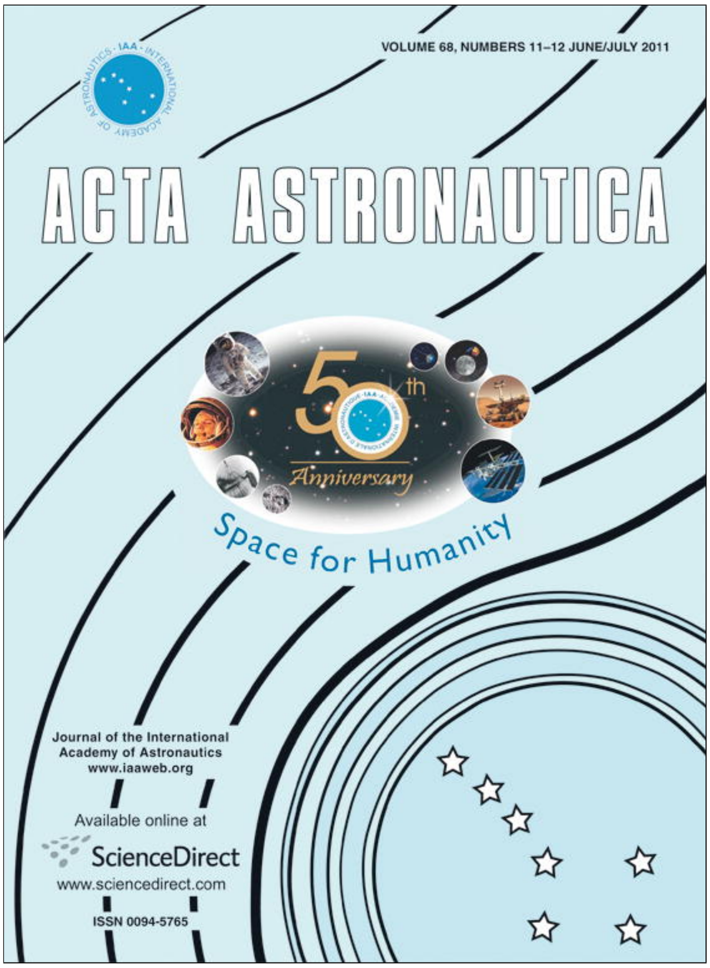
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Goals for space exploration based on stakeholder value network considerations

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ABSTRACT

We present a methodology that provides traceable analysis from stakeholders' needs to prioritized goals for human space exploration. We first construct a network to represent the stakeholder environment of NASA's human exploration efforts, then assess the intensity of these stakeholder needs, and build a numerical model to represent the flow of value in the network. The underlying principle is that as a rational actor, NASA should invest its resources in creating outputs that provide the greatest return of support to it. We showcase this methodology, seeded with test data, the results of which suggests that the most important outputs of the exploration endeavor are human and robotic exploration firsts and science data, but also include funding to the science community, providing interesting NASA mission event content directly to the public and to the media, and commercial contracts. We propose that goals should be structured to ensure these value outputs, and be written in such as way as to convey the subsequent creation of value in the network. The goals derived in this manner suggest that the majority of the value created by human space exploration derives from campaign level design, rather than from operation of transportation elements. There would be higher assurance that these value outputs would be delivered if a responsible official or entity within the exploration function was specifically tasked with ensuring stakeholder value creation.

1. Introduction

In the design of large systems serving a broad group of stakeholders, it can be difficult to prioritize objectives. Commercial entities tend to deal with stakeholders on a bilateral basis, and much of stakeholder theory has evolved for this case [1,2]. Government agencies in particular must cope with a more complex challenge. Within a network of other agencies with overlapping purposes, the Executive & Congress hold each agency accountable in satisfying a variety of different proxy interests. Indeed, it is clearly stated in the charters of many agencies that technical accomplishment is one of many success criteria. For example, the Space Act of 1958 [3] not only charters NASA to develop spacecraft and explore [4], but also further lists its responsibilities to include the creation of new markets [5], the encouragement of commercial space activities [6,7], and the development of international cooperation [8,9]. Furthermore, most of the interaction with these implied stakeholders are not bilateral, but instead involve longer chains or loops of interactions.

These diverse responsibilities highlight the breadth of NASA's stakeholder group [10]. We begin with the proposition that a sustainable exploration enterprise must deliver value to its key stakeholders – this is why the nation invests! The delivery of value is complex, and merits careful analysis.

Notably, we can work from stakeholders to value to the technical system, to derive the key priorities that should be embodied in the architecture. The general objective of this paper is therefore to showcase a method for prioritizing the outputs of a complex system, and then to translate

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those important outputs into rationally prioritized goals. This procedure is consistent with that outlined in the NASA Systems Engineering Handbook, NMP 7123.1 [11].

Previously, we developed a network model of NASA's stakeholder environment [12]. This analysis focuses on NASA and its environment – the method for this analysis is applicable to the space agencies of other countries, but the examples and valuation are all specific to NASA in this paper. We began by identifying the beneficial stakeholders – actors who receive benefit from an action or output of the system, but also have an output or action that is important to the system. We then enumerated the needs of these actors, and interpreted these needs as possible value delivery flows. Needs were enumerated by working from the role/mission of the stakeholder to its stated objectives, and then listing the needs corresponding to these objectives. Roles and objectives were derived from policy documentation where possible.

These flows then formed the basic structure of a network – each stakeholder was modeled as an input–output function, producing value in response to the satisfaction of its needs, as shown below in Fig. 1. For each stakeholder, we created a mapping between inputs and outputs, termed internal nodes, so as to connect only the pairs which are logically connected. The three internal nodes for Science are shown in Fig. 1, which are Science Knowledge, Science Technology, and Science Community. We then connected the individual stakeholders to form a network, which enabled a number of completeness and consistency checks – for example, identifying needs that are not served by the outputs of any other actor in the network. In the process of constructing the network, we recognized the omission of several flows by this completeness check – for example, the original model included *Policy Support* from the Security stakeholder, but did not include any flows from NASA to Security, prompting the addition of the '*Space Data*'.

