Stakeholder Value Network Analysis for Space-Based Earth Observations

by

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B.S. Aerospace Engineering
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Submitted to the Department of Aeronautics and Astronautics and the
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Master of Science in Aeronautics and Astronautics
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ABSTRACT

The Earth Science and Applications decadal survey released by the National Research Council in 2007 presents both an ambitious engineering challenge and a challenge for the entire Earth science community to come together to reach a consensus on priorities that cross conventional disciplinary boundaries. The vision established by the decadal survey requires a paradigm shift for Earth system science: Societal benefits must be considered equally with purely scientific benefits to guide the development of the future NASA and NOAA Earth Observations Program. The decadal survey focused heavily on the needs and objectives of the Earth science community, while providing much less thorough treatment of the other relevant stakeholders. To address this, I conducted a stakeholder value network analysis for the Earth Observations Program that includes the development of a comprehensive qualitative and quantitative stakeholder model.

The qualitative model includes a rigorous articulation of the needs and objectives of 13 major stakeholders; the development of a three-level stakeholder map including a baseline map, higher-level map, and lower-level map; and a complete stakeholder value network model with 190 individual value flows that capture the interactions between all the stakeholders.

The quantitative model includes a method for assigning numeric scores to each value flow; the calculation of 1880 unique and valid "value loops" within the stakeholder value network; and an analysis of the value loops that yields useful insights about the Earth Observations Program. The value loop analysis reveals the most important stakeholders, value flows, and value loops within

the stakeholder value network; as well as the most important outputs from and inputs to NASA and NOAA. The analysis also reveals the relative important of each of the six science categories representing the six science-themed panels of the decadal survey.

The results from the stakeholder value network analysis provide insights regarding the value produced by the Earth Observations Program, as well as the value-added roles of each stakeholder within the network. The most important value loops and Program outputs are used to derive a set of high-level program goals, including goals that suggest *what* NASA and NOAA should do, as well as *how* they should conduct business. Finally, the insights and results from the analysis provide the foundation for a set of recommendations for the Earth Observations Program, which complement the recommendations put forth in the decadal survey.

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I would also like to thank my partners in crime, the other graduate students in our System Architecture group (or whatever we're calling ourselves these days). Bruce Cameron offered me tremendous insight into the stakeholder modeling process, and his thesis was a key reference for my own thesis. Justin Colson helped develop our framework for analysis and did a magnificent job modeling the technical architecture of the Earth Observations Program. I spent countless hours with Wen Feng, Jim Keller, and Theo Seher mulling over stakeholder theory, reworking the Kano questionnaire more times than I care to remember. And as the senior PhD student in the lab, Wilfried Hofstetter offered many words of wisdom and never failed to point out when it was 1pm and I was just strolling into the office for the day.

I owe a great deal of thanks to our NASA sponsors, Bernie Seery and Bob Connerton. Their experience, guidance, and feedback were invaluable to me throughout the entire project. It was a great pleasure to work with them over the past two years.

Penultimately, I'd like to thank my close friends and roommates, and especially Chris^4. I couldn't have survived my second dose of MIT without them. They're also part of the reason why I didn't show up to the office until noon every day!

Lastly, and most importantly, I wouldn't be where I am today without the love and support of my parents Alan and Linda. They instilled in me the value of hard work and sacrifice, and I owe all my success to them. I'd also like to thank my sister Stephanie for her love and friendship over the years, and for those late night phone calls asking me random science questions: "Do pigs have bones?"

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Table of Acronyms

The following is a list of acronyms used throughout this thesis:

CCSP – Climate Change Science Program

DOD – Department of Defense

DOE – Department of Energy

DOT – Department of Transportation

EPA – Environmental Protection Agency

NASA – National Aeronautics and Space Administration

NGO – Non-Governmental Organization

NIH – National Institutes of Health

NOAA – National Oceanic and Atmospheric Administration

NRC – National Research Council

NSF – National Science Foundation

OMB – Office of Management and Budget

OSTP – Office of Science and Technology Policy

USAID – United States Agency for International Development

USDA – United States Department of Agriculture

USGS – United States Geologic Survey

"Understanding the complex, changing planet on which we live, how it supports life, and how human activities affect its ability to do so in the future is one of the greatest intellectual challenges facing humanity. It is also one of the most important challenges for society as it seeks to achieve prosperity, health, and sustainability."
—National Research Council Report, Earth Science and Applications from Space: National Imperatives for the Next Decade and Beyond, 2007

1 Introduction

1.1 Motivation

On June 23, 1988, NASA climate scientist Dr. James E. Hanson testified to Congress that the observed increase in global temperatures was not a natural variation but instead was caused by a buildup of carbon dioxide and other artificial gases as a result of human activity (Shabecoff 1988). Today, over twenty years later, our nation is only just beginning to tackle the challenges associated climate change. In addition to climate-related concerns, concerns about land-use changes, water shortages, human impact on natural ecosystems, and environmental effects on human health have also become more important over the past decade.

Scientists have begun studying the Earth as a complex system involving interactions among the land, water, atmosphere, ecosystems, and human activity. Fully understanding the Earth system requires the development of tools and models that can characterize the current state of the system and predict its future behavior. One such model is the MIT Integrated Global System Model, which is a comprehensive mathematical tool for analyzing global climate change and its social, economic, and environmental consequences (MIT Joint Program on the Science and Policy of

Global Change 2008). These models require accurate datasets that describe the dynamics of physical Earth processes such as ocean circulation, land carbon storage, atmospheric dynamics and chemistry, sea ice movement, surface heat fluxes, and countless more. Many of these measurements are obtained using Earth-orbiting satellites, which offer a reliable means for acquiring consistent, repeated measurements on a global scale.

In the United States, the agencies responsible for designing and operating civil Earth-observing satellites are primarily NASA and NOAA, with additional contributions from USGS. Currently NASA and NOAA operate approximately 25 space-based Earth observations missions carrying over 100 instruments. Several of these missions are approaching their end-of-lifetimes, and the number of operational missions and instruments is expected to drop roughly 25% by 2010 (National Research Council 2007). Given the increasing importance of Earth system science, and the need for space-based measurements to improve our Earth system models and predictive capabilities, a comprehensive review of our nation's Earth observations programs was warranted.

In 2007, the National Research Council Space Studies Board released a decadal survey for the Earth science and applications communities (National Research Council 2007). This report was the first of its kind for the Earth science community. It presents a vision for a decadal-scale program of Earth science research and applications that advances the fundamental understanding of the Earth system and increases the application of this understanding to serve the nation and the people of the world. The decadal survey is the foundation for this thesis, which complements the survey by offering a rigorous, in-depth stakeholder analysis using state-of-the-art techniques developed by our System Architecture research group at MIT.

1.2 The Earth Science Decadal Survey

The decadal survey makes a series of policy and programmatic recommendations, including a sequence of 17 satellite missions over the course of the next decade – referred to in this thesis as the Earth observation campaign. The recommended campaign presents both an ambitious engineering challenge and a challenge for the entire scientific community to come together to reach a consensus on priorities that cross conventional disciplinary boundaries. The vision established by the decadal survey requires a paradigm shift for Earth system science: Societal needs must help guide the scientific priorities, and emerging scientific knowledge must be actively applied to obtain societal benefits. The delivery of practical benefits to humankind must play an equal role with the quest for scientific knowledge about the Earth.

The decadal survey is the product of the collaborative effort of over 70 leading scientists and roughly 30 representatives from NASA, NOAA, international space agencies, commercial industry, and other government agencies. To emphasize the interdisciplinary nature of the interactions of the Earth system, the decadal survey participants were organized into seven thematic panels:

- Earth science applications and societal benefits
- Human health and security
- Land-use, ecosystems, and biodiversity
- Solid Earth hazards, natural resources, and dynamics
- Climate variability and change
- Weather science and applications
- Water resources and global hydrological cycle

The panels were tasked with recommending a modest number of satellite missions that would advance the state of knowledge within their particular field of study. They primarily used a group consensus process to establish a list of top priorities for each domain. Each panel was allocated an imaginary $1 billion to "spend" on future missions. Most panels spent the majority of their funds on one or two critical satellite missions and spread the rest over a few other less important missions (Hager 2007). In total, the six science-themed panels, which exclude the panel on Earth science applications and societal benefits, recommended 31 potential missions. The decadal survey committee worked with the individual panels to combine these into 17 missions by compromising on instruments or spacecraft operational characteristics and developing synergistic missions that satisfied multiple panels.

