 49kg per instrument. The Quality and Quantity metrics are normalized on [0,1], and then multiplied to yield the Science Data completion value.

The remaining proximate metrics were developed in a similar manner, each aligned to a particular value flow. In this manner, we calculate a [0,1] completion value for each of the NASA output value flows. The next section explains how the state of stakeholder stocks are calculated using our network model.

5.3 Propagation in the Value Model

Our value model already contains all of the connections necessary to trace a NASA output to all of the stakeholders impacted, but it does not yet contain equations for calculating flows or stocks that are a function of NASA outputs.

Predictably, we chose normalized scales for stocks and flows, in order to facilitate computation. Given that connectivity is already established by our network model, we only have to determine the relative weightings of the inputs.

For stock inputs, we use the Kano-Importance values as weights. While we had originally used a separate set of weights, we found that the difference between our decisions for weightings and those computed from the Kano-Importance were roughly equal to the error we were introducing (on the order of 20%). Using the Kano-Importance data does introduce a significant new assumption: given that Kano-Importance data is derived by asking the stakeholder group as a whole how they would value a given input, we are assuming individual stocks have the same preference distributions, owing to their specific function. However, for our purposes, this suffices.

For flow inputs, we assign our own values to the weightings of the stocks. Given that the stocks were created with the outputs in mind, the vast majority of outflows depend on only one stock. For those that depend on more than one stock, the dominant weighting is an even distribution.

Given that we now have information, solving the system is the final step. The equations described above are initially formulated into a linear system of coupled equations of the form AX = 0, where X is a vector of all of the value flows and stocks (including the known values), and A is the coefficient matrix.

6. Test Architecture Value Results and Discussion

From our set of test architecture values, we are chiefly interested in how broadly they span the value space described. Identification of value flows that are insensitive to changes in architecture values sheds light on both prioritization in the design process, as well as opportunities for greater stakeholder interaction. Given that we have not yet introduced budget or performance constraints, we do not select architectures at this stage – we merely examine the minimum and maximums of the value space.

The first test of our model is to ask how great a variation in NASA outputs it yields, shown in the diagram below.

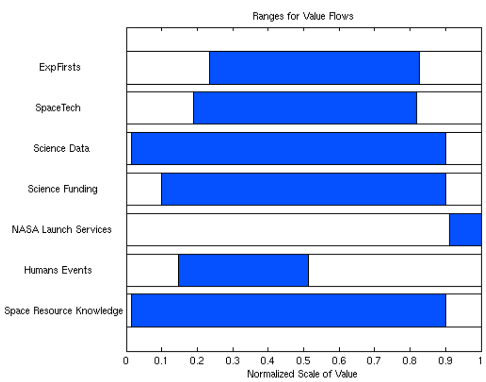
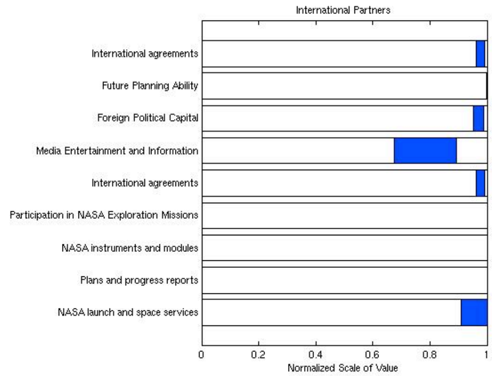
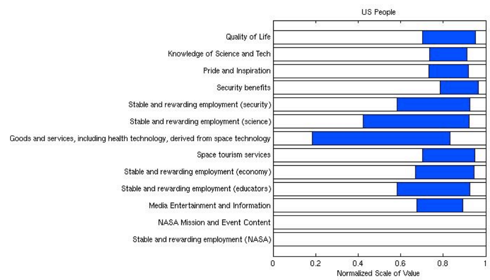