A representation of the network created is shown in Fig. 2. While the full network contains 8 stakeholders and 83 flows, only 30 of these flows are shown in Fig. 2. This network is obviously simplified – entire careers are spent in just understanding the relationship between the Executive and Congress, for example, who in our model are one stakeholder. However, when examining the entire network, it is necessary to create abstractions of stakeholders, combining those who behave in similar ways with respect to the reference stakeholder (NASA), and have similar inputs and outputs.

The specific objective of this paper is to analyze the stakeholder network quantitatively, and then produce a prioritized set of goals for NASA's exploration architecture, which can be logically derived from NASA's stakeholder needs.

This paper is organized into three subsequent sections – we first develop a method for characterizing needs, then we analyze the network results, and finally, we showcase how this analysis can lead directly to organizational goals.

2. Needs characterization

In this section, we develop a method for characterizing the relative importance of stakeholders' needs. This analysis proceeds according to two principles:

1. Establish and prioritize the needs of a given stakeholder based on the importance to them.
2. Establish and prioritize the stakeholders based on their importance to the organization (here NASA).

Fundamentally, these principles suggest that the delivery of value is an exchange between two actors who we will call the project and the beneficial stakeholder. Benefit is provided by each to the other, at a cost. A successful exchange takes place when the outputs of the project meet the needs of the beneficial stakeholder, and the outputs of the beneficial stakeholder meet the needs of the project, as shown in Fig. 3. A break in this feedback loop will disrupt value delivery. Therefore, characterizing the needs of stakeholders is essential to determining the strength of the value loops that serve those needs.

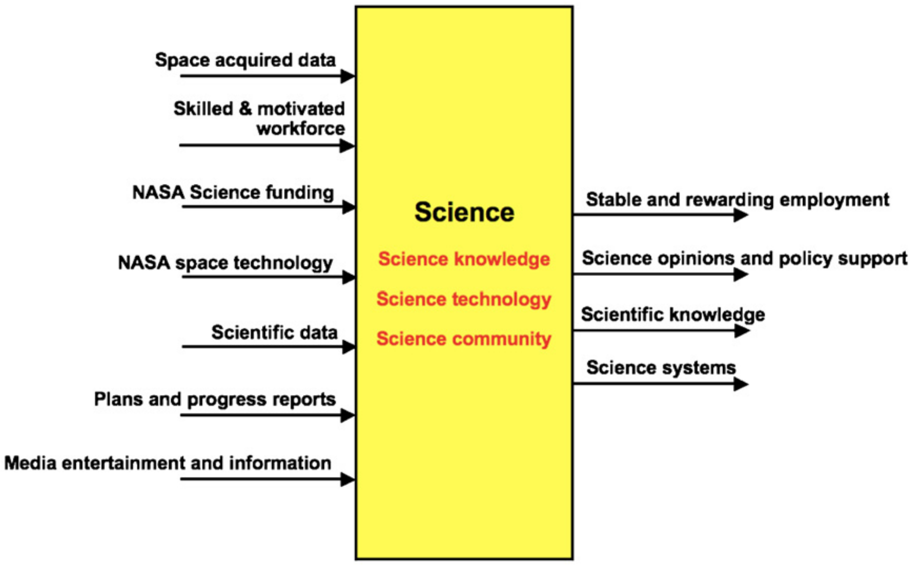

Fig. 1. Input–output model of the Science Stakeholder.