The publishing of the decadal survey was a monumental achievement for the Earth science community, but there were some aspects of the process and final report that could benefit from a more rigorous stakeholder analysis and system architecture analysis. First, the needs and objectives articulated throughout the report are described mostly from the perspective of the scientists. Although one of the panels focused on applications and societal benefits, the needs and objectives of other stakeholders received much less thorough treatment. This creates a lack of explicit traceability between the decadal survey's program recommendations and the specific needs and objectives of the non-scientist stakeholders. For example, the report does not describe the specific science knowledge that Congress will need to draft future climate-related legislation, or the datasets that commercial companies will need to provide innovative products and services to the public. Among the non-scientist stakeholders, top priority was given to climate-related concerns and urban air and health-related issues (Moore 2007).

Second, as the decadal survey indicates, the recommendations reflect the panels' prioritization of scientific observations but are not the result of an exhaustive examination of the entire trade space. The committee did not have the time or resources to conduct a rigorous analysis of the architectural trade space. In fact, much of the effort devoted to the process was spent on managing the group dynamics between science communities that had never worked together—and had often competed for resources—before the decadal survey (Hager 2007). More importantly though, the report does not indicate how its recommendations would change if the underlying assumptions about agency budgets, priorities, and mission costs were to change.

These aspects of the decadal survey are the motivation for this thesis and other concurrent studies being conducted by our System Architecture research group at MIT. Our goal has been to use a rigorous, quantitative approach to conduct a stakeholder analysis and system architecture analysis of the Earth Observations Program. In doing so, we have developed a methodology and set of tools that complement the results of the decadal survey. These tools provide a method for comprehensively articulating the needs and objectives of all the stakeholders; examining the entire mission trade space; and enabling the reconfiguration of mission timelines to respond to changes in budget, cost, technology readiness, and agency priorities. Figure 1 below shows a comparison between the decadal survey and the MIT stakeholder and system architecture studies.

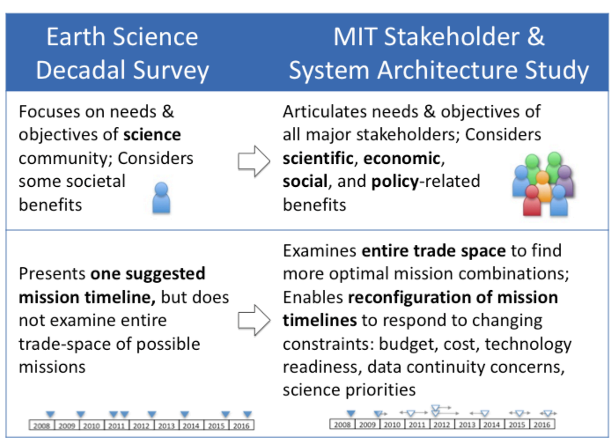


Figure 1. Comparison between decadal survey and complementary MIT studies

1.3 General Objectives

The three general objectives of this thesis are as follows:

- To further refine the stakeholder modeling technique developed by the MIT System Architecture group and apply it to NASA and NOAA's Earth Observations Program
- To provide specific insights and recommendations for the Earth Observations Program using the results of the qualitative and quantitative stakeholder analyses
- To present a general description of our stakeholder analysis methodology that can be applied to any complex system or network involving numerous stakeholders

1.4 Framework for Analysis

To help manage and understand the complexity of both the technical and social aspects of the decadal survey, we developed a comprehensive framework for analyzing the Earth Observations Program. The framework, shown below in Figure 2, decomposes the complexity and facilitates the ongoing development of our tools and methodology for modeling the stakeholders and system architecture.

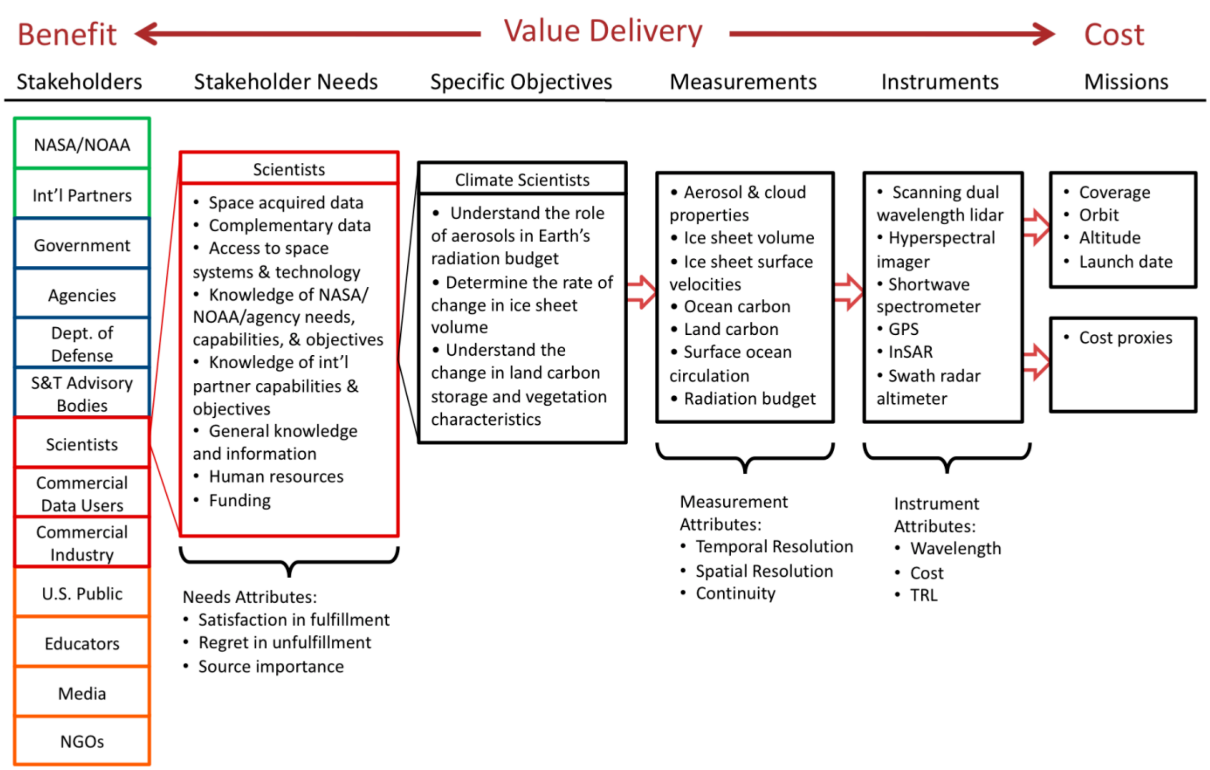


Figure 2. Framework for analysis of stakeholders and system architecture for the Earth Observations Program

The framework is structured around the delivery of value to the numerous stakeholders and beneficiaries of an Earth-observing system of satellites. In this framework, benefit is realized along the left side of the diagram and cost is incurred along the right side. Note that the information populating the framework is notional only, and the needs and objectives of a single science community have been expanded to illustrate the structure of the framework.

A description of each column within the framework is as follows: The first column on the left side of Figure 2 identifies each relevant stakeholder or beneficiary group. We define each stakeholder group in terms of its role and function within the Earth Observations Program value chain. The second and third columns articulate the primary needs and objectives of each stakeholder. The needs are characterized by three attributes: Level of satisfaction in fulfillment of the need, level of regret if the need goes unfulfilled, and the importance of a particular source in fulfilling the need. Each stakeholder objective can be linked to an individual scientific measurement or set of measurements that must be produced in order to achieve that objective. The measurements, shown in the fourth column, have distinct attributes that include temporal and spatial resolution as well as considerations such as data continuity constraints. Each measurement can be linked to one or more scientific instruments, shown in the fifth column. The instruments have distinct attributes such as wavelength, cost, and technology readiness level (TRL). Finally, the last column on the right shows the assignment of each instrument to a specific mission with operational attributes such as global coverage, orbit, altitude, and launch date. Each mission also incurs cost, which can be characterized by cost proxies listed in the lower right half of the last column. To populate this framework, we established the linkages between stakeholder objectives, measurements, instruments, and missions based on information contained in the decadal survey, the Space Act, NASA policy documents, stakeholder mission statement documents, various reports from the Climate Change Science Program (CCSP), and through interviews with prominent university and NASA Earth scientists.