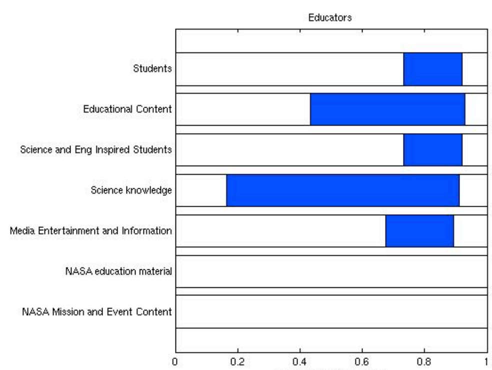
Figure 8 NASA Output Flow Ranges

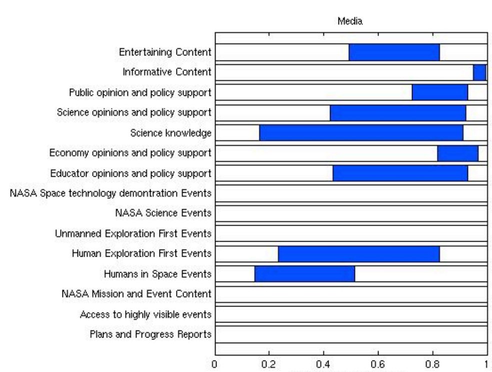
We see a fairly wide range covered by our test architecture. With the exception of NASA launch services. This is due to the construction of the utility curve, which assumes that a marginal increase in the maximum launch weight, over a Delta IV Heavy, would provide significant value. The utility curve uses a working assumption that offering double the security community's current launch mass would deliver 90% of the value. Human in Space Events shows a fairly narrow range as well, primarily because the duration component of the metric, which postulates that the public's perception of a 'long' stay in space is on the order of a year, which is well outside the architecture space.

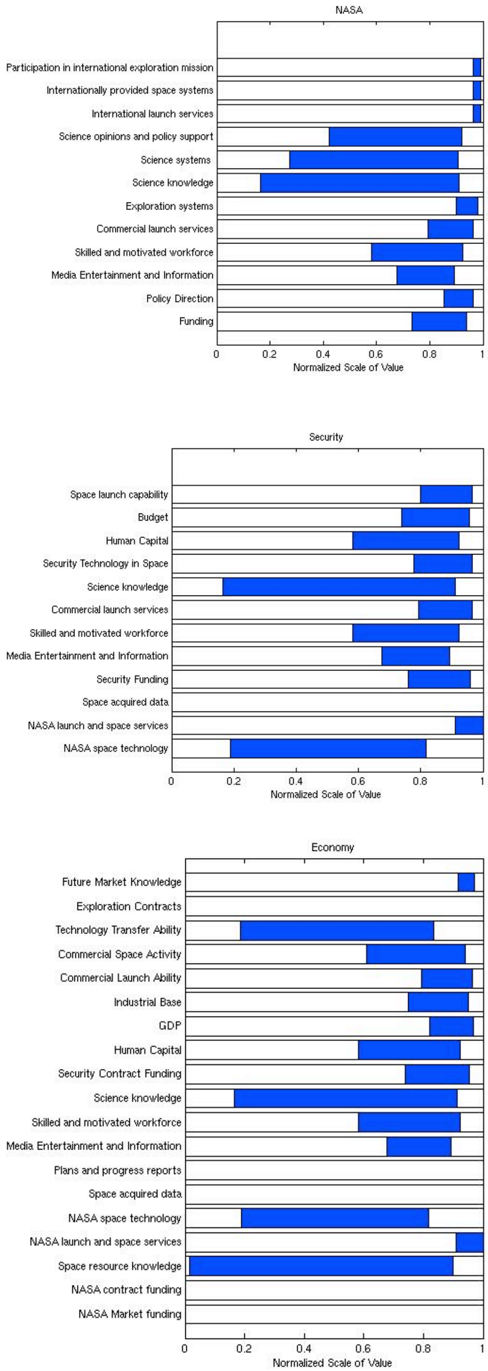
After propagating these 7 NASA Outputs through the model, and assuming the other 14/21 outputs are equal to one, we see the following behavior. Note that a blank bar indicates that the flow or stock contains only the value one, not zero, because we assumed all other flows are at their maximums.