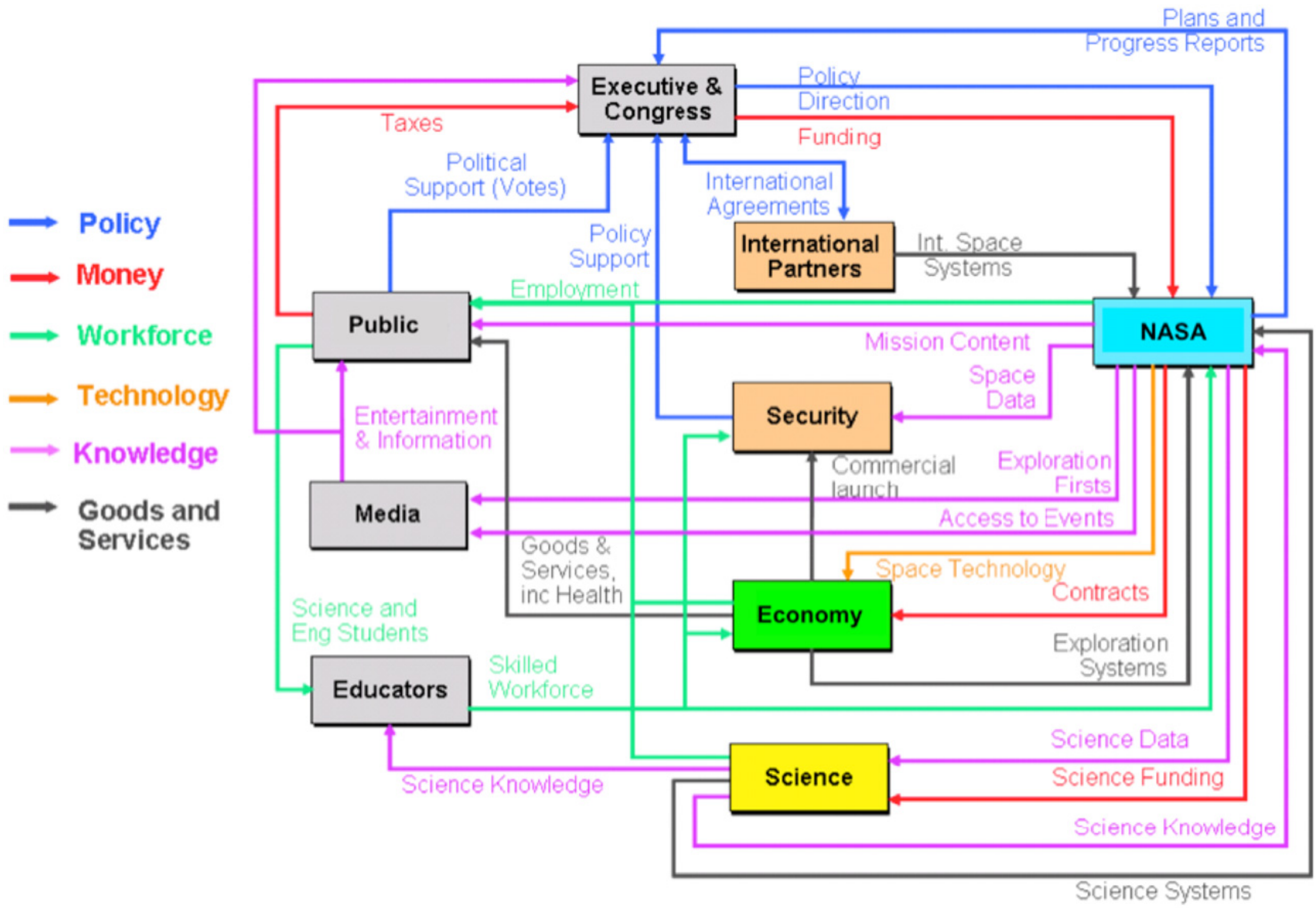

Fig. 2. Value delivery network for NASA Human Spaceflight Exploration, showing stakeholders and some of the links or value flows.

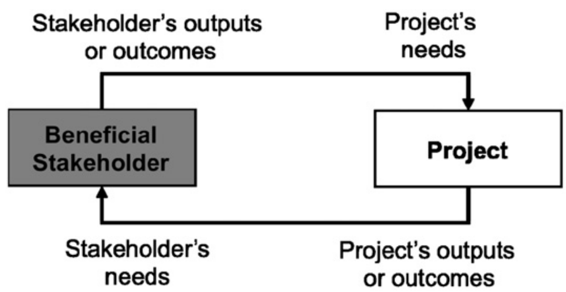

Fig. 3. Exchange of benefit in a simple two stakeholder transaction – the needs of the beneficiary are met by the project, and vice versa.

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 (the reference project stakeholder). Defined in this manner, a loop could be two links in length (a reciprocal or bilateral transaction between two stakeholders), or many links long, up to 9 in this particular network (no loop can pass through a given stakeholder more than once). In this paper, we focus exclusively on loops that begin and end with NASA, and more specifically NASA's human spaceflight endeavor. One of the key observations from our previous modeling work was that the majority of the important loops beginning and ending with NASA are not short or direct, but pass through a number of intermediary stakeholders. Said another way, there are very few things for which NASA is directly paid. Rather, it creates benefits that permeate through the network and eventually return to NASA by circuitous routes. A good example of this is 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 & Congress, which then provides resource and policy direction to NASA. This politically important loop is 6 links long.

We developed a loop valuation [13] that expressed the value of each loop from NASA output, through the network, back to the inputs to NASA. This valuation is calculated as the product of the needs intensity of each constituent link in a given loop. The appropriateness of this valuation can be derived from a utility maximization problem, assuming linear utility functions for stakeholders.

We selected a modified Kano analysis [14] to value each link. The Kano methodology was originally used to classify product attributes from the consumer's perspective. The three main Kano categories are:

1. Must Have: the stakeholder is discontent if the flow is not present, and neutral if it is satisfied. For example, cars must have brakes. In our model, *Funding* is a must have flow for NASA.

2. One-dimensional: the stakeholder is linearly more content the more of the attribute is present. For example, increase in gas mileage returns increase in satisfaction in a car. In our model, *Science Knowledge*, flowing from Science to Educators, is a one-dimensional attribute.
3. Exciter: the stakeholder is neutral if the attribute is not present, but is delighted if the attribute is present. For example, a surround-sound audio system in a car falls in this category. In our model, the provision of *Space Tourism Services* from the Economy to the Public is an exciter attribute.

We augment the Kano methodology by specifying an 'Importance' rating for each flow as well. While the Kano categories classify the nature or shape of the attribute's satisfaction curve, the Importance rating specifies the degree of intensity of the need. For example, a surround-sound audio system 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', as shown below in Table 1.

The next step is then to create numerical metrics for these two scales, which allow them to be combined (Table 1). The two scales are

1. Kano Multiplier: The Kano categories have a fundamentally non-linear sense to them. At equivalent importance ratings, a 'must have' is multiplicatively more of a value creator than a 'one-dimensional' feature, and likewise a 'one-dimensional' is greater than an 'exciter'. For our purposes, the ratio was set at 3 after consulting several test cases, as can be seen from the first row of Table 1. In the analysis below, this will force the Must Have features to have a high value of fulfillment.
2. Importance: For two flows having the same Kano category, the spread in importance is a more linear relationship. We anchored this linear scale such that the maximum on the importance scale ('extremely important') in one Kano category is equivalent to the second lowest importance rating ('somewhat important') in the next more satisfying Kano category.

In addition, we enforced that the valuation should be normalized such that the maximum would be unity (e.g. the upper left corner of Table 1). This normalization will produce the property that a chain of value flows can be multiplied together and retain the same range – between zero and one.

Table 1
Value flow weighting scale combining Kano and Importance measures into a single metric.

	Must have	One-dimensional	Exciter
Extremely important	1.00	0.33	0.11
Very important	0.78	0.26	0.09
Important	0.55	0.18	0.06
Somewhat important	0.33	0.11	0.04
Not at all important	0.11	0.04	0.01

Using this methodology, we created the Kano and Importance data for each link in the model based on the general knowledge of the authors and with reference to obtainable documentary evidence. In an ideal situation, this data would have been composed of broad stakeholder interviews and/or detailed documentary evidence. However, our interest was to test the methodology and to determine the dominant trends of behavior, rather than to produce exact results. Thus the detailed results that are obtained should be considered representative, but not exact in any sense.

In order to perform a reality check on our evaluations, we conducted stakeholder interviews with surrogates for three of the main external stakeholders: the economic, scientific, and security stakeholders. The surrogates were the CEO of a Global Top 100 Aerospace firm, a former NASA Associate Administrator for Science, and a former secretary of the Air Force. In a blind survey, these surrogate stakeholders were asked to bucket the needs of their stakeholder into one of the following: Top 3, Middle, Low, Very Low, Very Small, or Irrelevant. The intent behind this categorization was to use language familiar to senior executives and policy makers, rather than teaching them the Kano process.