Within this framework, value is delivered when instruments provide measurements that satisfy the needs and objectives of the stakeholders. We therefore define an Earth observation campaign as follows:

Earth observation campaign:

A prioritized sequence of Earth-orbiting missions containing instruments that produce measurements of the Earth, which deliver value to a diverse range of stakeholders by satisfying specific scientific and societal objectives.

The delivery of value and the satisfaction of stakeholder needs and objectives should guide the architectural and programmatic decisions for the type of Earth observation campaign proposed by the decadal survey. Our framework and associated tools are useful for understanding how cost-incurring decisions involving instruments and spacecraft affect the delivery of value to the stakeholders.

This thesis focuses on the left half of the framework presented above, which involves the delivery of benefit to the stakeholders. The analysis and results presented here complement the Masters thesis of Justin Colson, which focused on the right half of the framework by analyzing the technical aspects of the system architecture of Earth observation campaigns (Colson 2008).

1.5 Justification for Stakeholder Analysis

While performing a stakeholder analysis at the beginning of a major project is now a standard business practice, there are two relevant documents that specifically justify a rigorous stakeholder analysis for the Earth Observations Program. The first is the NASA Systems Engineering Processes and Requirements handbook, NPR 7123.1A (NASA 2007). Compliance with all procedures and requirements in the handbook is mandatory. Process Requirement 3.2.1, Stakeholder Expectations Definition Process is shown below in Figure 3. The handbook also provides a typical template for performing the stakeholder expectations definition process, which is discussed further in the literature review in the next section.

NPR 7123.1A NASA Systems Engineering Processes and Requirements

3.2.1 Stakeholder Expectations Definition Process

3.2.1.1 The Center Directors or designees shall establish and maintain a process to include activities, requirements, guidelines, and documentation, for the definition of stakeholder expectations for the applicable WBS model.

3.2.1.2 The stakeholder expectations definition process is used to elicit and define use cases, scenarios, operational concepts, and stakeholder expectations for the applicable product-line life-cycle phases and WBS model. This includes requirements for:

(a) operational end products and life-cycle-enabling products of the WBS model;
(b) expected skills and capabilities of operators or users;
(c) expected number of simultaneous users;
(d) system and human performance criteria;
(e) technical authority, standards, regulations, and laws;
(f) factors such as safety, quality, security, context of use by humans, reliability, availability, maintainability, electromagnetic compatibility, interoperability, testability, transportability, supportability, usability, and disposability; and
(g) local management constraints on how work will be done (e.g., operating procedures).

The baselined stakeholder expectations are used for validation of the WBS model end product during product realization.

Figure 3. Stakeholder Expectations Definition Process as listed in NASA NPR 7123.1A handbook

The second justification arises from the decadal survey itself. The full committee report emphasizes the need to consider societal benefits equally with purely scientific benefits to guide the development of the Earth Observations Program. The Earth Science Applications and Societal Benefits panel report discusses in more detail the need for stakeholder engagement throughout the planning process. The panel notes that agencies will have to "listen to the needs of and desires of new user communities, and ensure that both stakeholder and advisory processes are in place to enable sufficient feedback to occur to the benefit of both users and data providers" (National Research Council 2007). Furthermore, the panel report presents a list of questions for planners to consider when setting priorities for mission selection. A subset of these questions is presented below:

Questions to Consider When Setting Priorities for Mission Selection
(Adapted from Box 5.2 of the Decadal Survey)

- What is the immediate need? What is the projected need?
- Has an analysis of benefits been done? Who are the beneficiaries? How does information from the measurement reach them?
- What alternative sources of information exist for the application? In situ sources? Foreign sources?
- What are the means for funneling data to decision-makers, either directly or indirectly through data brokers (e.g. Weather Channel) or interpreters (e.g. NGOs)?
- What is the weakest link in the chain from measurement to use?

The stakeholder analysis techniques presented in this thesis can be used to satisfy NASA's procedural requirements as well as provide insights and answers to these questions posed by the decadal survey.

1.6 Relevant Literature

This section presents relevant literature on topics in stakeholder analysis theory, traditional stakeholder analysis methods, previous MIT work, and alternative methods for analyzing large, complex systems. It also includes a discussion about the study of complex engineering systems and the contributions of this thesis' methodology to further maturing the discipline.

1.6.1 Stakeholder Analysis Theory and Methods

Much of modern stakeholder theory derives from Freeman's *Strategic Management: A Stakeholder Approach*. Freeman motivates the need for stakeholder analysis as a form of strategic management to better understand and manage both internal and external exchange. He broadly defines a stakeholder as "any group or individual who can affect or is affected by the achievement of an organization's purpose," recognizing that even "illegitimate" groups must be included if they have the potential to prevent the organization's accomplishments (Freeman 1984).

Freemen presents a stakeholder mapping technique that considers the central organization and the stakeholders with which the organization interacts directly, shown in Figure 4 below. The stakeholder map incorporates a diverse set of stakeholders and uses arrows to indicate the direction of interactions between the organization and each of the stakeholders. These interactions are all direct transactions involving the organization and one other stakeholder.

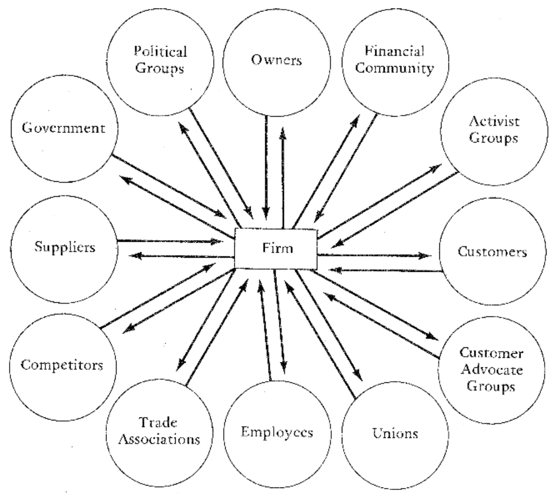


Figure 4. Stakeholder mapping technique showing direct transactions between the central stakeholder and other stakeholders (Freeman)

Freeman also introduces the idea of indirect transactions and dealing with a network of stakeholders. He presents examples of simple networks containing up to five stakeholders, shown in Figure 5 below. He acknowledges that, "…little is known in the way of formulating strategies for utilizing such networks in a positive and proactive fashion. Little is known, prescriptively, about what range of alternatives is open to managers who want to utilize such an indirect approach to dealing with stakeholders" (Freeman 1984). The value loop analysis approach presented in this thesis provides the tools necessary to use an indirect approach to understanding and managing stakeholders.

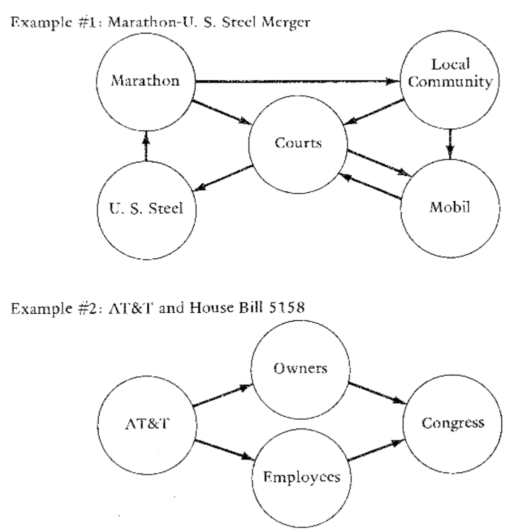


Figure 5. Examples of simple stakeholder networks (Freeman)

Finally, Freeman introduces the concept of qualitatively scoring the interactions between each stakeholder, indicated below in Figure 6. He uses "+", "-", and "=" to indicate a generally positive, negative, or neutral relationship. The quantitative stakeholder model presented in this thesis expands on this idea and offers a more rigorous method for scoring the interactions, between stakeholders.