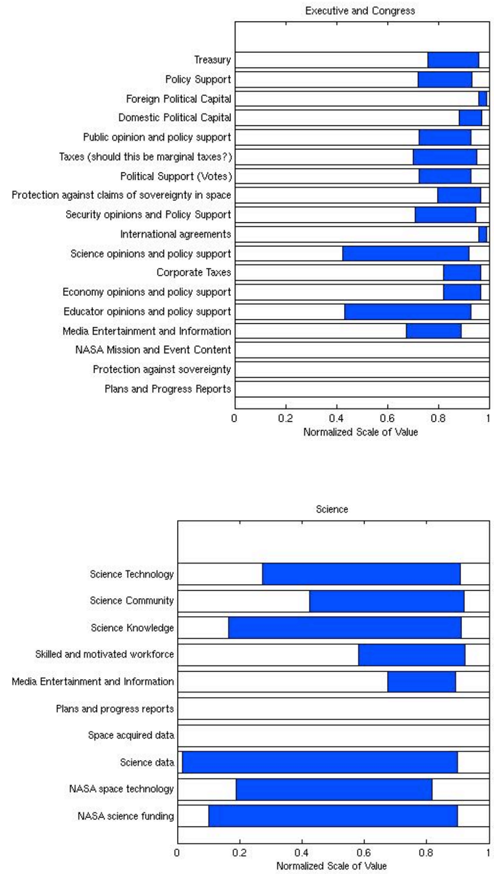


Figure 9 Value ranges for stakeholder inputs and stocks

The model clearly demonstrates that several flows are insensitive to the architectural space we have established. For example, international agreements vary very little, as does the Economy's ability to provide Exploration Systems. We also see large ranges over some flows, notably Science Knowledge and Goods and Services Derived From Space Technology (from the Economy to the US People).

With a view to capturing the extent to which different stakeholder see a wide range of value delivery, we computed the average range over which their input flows varied. This is not intended as a measure of stakeholder satisfaction, because it does not apply a weighting to different inputs.

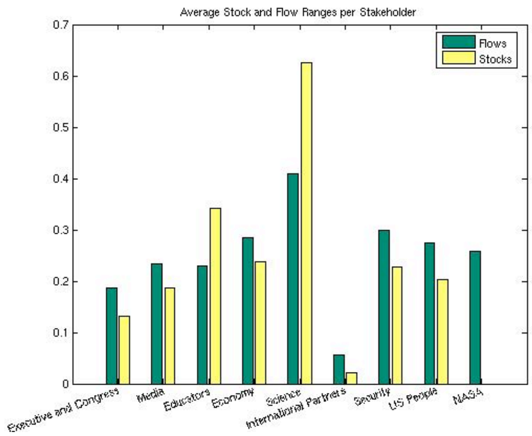


Figure 10 Average value ranges across stakeholders

Science stocks show the greatest variation by far. Given the selection of a subset of value flows that we have chosen, it is reasonable to wonder whether we have applied some selection bias, and in doing so, have illustrated more of the decisions relevant to science but not those relevant to other flows. While this is a legitimate concern, an examination of the remaining architecturally significant flows suggest that we are unlikely to see a radically different picture:

- Participation in NASA Exploration
- NASA Contract Funding
- NASA Market Funding
- Unmanned Exploration First Events
- Space Technology Demonstration Events
- NASA Science Events
- Space Acquired Data

Therefore, we see clearly that the most technical stakeholder is likely to be most sensitive to architectural decisions. Given that we are attempting to link technical architecture considerations to non-technical value considerations, this seems appropriate. Conversely, if we were to examine the feasibility of making organizational decisions based on stakeholder input, we would expect to see Educators and the US People highly sensitive to the decisions made.

7. Conclusions and Future Work

In this paper, we have explored the feasibility of making architectural decisions based on stakeholder analysis and externally-delivered value, showing that a subset of NASA's outputs are sufficiently sensitive to architectural decisions to discriminate between architectures.

This result was achieved by constructing a value flow model around NASA, and by populating its transactions with a weighting scheme designed to capture the essential valuation by stakeholders. An architectural test space was constructed, and linked to the value delivery using a set of proximate metrics. The architecture and value spaces were then explored in tandem, highlighting minimum and maximum value cases.

Future work would include looking at the subset of technically and fiscally feasible architectures, to examine whether the value-space remains open or significantly narrowed. Construction of the remaining proximate metrics based on a broader architecture will be undertaken. Finally, it would be desirable to link this model directly to cost and performance constraints, to determine how the relative weightings of value, performance and cost influence the chosen architecture.

The thrust of this work is not to determine precise architectural implications of value considerations, given that the fidelity of the models employed. Rather, it is to represent the decisions made with respect to stakeholders explicitly, and to enable traceability of architectural features to value delivery. In this manner, we strive to illustrate linkages and capture causality across a very broad and complex system. While future work will refine some of the approximations here, the thrust remains to capture how trends are determined by the underlying network structure.

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