A comparison between the authors' valuation and the surrogate's valuation for the economic surrogate stakeholder is shown below in Table 2. Given the difference in scales, this should be read as an ordinal ranking. Except for *Funding* for Security, for which the surrogate had a different perspective on model boundaries, the ordering from the interview largely confirmed our evaluation. It is also worth discussing *Plans and Progress Reports*, which is ranked higher in the model than the surrogate's ranking. This value results from a one-dimensional Kano type (more plans and disclosure is always better), with the Importance ranking set at maximum, to reflect that NASA is the sole source of this supply. *Plans and Progress Reports* are treated in the model as the value of future contracts to the Economy, as opposed to the existing contracts already in place to a subset of firms – hence the higher prioritization compared to *Contract Funding*. For reference, reducing this flow would reduce NASA's ability to influence the Economy

Table 2
Surrogate economic stakeholder evaluation of their needs compared to evaluation by the authors.

Economic stakeholder evaluation	Benefit flow to economy stakeholder	Author evaluation
Top 3	Skilled workforce from Educators	0.68
Top 3	Contract funding from NASA	0.26
Middle	Market funding from NASA	0.18
Low	Plans and progress reports from NASA	0.39
Low	Space acquired data from NASA	0.18
Very low	Space resource knowledge from NASA	0.12
Very low	Launch and space services from NASA	0.05
Very low	Science knowledge from Science	0.05
Very small	Informative and entertaining content from Media	0.02

stakeholder, and would have the effect of shifting priorities to *Skilled Workforce*. Similar results were found from the other two interviews.

We used an Object Process Network (OPN) [15] to represent the value flow network and the associated link valuation data. OPN is a graphical programming language for generating networks – it enables us to create a network, with information recorded at each of the nodes (stakeholders), and logic on each link of the model. The net result is that we can enumerate all of the possible value loops in the model.

3. Numerical results

Using the method detailed in Section 2, we enumerate all of the possible loops in the network, with the intention of better understanding the value flow in the network, and eventually creating the simplified representative value network shown in Fig. 5. The first step in the numerical analysis is to rank those loops from strongest to weakest, based on their ability to return value to the inputs of NASA as a fraction of NASA's effort expended at its output. We ranked the loops – from those loops that are most effective at returning value to NASA down to those that return least value, and selected the subset of loops that were most important to NASA.

Next, we examined which individual links (a single link can be in multiple loops) are most important in the network. Because of common paths over some links, a few important links emerge that are not necessarily part of any of the key loops, but are nonetheless important to preserve in a simplified model. Fig. 5 shows the results of this analysis, indicating the key links in the strongest loops. In this figure, the thickness of the links has been scaled by its weighted occurrence score [16] – the sum of all the loop scores containing the link. The color of the link indicates its nature: policy/opinion, monetary, knowledge/information, goods and services, or jobs/public benefits. Because the methodology uses a normalized utility formulation, it has no difficulty tracing value loops that move from one to another of these types of flows.

Examining just the links and loops in Fig. 5, it can be clearly seen from this diagram that the strongest links are the policy/opinion related links of *Policy Direction* from the Executive and Congress to NASA, and *Votes* from the Public to the Executive and Congress. Close behind is *Funding* from the Executive and Congress to NASA. These general governmental flows form the backbone for many of the important loops, and trace back to the Public as a key stakeholder. The strongest link to the Public is from the Media in the form of *Entertainment and Information*. This output of the Media plays an important role in building support for NASA's activities. Various forms of content flow from NASA to the Media, closing these strongest loops. In order to further deconstruct this chart, we present methodologies for ranking important stakeholders and important outputs of NASA below.

To determine the 'importance' of stakeholders, we used a weighted sum of the stakeholder's participation in important loops, called the Stakeholder Loop Occurrence (SLO). For each time that a stakeholder participates in a loop, the score for that loop is added to the stakeholder's total. The final values are normalized by the sum of the scores for the loop set considered. This normalization has the effect of setting the range of outputs on [0,1].

$$\mathrm{SLO}(s) = \frac{\sum_{i \varepsilon S} r_i}{\sum_{\forall i} r_i}$$

where r is the rank of loop, s the set of all loops that contain the stakeholder and i the loop index.

The weighted stakeholder occurrence measure is shown graphically in Fig. 6, and is also represented in Fig. 5 with bolder box lines for more important stakeholders. The Executive and Congress, together with the Public, are clearly the most important stakeholders. Since there are relatively few key loops passing only through these two stakeholders, we have included the Media as among the most important stakeholders in the simplified representation of Fig. 4. Science and the Economy play the next most important roles (indicated by more heavily dashed boxes on Fig. 5), followed closely by the Educators and Security (indicated by the more lightly dashed boxes of Fig. 5).

Lagging well behind are the International Partners. International Partners are a weak stakeholder, primarily because the Kano valuation data assume that international participation is not necessary but desirable, which makes all of its outputs exciters, significantly decreasing their rankings. In fact no key loop in the model touches the International Partners. This valuation was chosen based on a review of policy documents, including the Vision for Space Exploration, the NASA Annual Report, and progress updates on the Heavy Lift planning, to accurately reflect the perspective of the Constellation program.

Similarly to the weighted average of stakeholder presence in important loops, we can compute the weighted average of NASA outputs in important loops, as shown in Fig. 7. For this metric, the normalization constant is the value of the highest output – more formally, it is the sum of loop scores for all loops in which NASA *Science Funding* occurs.