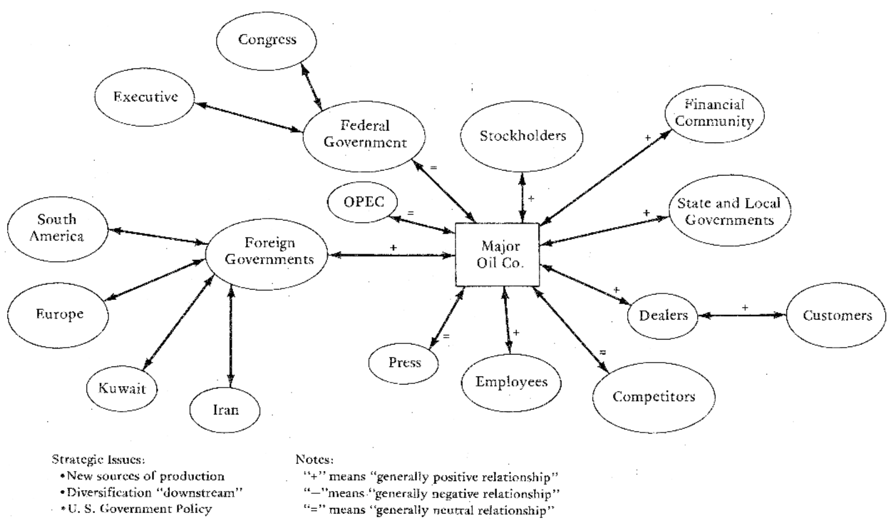


Figure 6. Stakeholder map indicating polarity of each interaction (Freeman)

In further developing stakeholder theory and applications, Winch builds upon the work of Cleland and presents a methodical stakeholder process that involves the following:

- Identify those stakeholders with a claim on the project
- Specify the nature of each stakeholder's claim
- Assess each stakeholder's ability to press that claim
- Manage the response to that claim so that the overall impact on the definition and execution of the project are minimized.

He also proposes stakeholder mapping as a valuable aid to completing this process successfully and introduces Bonke's framework for creating a stakeholder map. Using this framework he presents a stakeholder map, shown in Figure 7 below, for a project involving the development of a system to computerize the post-trade system by which stocks are exchanged for cash between sellers and buyers (Winch 2004).

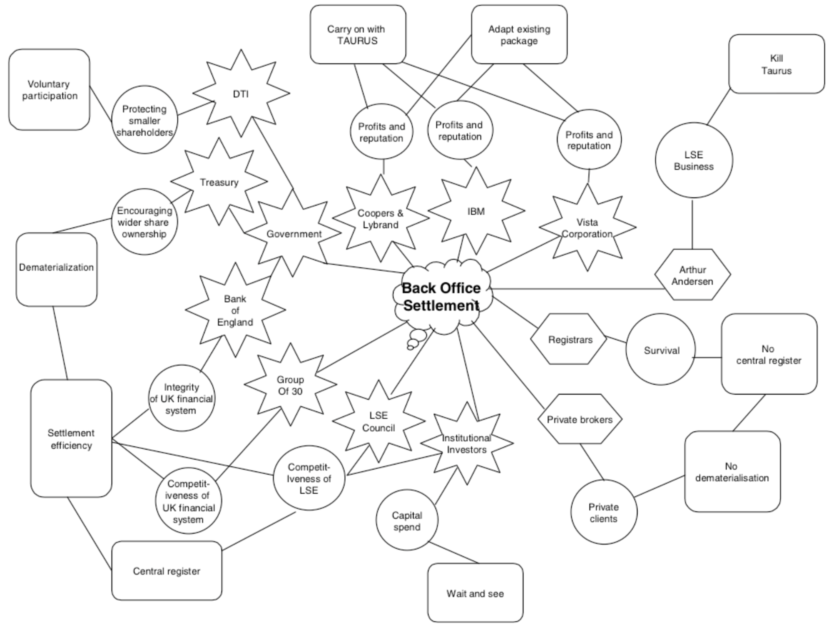


Figure 7. Example of stakeholder map using Bonke's framework (Winch)

Winch, summarizing the work of Handy, introduces the concept of five different types of stakeholder power: physical, positional, resource, expert, and personal power. He proposes a more rigorous method for classifying stakeholders by using a power/interest matrix to describe four types of stakeholders:

- Those who require *minimal effort*, such as a client's customers
- Those who must be *kept informed*, such as the local community
- Those who much be *kept satisfied*, such as regulatory bodies
- The *key players*, including the enterprise and other crucial stakeholders

Figure 8 below shows the power/interest matrix.

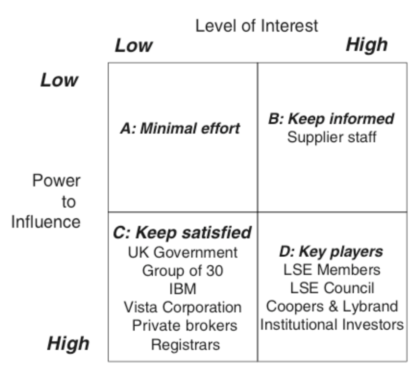


Figure 8. Power/Interest matrix to describe four types of stakeholders (Winch)

Finally, Baron discusses differences between market and non-market strategy, where the "non-market" environment includes interactions between the public, government, media, public institutions, and other stakeholders. He introduces the concept of the "four i's" that characterize the non-market environment: issues, institutions, interests, and information. Institutions and interests, as defined, represent two categories of stakeholders. Baron introduces an integrated strategy map for a company seeking approval for a new food additive (Baron 1995). The map, shown below in Figure 9, shows some of the key stakeholders and the information and policy-related flows between them. It also introduces the concept of timing, as the interactions between stakeholders occur chronologically from left to right.

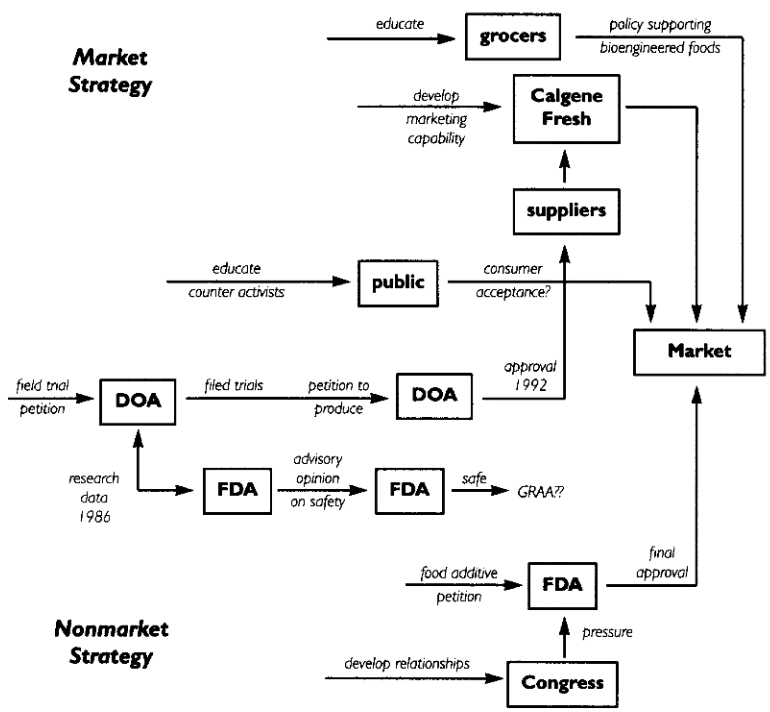


Figure 9. Example of market and non-market strategy map (Baron)

The stakeholder analysis technique presented in this thesis builds upon many of these techniques described in the literature. The most significant contributions to the field are as follows:

- Providing a structured template for articulating stakeholder needs and objectives
- Incorporating different types of interactions between stakeholders, such as policy, monetary, information, and goods & services.
- Introducing a rigorous quantitative analysis technique to accompany a more traditional qualitative stakeholder analysis.

1.6.2 NASA Stakeholder Analysis Method

As mentioned in the previous section, the NASA Systems Engineering Processes and Requirements handbook requires a Stakeholder Expectations Definition Process for all new programs and projects. The purpose of this process is to elicit and define use cases, scenarios, operational concepts, and stakeholder expectations for the applicable project. The inputs for this process are the customer expectations, other stakeholder expectations, and customer flow-down requirements from previous design iterations. The outputs of the process are a set of validated stakeholder expectations, baseline operational concepts, a baseline set of enabling product support strategies, and measures of effectiveness(NASA 2007).

The Stakeholder Expectations Definition Process typically involves the following activities:

- Establishing a list of customers and other stakeholders that have an interest in the system
- Eliciting customer and other stakeholder expectations (needs, wants, desires, capabilities, external interfaces, and constraints)
- Establishing operational concepts and support strategies
- Defining stakeholder expectations in acceptable statements that are complete sentences and exhibit the following characteristics:
    - Individually clear, correct, and feasible to satisfy
    - Not stated as to how they are to be satisfied
    - Implementable and can be validated
    - Not redundant or contradictory
    - Consistent
- Analyzing stakeholder expectation statements to establish a set of measures of effectiveness (MOEs) by which the system will be judged and customer satisfaction will be determined

The stakeholder analysis process described in this thesis is consistent with the goals of NASA's Stakeholder Expectations Definition Process. It is a powerful technique that adds a level of rigor and sophistication to the process suggested in the NASA handbook.

1.6.3 Previous MIT Work

Most of the stakeholder analysis methods presented in this thesis build on the techniques developed by Bruce Cameron for his Masters thesis (Cameron 2007). Cameron presented a technique for creating a stakeholder map, creating a value flow model, and quantitatively ranking the stakeholder interactions, called "value loops," that occur within the model. He also derived many of the techniques for analyzing the value loops to provide useful insights and recommendations.

Cameron used the NASA Exploration Program as the subject of his thesis. Figure 10 below shows a simplified version of the stakeholder model. The NASA Exploration Program shares many of the same stakeholders and value flows as the Earth Observations Program, the subject of this thesis. However, because science and societal needs are the primary focus of Earth observations, the importance of many of the value flows differs between the two programs.

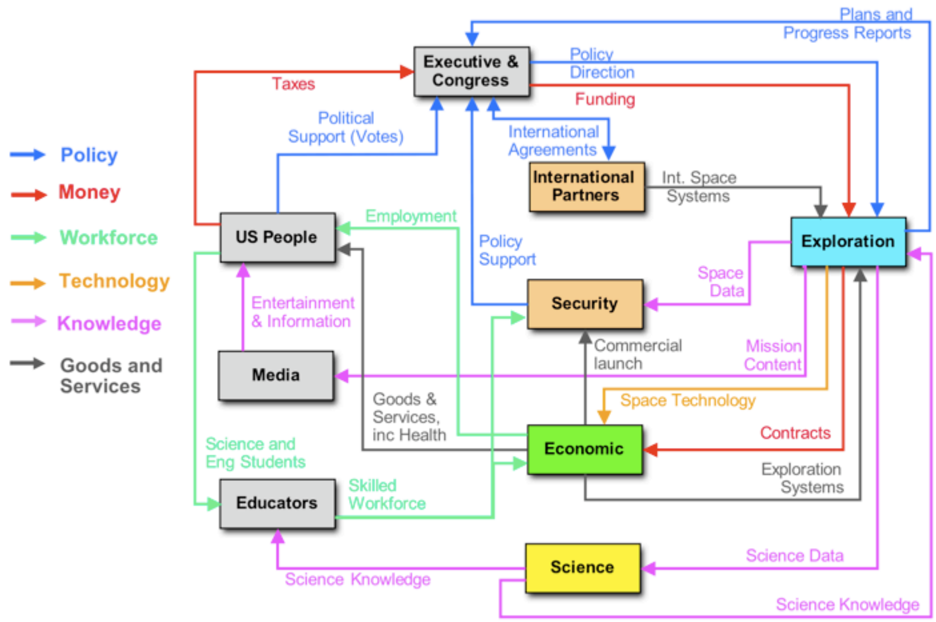


Figure 10. Stakeholder value network diagram for NASA Exploration Program (Cameron)

Cameron's thesis focused largely on the development of the value loop analysis technique, whereas this thesis focuses largely on the application of the technique to the current NASA & NOAA Earth Observations Program to provide insights and recommendations for program managers. The stakeholder analysis methods presented in this thesis offer the following improvements or refinements from Cameron's technique:

- **Three-level stakeholder map**: Using the baseline stakeholder map, I created a "one-up" and "one-down" version of the map that offer a higher-level view of the context within which the Earth observation system operates, and a more detailed view of the hierarchy and aggregation among the stakeholders in the baseline model.
- **Stakeholder objectives, needs and inputs template**: I created a formal template for articulating the role of each stakeholder, its primary objectives, its specific needs, and the inputs it receives from other stakeholders. This improves the traceability of stakeholder inputs to the needs and objectives.
- **Assigning scores to value flows:** Working with others in the MIT System Architecture research group, we refined the questionnaire that we use to assign numeric scores to each value flow. The new questionnaire resolves previous ambiguity and captures the importance of the supplier of a particular need.

- **Validation of value flow rankings:** By using information contained in the literature, as well as surveys and other data-gathering techniques, I demonstrate additional techniques for validating the relative rankings of the value flows in the model.

In addition to Cameron's thesis, there is ongoing work by members of the MIT System Architecture group to develop the mathematical theory that justifies our quantitative stakeholder analysis method. This work uses utility theory to derive the equations used to calculate value loop scores. Further discussion of this work is presented in Section 4.8.5.

1.6.4 Alternative Methods for Systems Analysis

Many methods have been developed for analyzing large, complex systems. This section describes two methods—cost-benefit analysis and system dynamics—and discusses some of the strengths and weaknesses of these approaches compared to the value network analysis method presented in this thesis.

Cost-Benefit Analysis

Cost-benefit analysis (CBA) is an analytic technique that compares the estimated cost of a project to its expected benefits. To perform this comparison, the benefits must be converted into monetary units. This conversion often makes use of the concepts of "willingness to pay" (WTP) and "willingness to accept" (WTA). Willingness-to-pay represents the amount that someone who does not have a good would be willing to pay to buy it; willingness-to-accept represents the amount that someone who has a good would be willing to accept to sell it. Benefits are thus the sum of the WTPs for changes that provide gains, and of the WTAs for changes that result in losses. (Zerbe 2006)

The Army Corp of Engineers first introduced cost-benefit methods in the U.S. in the early twentieth century. The Corps had started quantifying project benefits and costs as a means of simplifying the decision-making process for Congress. By the 1920s, the Corps required its recommended projects to provide a level of benefits that exceeded costs. Over the next few decades, CBA became institutionalized within Congress and certain Federal Agencies. President Reagan issued an Executive Order in 1981 that mandated the use of CBA by requiring that Regulatory Impact Analyses be conducted for major initiatives. Another Executive Order signed by President Clinton in 1994 further confirmed the government's commitment to cost-benefit analysis methods. (Zerbe 2006)

One of the criticisms of cost-benefit analysis is that it requires every benefit to be converted to monetary units. This can be difficult to do for some types of benefit, and nearly impossible for others. For example, what is the monetary benefit of the national prestige bestowed upon the U.S. during the Apollo mission moon landings? Some benefits simply cannot be monetized. Another criticism of CBA arises because consideration of the monetary costs and benefits requires using an economic discount rate. The choice of discount rate can be controversial, and applying a discount rate to future benefits may be considered unethical in some cases. For example, is it fair to apply a discount rate to the value of future human lives that may be saved due to a regulation that is implemented today? Finally, converting the benefits of every project into monetary units can lead to the loss of insight and intuition regarding their true value, which may include intangible benefits such as national prestige or scientific inspiration.

While using cost-benefit analysis may be appropriate in certain cases where monetizing the benefits is fairly straightforward, there are many examples where this is not the case, and other methods are needed. One of the advantages of our stakeholder value network analysis technique is that it can accommodate benefits of any type, rather than just monetary benefits.

System Dynamics

According to the premier textbook on the topic, system dynamics is "a perspective and set of conceptual tools that enable us to understand the structure and dynamics of complex systems"(Sterman 2000). System dynamics models are simulations of complex systems that can be used to design more effective policies and organizations. Figure 11 below shows a typical system dynamics model showing the adoption of a new technology by consumers.