It is interesting to note that *Science Funding* figures so prominently in NASA's outputs, and yet science is at best an average stakeholder. This suggests that science should be

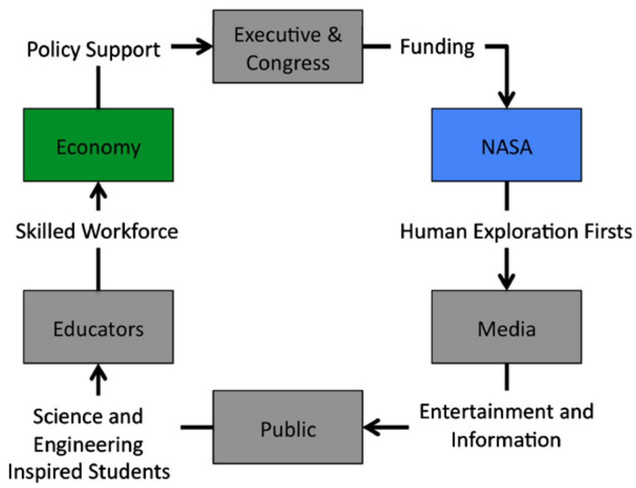

Fig. 4. A strong indirect loop.

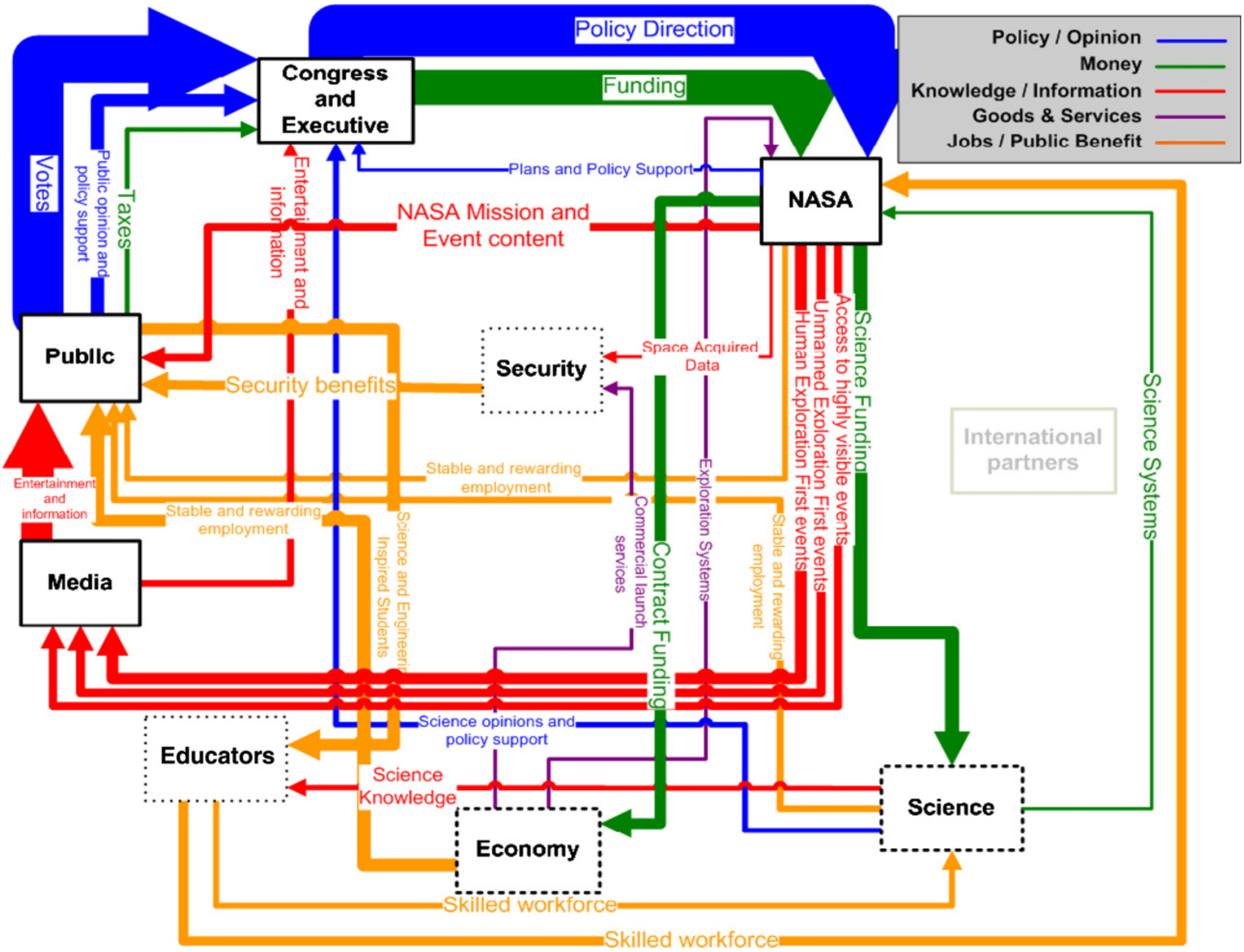

Fig. 5. Simplified evaluated value network – line thickness scaled for importance of links, and colors indicate the nature of the value flow on the link.

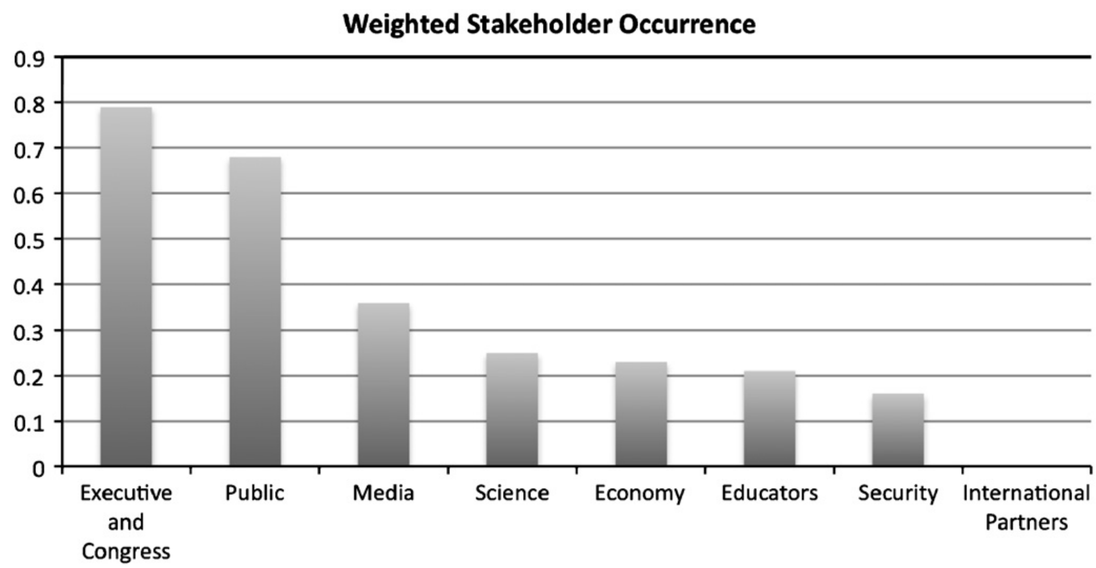

Fig. 6. Weighted Stakeholder Occurrence, indicating presence in important loops.