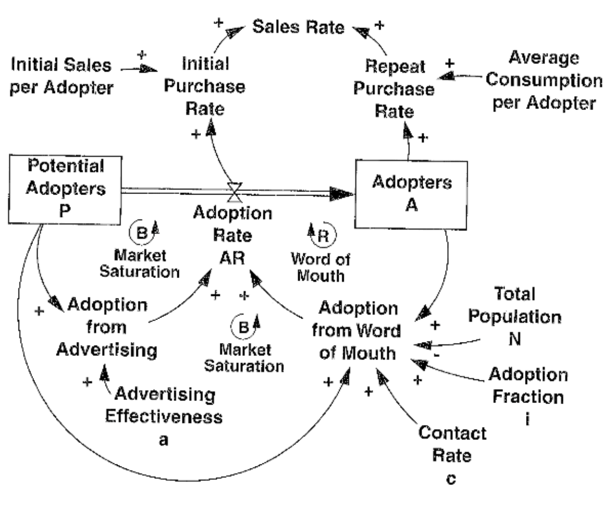


Figure 11. System dynamics model for new technology adoption (Sterman)

Executing a system dynamics model requires a set of equations that relate the stocks, flows, and variables in the model. The output of the model is a prediction of the *dynamics* of the system; that is, how each variable in the model changes over time.

While system dynamics models work well for modeling cases such disease outbreaks or the dynamics of a market bubble, they would not work well for modeling the NASA & NOAA Earth Observations Program. First, it would be nearly impossible to determine mathematical equations to relate many of the value flows in the model. Second, the stakeholder model described in this thesis does not incorporate the aspect of time—that is, the model treats the system as steady-state with no changes over time (i.e. dynamic behavior). Clearly a system dynamics model is not the appropriate tool for this type of analysis.

1.6.5 Complex Engineering Systems

The satellite Earth observation campaign proposed in the decadal survey is an example of a contemporary *complex engineering system* – one that is technologically enabled, has substantial complexity, and has significant socio-technical interactions. Complex engineering systems have nonlinear properties, such that the ultimate outputs or value derived from the system do not have simple relations to the inputs, and there are emergent properties in how society uses or responds to the system (Hastings 2004).

The field of Engineering Systems is immature compared to other well-understood disciplines such as thermodynamics. According to Hastings, the hierarchy of our understanding of a particular field of knowledge is as follows:

1. Observation
2. Classification
3. Abstraction
4. Quantification and Measurement
5. Symbolic Representation
6. Symbolic Manipulation
7. Prediction

At the time of the 2004 MIT Engineering Systems Symposium, the current state of Engineering Systems was somewhere between levels 2 and 4 on the scale above (Hastings 2004). The stakeholder value network analysis method presented in this thesis provides evidence that the state of knowledge has progressed further up the scale. The stakeholder analysis technique produces a quantitative model whose outputs yield an enormous amount of insight regarding the social and technical interactions within the system. Through further refinement of Cameron's model we have converged on a standard symbolic representation, and by concurrently developing the underlying theory driving the model's behavior, we will improve our capacity for symbolic manipulation. Thus, the current state of knowledge for Engineering Systems may now fall somewhere between levels 4 and 5.

1.6.6 Summary

The stakeholder value network analysis described in this thesis builds upon much of the previous stakeholder literature mentioned above. The techniques presented here add a greater level of rigor and introduce quantitative capabilities into the stakeholder modeling process. The result is a sophisticated model that produces a wealth of insights for the Earth Observations Program. These insights provide a deep understanding of how the program delivers value to the entire stakeholder network. The insights and recommendations presented in this thesis are complementary to those in the decadal survey.

1.7 Specific Objectives

There are five specific objectives of this thesis. Each objective is written using Crawley's To/By/Using template for formulating goal statements (Crawley 2006). The specific objectives are as follows:

- **To** develop a more complete understanding of the stakeholders of an Earth Observations Program **by** articulating the goals, objectives, and needs of every stakeholder **using** information contained in stakeholder policy or strategy documents, mission statements, websites, the decadal survey, government reports, legislation, and other official stakeholder documents.
- **To** understand the important interactions among all stakeholders **by** constructing a detailed stakeholder map showing the inputs and outputs of each stakeholder **using** information garnered from the articulation of stakeholder needs
- **To** identify the most important stakeholders, the highest value-producing interactions among stakeholders, and most important NASA & NOAA outputs **by** conducting a rigorous quantitative stakeholder analysis **using** the stakeholder value network analysis approach.
- **To** complement the recommendations of the decadal survey **by** providing more specific, targeted insights and recommendations **using** the results of the qualitative and quantitative stakeholder analyses presented in this thesis.
- **To** make the stakeholder analysis techniques presented n this thesis more broadly applicable as a business practice **by** generalizing the methodology for conducting the

analysis **using** a set of templates for commonly encountered projects or systems with significant stakeholder concerns.

These specific objectives support the central question of this thesis:

Central Thesis Question:

To establish a set of priorities for the Earth Observations Program, can a mathematically rigorous stakeholder analysis yield additional or more specific insights and recommendations than the group consensus process used by the Decadal Survey Committee?

1.8 Overview of Thesis Chapters

This thesis consists of six chapters, the first of which is the current chapter. The remaining five chapters are organized as follows:

- Chapter 2 presents the qualitative stakeholder model. It describes the process used to identify stakeholders, create a stakeholder map, articulate stakeholder needs and objectives, and map the input and output value flows between each stakeholder.
- Chapter 3 presents the quantitative stakeholder model. It describes the technique used to quantify the value flows between each stakeholder; presents several methods for validating the value flow scores; and describes the method used to calculate the "value loops" within the stakeholder network.
- Chapter 4 presents the analytic results of the quantitative stakeholder analysis. This includes the identification of the most important stakeholders, value flows, value loops, and NASA/NOAA inputs and outputs. It also reveals the relative importance of each science category representing the six science-themed panels of the decadal survey.
- Chapter 5 describes the major insights yielded from the stakeholder value network analysis and presents a list of recommendations for the Earth Observations Program. This chapter is intended to function as a stand-alone executive summary for program planners interested in the results of the stakeholder analysis.
- Chapter 6 presents a generalized description of the stakeholder analysis process described in this thesis. It is intended to function as a stand-alone document that can be used as a handbook for conducting stakeholder analyses as a general business practice.

2 Qualitative Stakeholder Model

The qualitative stakeholder model is a tool that can help provide an in-depth understanding of the numerous stakeholders within the system. It is useful for articulating each stakeholder's needs and objectives and understanding the complex interactions between the stakeholders. By incorporating the most important inputs and outputs of each stakeholder, the model allows one to visualize and understand, in a qualitative sense, how value is created and delivered throughout the system. It also provides an indication of the connectedness of each stakeholder to the entire stakeholder network.

This chapter describes in detail the qualitative portion of the stakeholder analysis. The objectives of this chapter are as follows:

Objectives of Qualitative Stakeholder Analysis:

- **To** develop a more complete understanding of the stakeholders of an Earth Observations Program **by** articulating the goals, objectives, and needs of every stakeholder **using** information contained in stakeholder policy or strategy documents, mission statements, websites, the decadal survey, government reports, legislation, and other official stakeholder documents.
- **To** understand the important interactions among all stakeholders **by** constructing a detailed stakeholder map showing the inputs and outputs of each stakeholder **using** information obtained from the articulation of stakeholder needs

The methodology presented in this chapter builds upon Cameron's Master's thesis, which presents a stakeholder analysis of the NASA Exploration Program (Cameron 2007). Creating a stakeholder model using this methodology involves the following steps:

- Identifying and characterizing stakeholders
- Developing a visual stakeholder map
- Articulating stakeholder needs and objectives
- Determining the interactions, or value flows, between each stakeholder
- Mapping value flows onto the stakeholder map

This chapter is organized according to the process flow described above. There are two additions to Cameron's method that are described in this chapter: (1) the development of a three-level stakeholder map, described in Section 2.2; and (2) the development of a formal template for articulating stakeholder objectives, specific needs, and inputs, described in Section 2.3. The stakeholder model presented here is specific to the Earth Observations Program. A generalized description of this methodology, which is broadly applicable to any complex system involving numerous stakeholders, is presented in Chapter 6.