treated as an integral part of exploration. Note that in our stakeholder model, we have treated the project reference stakeholder as NASA's exploration endeavor, and not recognized a firm boundary around the Constellation Program or the Exploration Systems Mission Directorate. There are several reasons why this output appears high on the list. First, we note that in this model, the Science community, even that within NASA, has been abstracted to a group outside NASA. *Science Funding* is one of the key methods *by which Science Knowledge, Science Opinions and Support, and Stable and Rewarding Employment,* among the most important non-policy/funding intermediate flows, are stimulated. Second, *Science Funding* also returns *Science Systems*, which are assumed to be produced by the Science community.

It is also interesting to note that *Space Acquired Data* ranks slightly higher than *Science Data* as an output of NASA. The distinction between the two is that *Space Acquired Data* focuses on measurements useful for technology or design purposes, which might not otherwise merit scientific attention. Examples include calibration of radiation models or re-entry models. *Space Acquired Data* is present in fewer loops, but they are on an average shorter than *Science Data* loops.

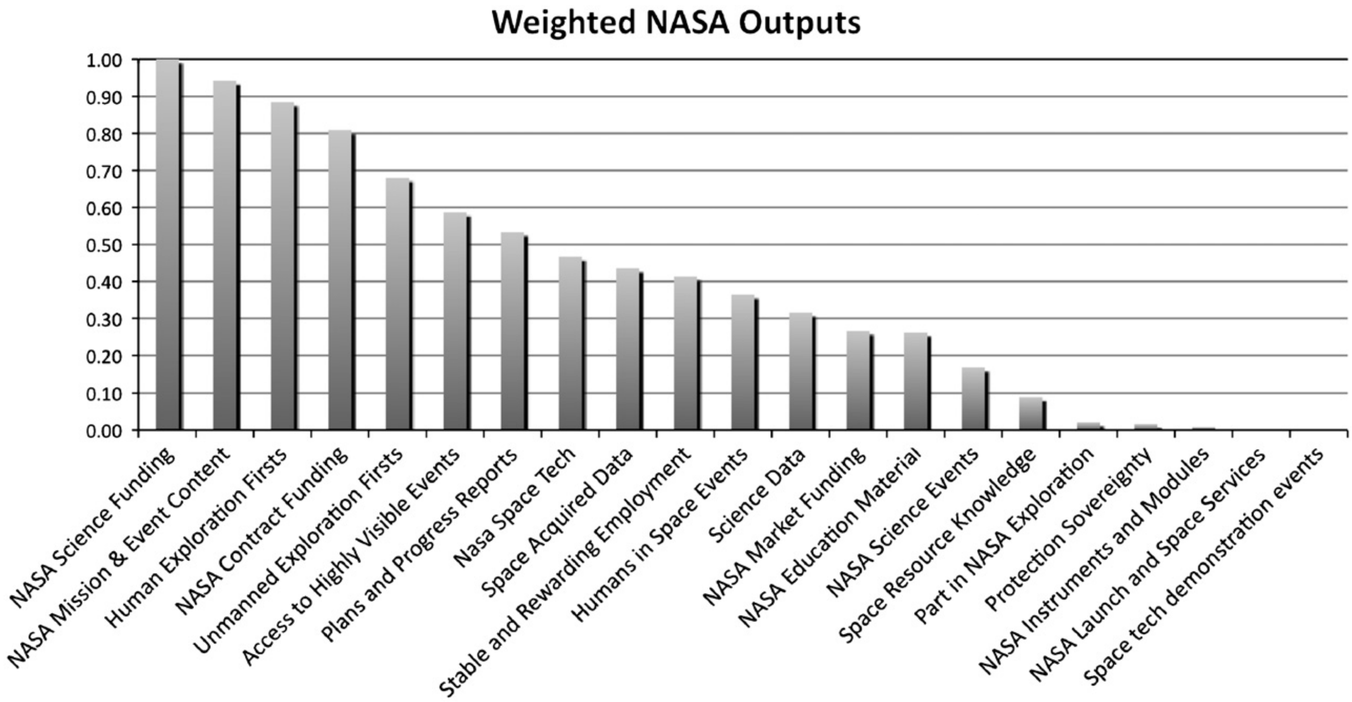

Fig. 7. Weighted NASA outputs, indicating the outputs, which occur in important loops.

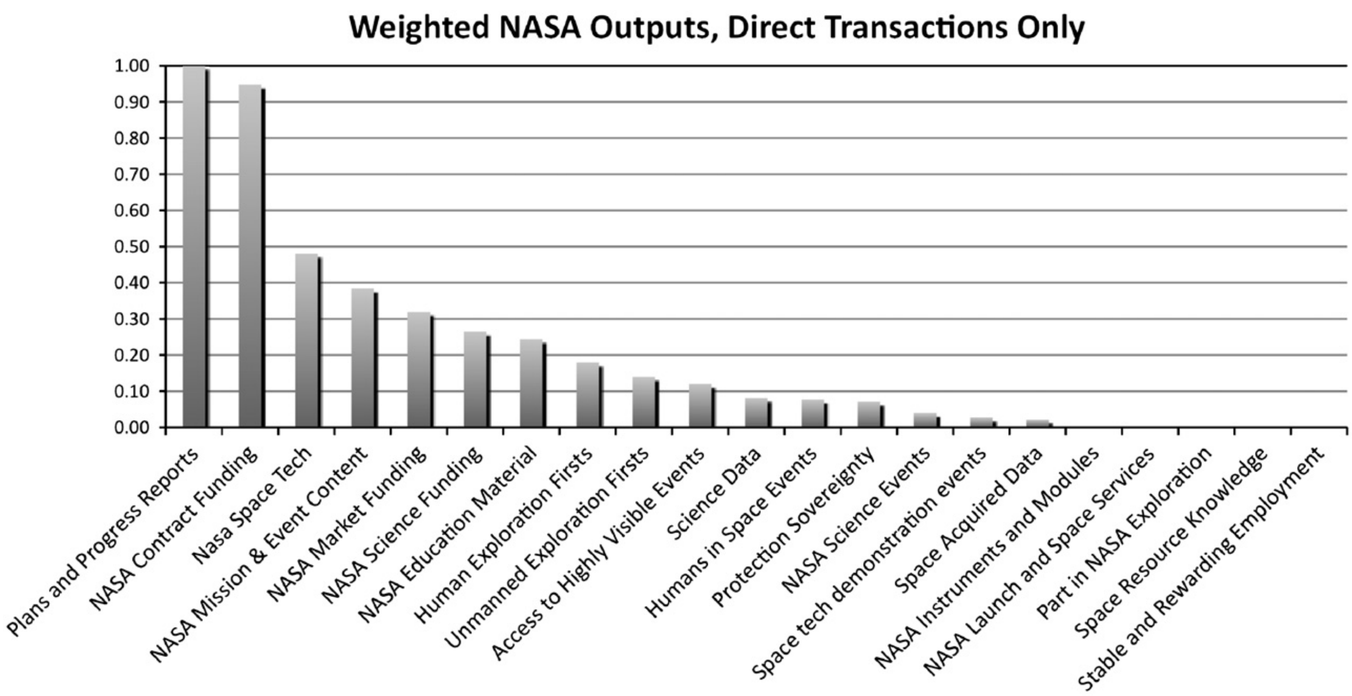

Fig. 8. Weighted NASA outputs, where only direct transactions are included.

Also high in importance are the outputs of NASA that close the Public–Executive and Congress loops. First among these is direct provision to the public of *NASA Mission and Event Content* (through for example web streaming and participatory exploration). The other way of closing these strong loops is through the media. The outputs that flow to the Media, which are prominent, include *Human Exploration Firsts, Unmanned Exploration Firsts, and access to Highly Visible Events* (essentially media content and media access). Some more generic outputs such as *Funding*, and *Plans and Progress Reports*, also figure prominently in the list of outputs.

We can contrast these results against the case of 'Direct Transactions Only'. In the direct case, we exclude all loops, leaving only direct transactions between parties. It can be argued that this is the default frame of reference for stakeholder analysis; it takes account of individual relationships but excludes any network effects or indirect action.

As seen in Fig. 8, considering only direct transactions drastically changes the organization's priorities. Issuing contracts and reports dominate priorities, as they both have concrete near-term payouts, while outputs with more diffuse benefits, such as *Science Data* and *Employment* fall much further down the list. This stark difference highlights the importance of examining stakeholders from a network perspective.

Having now determined how NASA's needs and then needs of its stakeholders are best satisfied, we now derive prioritized goals for NASA's exploration program.

4. Deriving goals

We have structured this analysis to proceed from needs to goals. Having now prioritized stakeholders and their needs, we showcase how the network can also be used to understand how goals should be derived from needs.

Goals should embody several principles. First, goals should link directly to the delivery of value – that is to say, they should represent an explicit action relative to an output of NASA. Second, goals should capture the intent behind the value delivery, with a view to linking stakeholder need satisfaction to NASA's needs. This implies that goals should reference the subsequent links in the value chain, occurring one step beyond the direct output of NASA. Third, goals should be complete, which we have already accomplished by defining a closed system and exhaustively enumerating the possible actions.

These criteria are met with the help of value chains. The direct link to value derives from the output of NASA. To this output, we tag the most important subsequent flows in order to capture the intent of the output.

For example, we can derive a goal statement from the output of NASA called *NASA Mission and Event Content,* which flows to the Public. Examining the outputs of the Public that link to this input, we can identify: *Votes, Public Opinion and Policy Support,* and *Science and Engineering inspired Students*. We can represent this flow by the first two branches of the tree network shown in Fig. 9. The fulfillment of this flow, together with the follow-on outputs, can be translated into a goal with associated intent.

> NASA shall make available to the Public web, video and audio content of its exploration program, *with the intent of* informing the public, building support and inspiring the youth.

The first intent statement indicates the impact on the Public itself, and the later two phrases suggest the follow-on influence on the body politic and youth. If a set of goals were to be consistently derived in this manner, they would be linked to the delivery of value and associated priority, and rationalized with respect to intent.

In the following discussion, we have developed such a set of representative goals and have prioritized these goals based on the importance of the associated weighted NASA outputs. These would focus NASA actions on outputs that will flow eventually to the inputs NASA needs for a sustainable program. The goals are ranked according to the weighted outputs from Fig. 6 (with scores renormalized), which are shown in brackets after each goal. We have also separated goals into two types: those that influence what NASA does and goals that suggest how NASA does business. This distinction does not arise from the network, it is a post-processing step. These two types of goals have different impacts on the organization – *what goals* impact the choice of missions and activities, whereas *how goals* govern important activities that should be undertaken regardless of the choice of missions and activities. In other words, *what goals* impact architectural variables, whereas *how goals* relate to the delivery of value, regardless of what architecture or destination is chosen. Therefore *what goals* must be present in the requirements of writing process, whereas *how goals* must be carefully

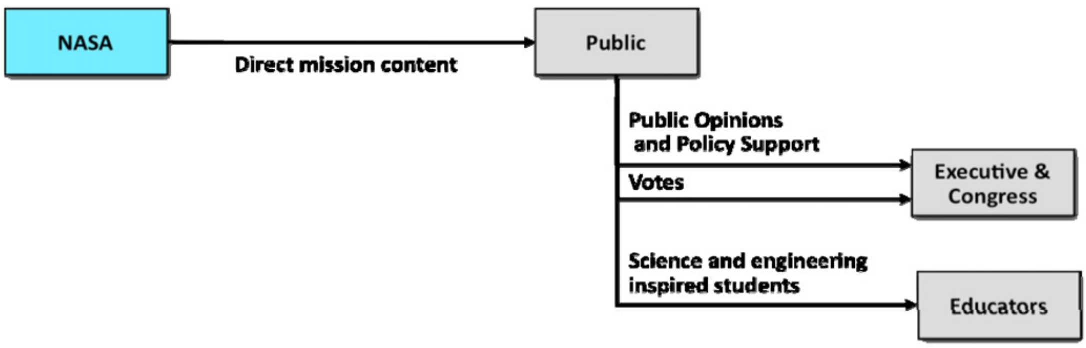

Fig. 9. Flow of direct mission content from NASA to the Public, and its influence on subsequent flows.

considered when defining the program and issuing contracts.