This chapter is organized into the following sections:

- **Section 2.1: Identification of Stakeholders.** This section describes the process used to identify the stakeholders of the Earth Observations Program.
- **Section 2.2: Stakeholder Map.** This section describes the development of a three-level stakeholder map that includes a baseline map as well as "one-up" and "one-down" maps.
- **Section 2.3: Stakeholder Objectives, Specific Needs, & Inputs.** This section describes the template used to characterize each stakeholder by articulating the objectives, specific needs, and inputs of each stakeholder.
- **Section 2.4: Value Flows and the Stakeholder Value Network Model.** This section describes the process used to determine the value flows among the stakeholders and the creation of a stakeholder value network map.
- **Section 2.5: Summary of Qualitative Stakeholder Model.** This section provides a summary of the qualitative stakeholder model developed in this chapter.

2.1 Identification of Stakeholders

The first step in the stakeholder analysis involved identifying the stakeholders to include in the model and characterizing their objectives and specific needs. Stakeholders were considered from the viewpoint of NASA and NOAA's Earth observation activities. I used a fairly broad definition of the term stakeholder. Stakeholders are those who (1) have a direct or indirect affect on NASA/NOAA's Earth observation activities, **or** (2) receive direct or indirect benefits from Earth observation activities, **or** (3) possess a significant, legitimate interest in Earth observation activities. I identified potential stakeholder groups as those mentioned in the decadal survey, the Space Act of 1958, NASA policy documents, and participants in the U.S. Climate Change Science Program. Table 1 below shows the initial list of stakeholders that were considered for the model. Abbreviations are listed in the List of Acronyms at the beginning of this thesis.

Table 1. Initial list of stakeholders considered for the stakeholder model

Congress	Dept. of Defense	NASA Headquarters	Scientists
Executive Branch	EPA	NASA Earth Science Division	
President	NSF	NOAA	Schools
State Dept.	NIH	USGS	Museums
OSTP	Dept. of Transportation		
OMB	USDA	International Partners	Media
Judiciary	Dept. of Energy		
State & local govts.	US AID	Commercial Data Providers	NGOs
International govts.	World Bank	Commercial Data Users	
		Commercial Industry	Public / Society
National Academies			

Next, I refined this initial list by classifying the stakeholders into a smaller number of stakeholder groups based on their primary function within the stakeholder network. I used the concepts of aggregation and hierarchy to refine the initial list, as described further below. Table 2 below shows the revised list of stakeholders. Reducing the number of stakeholders was desirable for two reasons – first, limiting the number of stakeholders to approximately ten helps keep the model conceptually manageable. Second, the stakeholder network model treats each stakeholder as a node, and the number of possible links in the system scales combinatorially with the number of nodes. Therefore, limiting the number of stakeholders also helps keep the model computationally manageable.

Table 2. Revised list of stakeholders included in the model

Government	NASA/NOAA	Scientists
Science & Technology Advisory Bodies	International Partners	Educators
	Commercial Data Users	Media
Dept. of Defense		
	Commercial Industry	NGOs
Federal Agencies		
		Public / Society

The challenge in this part of the process was to define the stakeholder groups so that the model was as simple as possible yet captured enough complexity to produce insightful results. I used two classification schemes to simplify the model: aggregation and hierarchy.

Aggregation involves combining multiple stakeholders based on their roles or functions. Aggregation can also be used if two or more stakeholders have identical, or nearly identical, inputs and outputs in the stakeholder model. This is similar to the concept of market segmentation—each of the aggregated stakeholders has approximately the same interests at the level of fidelity in the model. I aggregated Congress, the Executive Branch, and the Judiciary into one stakeholder called the Government. Due to the complex interactions between the three branches of the U.S. Government, I decided not to include that level of detail in the model. I also aggregated most of the U.S. Government Agencies with USAID and the World Bank into a stakeholder called Federal Agencies. Although the objectives of each agency differ substantially, their roles within the Earth Observations Program are largely the same: Agencies use Earth observations data to help achieve their regulatory or organizational objectives. I chose to include USGS in the aggregation of Federal Agencies. Although USGS was a sponsor of the decadal survey, it plays a much lesser role than NASA and NOAA in Earth observations and functions more as a Federal Agency as defined in this model. The third aggregation included schools and museums, which I combined into a stakeholder called Educators.

I also aggregated NASA Headquarters, NASA Earth Science Division, and NOAA into a single stakeholder group called NASA/NOAA. Similar to the Government, the interactions between the divisions within NASA are too complicated to include in this model. The inputs and outputs of NASA and NOAA would be almost identical if they were modeled separately, although there are differences in the type of science data they produce. Also, the operational boundaries between NASA and NOAA can be fuzzy at times. Traditionally, NASA designs and operates research satellites, while NOAA's satellites are operational in nature. However, some of the decadal survey recommendations blur this distinction. NASA and NOAA are therefore treated as a single stakeholder in the model. Section 4.8.4 investigates how the model results would differ if NOAA were considered separately.

Hierarchy involves combining stakeholders such that each level within the hierarchy has jurisdiction or control over lower levels. I used hierarchy in the model to place the President, Department of State, OSTP, and OMB within the Executive Branch of the Government. As mentioned previously, the interactions between these stakeholders are too complex to be included in the stakeholder model.

I deleted from the model three stakeholders from the initial list: State & Local Governments, International Governments, and Commercial Data Providers. While state and local governments use data and knowledge from the Earth Observations Program, their inputs and outputs within the model would be largely redundant with the Government stakeholder. Also, within the U.S. there would be far too many state and local governments to consider for this model. International Governments were deleted because they largely fulfill the same role in their host countries as the Government stakeholder, which would create a redundancy in the model. I deleted Commercial Data Providers because of the assessment in the decadal survey that most of what is important scientifically will not be provided in the foreseeable future by commercial providers (National Research Council 2007).

Finally, I generalized the National Academies from the initial list as Science & Technology Advisory Bodies in the revised list. While the National Research Council, part of the National Academies, published the decadal survey and other related reports, there are other important advisory bodies such as the NASA Advisory Council that regularly provide science- and technology-related policy advice to NASA, NOAA, and the Government.

Determining which stakeholders to include in the revised list was an iterative process – as the development of the model progressed, it became clearer how to aggregate and simplify the list of 33 original stakeholders into the 13 stakeholder groups listed above in Table 2. Table 3 below provides a detailed description of the definition and role of each of the final 13 stakeholders.

Table 3. Definition and role of the 13 stakeholders included in the model

Stakeholder Group	Definition and Role
Commercial Data Users	Companies that rely on space-acquired Earth observations data and derived knowledge, products, and services. Examples include Google Earth (detailed land imagery), weather forecasters (weather data), petroleum exploration companies (natural resource deposits), and insurance companies (solid Earth hazard data).
Commercial Industry	Companies that interact directly or indirectly with NASA/NOAA and rely on funding, commercial contracts, launch and space services, and space technology from NASA/NOAA. These companies also provide science systems (e.g. satellites and sensors) and launch & space services to NASA/NOAA. Examples include Lockheed Martin, Orbital Sciences, and Boeing.
Department of Defense	The U.S. military as it interacts with NASA/NOAA on collaborative Earth-observing missions such as NPOESS. Also includes units such as the National Guard and Army Corp of Engineers that rely on Earth-related knowledge, products, and services (e.g. flood predictions, weather forecasts).
Educators	Individuals and institutions that comprise the U.S. educational system, from the primary level to universities (does *not* include university scientists). Includes museums that display Earth-related science exhibits.

Federal Agencies	U.S. Federal Agencies and other organizations involved in public health, safety, environmental protection, scientific research, land use, transportation, energy, and agriculture. Aggregation of USGS, EPA, NSF, DOT, USDA, NIH, DOE, USAID, and the World Bank. Does *not* include Federal Agency scientists.
Government	The legislative, executive, and judicial branches of the U.S. government. Includes the State Department, OMB, and OSTP. Does *not* include Federal Agencies or State & Local Governments.
International Partners	Non-U.S. national space agencies that collaborate with NASA/NOAA and fulfill the same role as NASA/NOAA in their respective nations.
Media	Organizations responsible for the acquisition, composition, and distribution of news and information.
NASA/NOAA	U.S. Federal entities that provide the means with which to expand human knowledge of the Earth and space. Responsible for program organization, management, data acquisition, and providers of products and services derived from space-based Earth observations. Does *not* include NASA/NOAA scientists.
Non-Governmental Organizations (NGOs)	Advocacy and industry trade groups that promote the importance of Earth science and observations on behalf of scientists, industry, and the public. Examples include the Institute for Global Environmental Strategies, the Management Association for Private Photogrammetric Surveyors, and the Natural Resources Defense Council.
Public/Society	The general U.S. population and society as a whole.
Science & Technology Advisory Bodies	The science and technical advisory organizations for the U.S. federal government. Examples include the National Research Council and NASA Advisory Council.
Scientists	Scientists employed by academia, NASA, NOAA, Federal Agencies, and the commercial sector that use Earth observation data to generate useful knowledge; develop science systems for NASA/NOAA; and provide science knowledge and opinions to other stakeholders in the model.