4.1. What goals

1. NASA shall make available to the public web, video and audio content of its exploration program with the intent of informing the public, building support and inspiring the youth (.94).
2. NASA shall design its exploration so as to produce a string of human exploration firsts with the intent of conveying through the media content for ultimate consumption for the people, body politic, and youth (.88).
3. NASA shall design its exploration so as to produce a string of unmanned exploration firsts with the intent of conveying through the media content for ultimate consumption for the people, body politic, and youth (.68).
4. NASA shall include in its exploration missions capabilities that enable greater depth of (non-NASA) media coverage (camera's bandwidth, etc.) with the intent of providing access to the media for coverage with ultimate consumption by the people, body politic, and youth (.59).
5. NASA shall design its exploration program to provide regular reports of progress in a measured and sequential fashion with the intent of informing the planning and oversight of the body politic (.53).
6. NASA shall produce data from space relevant to Economic and Security interests, including information valuable for building and operating space systems (.44).
7. NASA shall design its exploration program to project events associated with humans in space, but not necessarily firsts or on planetary bodies (.36).
8. NASA shall produce data of interest to the Science Community (.32).
9. NASA shall design its exploration program so as to create interest in science events, such as photographs or discoveries (.17).
10. NASA shall produce data of interest to the commercial community on potential space resources (.09).

4.2. How goals

1. NASA shall provide funding to the Science Community for the analysis of data and development of instruments with the intent of producing science systems, producing stable and rewarding employment and obtaining the policy support of the Science Community (1.00).
2. NASA shall provide contract funding to the economic community with the intent of producing exploration systems, producing stable and rewarding employment, and supporting the commercial launch industry and launch infrastructure (0.81).
3. NASA shall develop space technology appropriate to space applications, and with impact on goods and services, including human health (.47).
4. NASA shall provide stable and rewarding employment to its workforce (.41).
5. NASA shall provide funding through market based mechanisms for the acquisition of systems and services (.27).
6. NASA shall develop and disseminate educational content based on its missions specifically designed to be used by teachers (.26).

Notice that most of the value outputs do not relate directly to the design of the Orion, the Ares launch vehicles, or the lunar mission mode. Rather, many of the goals listed above are tied to valued outputs from the campaign design, such as "human exploration firsts", "unmanned exploration firsts", "regular progress", "events associated with humans in space", and "create interest in science events". We observe that direct value delivery is largely driven by the campaign design, surface activities, and the sensors and communications network that returns that information to the Earth. These campaign design issues relate to the exploration strategy decision in the recent report of the US Human Spaceflight Plans Committee [17].

The large vehicle designs currently underway should be seen as infrastructure supporting this value delivery. The infrastructure should be designed to provide sufficient flexibility to shift valued activities as campaign design proceeds, and leave sufficiently budget for the campaign to successfully execute direct value delivery activities. For example, the lunar mission mode decision is largely an infrastructure decision, but it needs to enable a variety of possible landing sites, consistent with a string of *Human Exploration Firsts* and *Unmanned Exploration Firsts*.

Where activities have a large impact on value, and a minor but necessary impact on infrastructure design, care must be taken to uphold the associated goal. For example, "direct video, web, audio content", and "greater access and depth of media coverage" do impact on the requirements for the communications system, operations concepts, and sensors. In a time-phased project where infrastructure design precedes campaign design, it is important that value-related activities receive greater attention than their small mass, cost, or design impact would suggest, such that they do not get lost.

These goals provide guidance on how to ensure that large exploration project endure by providing sustainable value to their stakeholders. It is important that the breadth of these goals or the simplicity of their underlying value contributions not deter NASA from managing them as closely as they would other requirements.

5. Conclusion

We have previously asserted that a sustainable exploration enterprise will deliver value, control operational risk, be designed to be politically robust, and be affordable. This paper contributes a worked example of a methodology for prioritizing benefit produced by NASA, using test data to showcase the method.

We develop a method to understand and design for sustained value delivery. We took a systems view of NASA's stakeholders, and developed a closed loop network representation that traces the flow of value through the systems. On top of this network representation, we layer a numerical methodology to represent analytically the flow of value. This closed system representation enables the use of a maxim of self-interested action to prioritize NASA's actions, with a view to delivering the resources and inputs needed by NASA. The inference is that NASA should set goals that insure the prioritized generation of benefit flows to its stakeholders in such a way that the greatest benefit is returned to NASA, thus providing a sustainable exploration enterprise.

This value network analysis, populated only by test data, suggests that most of the value is delivered by the campaign design, and in the way NASA does business. The physical and informational systems, which comprise the underlying infrastructure for exploration must be made sufficiently capable to be assembled into the campaigns that will deliver value. From a management perspective, this suggests that it might be desirable to develop an explicit role (and perhaps organization) to ensure that stakeholder value is safeguarded and actively managed throughout the infrastructure phase of the program. This role or organization would naturally also be charged with representing the value delivered to beneficiaries.

Future work on this methodology includes sampling stakeholders to produce data for validation of the model – as such we have presented only test data for illustration purposes. Comparison of data against existing prioritizations of outputs would yield a useful mechanism to derive how current actors perceive their local network. Additionally, the outputs prioritized in this example are not yet compared against the resources required to deliver outputs. While this model is not intended to be a causal financial tool, future analysis would benefit from an evaluation of the relative effort against the benefit returned.

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