Nearly all the stakeholders listed above in Table 3 are either explicitly or implicitly enumerated in the Space Act of 1958, as Amended (The National Aeronautics and Space Act, as Amended 1958). The only stakeholders not appearing are the Media and NGOs. These two stakeholders, however, have significant influence in affecting Public opinion and providing information to NASA/NOAA and the Government, so their inclusion in the list is appropriate.

2.2 Stakeholder Map

The next step in the stakeholder analysis process was to arrange the stakeholders on a visual map. A coherent stakeholder map allows one to visualize the connections between the stakeholders and to better understand how value is delivered throughout the stakeholder network. Ideally the stakeholders can be arranged such that individual areas of the map represent distinct functions within the stakeholder network.

Building upon Cameron's map of the NASA Exploration Program stakeholders, I developed a three-level stakeholder map for the Earth Observations Program. The three levels correspond to the baseline stakeholder map as well as a "one-up" (i.e. one higher level of abstraction) and "one-down" (i.e. one more level of detail) version of the map. The "one-up" map, referred to as Level 1, offers a high-level view of the context within which the Earth observation system operates. The baseline map, referred to as Level 2, includes the revised list of 13 stakeholders. The "one-down" map, referred to as Level 3, offers a more detailed view of the aggregation and hierarchy within the stakeholders in the baseline map.

The Level 1 map, shown below in Figure 12, is a high-level abstraction of the process by which the Earth Observations Program delivers value to its stakeholders. Beginning in the upper left quadrant of the figure, policy makers provide funding and policy direction to data providers in the upper right quadrant. Data providers acquire Earth measurements and transmit the data to data users in the lower right quadrant. Data users analyze the data to produce knowledge, which they pass along to the public and beneficiaries in the lower left quadrant. The public and beneficiaries interpret the knowledge and use it to make decisions and provide support to the policy makers in the upper left quadrant; thus completing the cycle.

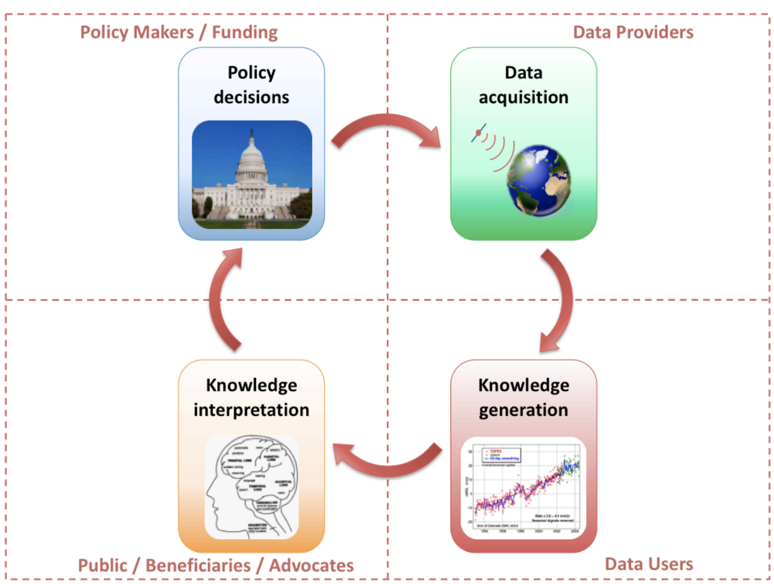


Figure 12. Level 1 stakeholder map

The Level 2 map, shown below in Figure 13, contains the 13 major stakeholder groups identified above in Table 3. The stakeholders are situated on the four quadrants of the Level 1 map according to their primary roles within the value chain. Some of the stakeholders span multiple quadrants because they serve multiple roles within the system. For example, the Department of Defense provides some funding to NASA and is both a generator and user of weather-related data. At this level, the roles of each stakeholder, described previously in Table 3, have been simplified and idealized in order to create a model that is sufficiently detailed yet conceptually and computationally manageable.

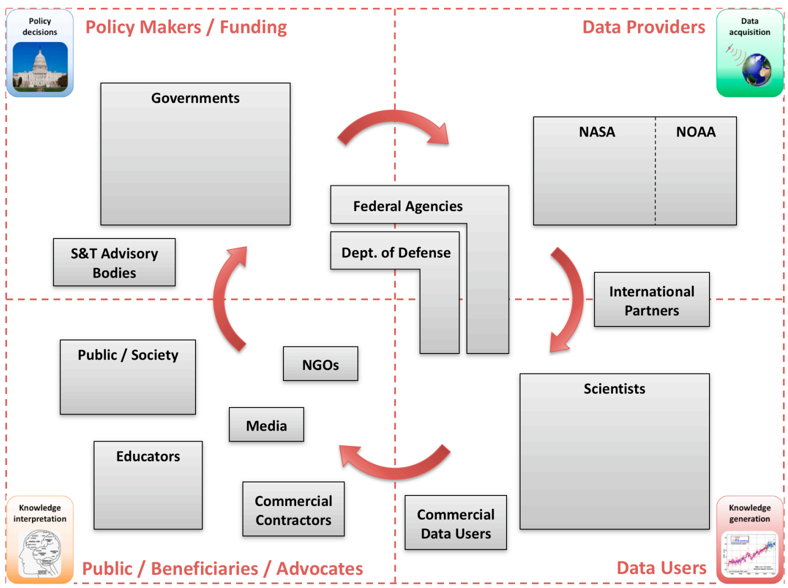


Figure 13. Level 2 stakeholder map

Finally, the Level 3 map, shown below in Figure 14, contains the original 33 stakeholders listed in Table 1. This map illustrates the hierarchy and aggregation within some of the stakeholder groups. While this level of detail is not carried throughout the entire stakeholder analysis, it is useful to have a finer view inside some of the stakeholders with significant influence on the Earth Observations Program. For example, the Office of Management and Budget (OMB) is a crucial stakeholder in setting the annual funding levels for NASA and NOAA. The Level 3 map also contains the stakeholders that were deleted from the original list: State & Local Governments, International Governments, and Commercial Data Providers.

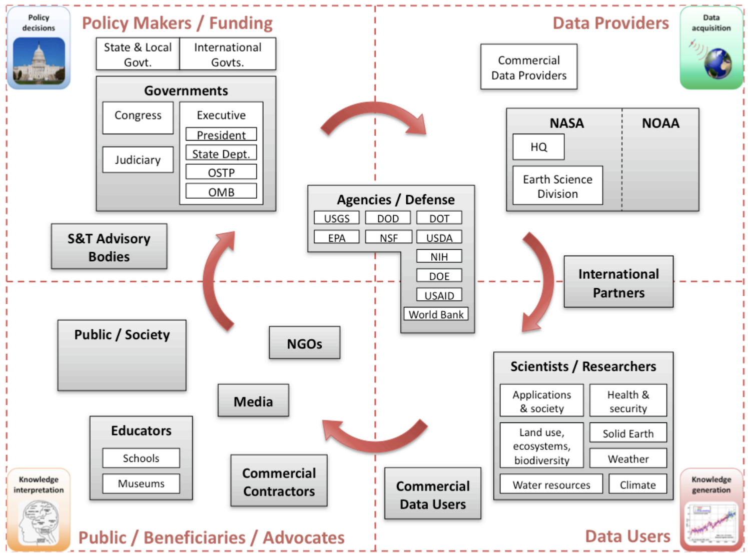


Figure 14. Level 3 stakeholder map

The Level 2 stakeholder map was used as the basis for stakeholder value network analysis described in this thesis. Performing this sort of analysis for the entire Level 3 map would have been far too complex; however, analyzing a single stakeholder at the Level 3 detail could be useful for future analyses. It remains useful, however, to keep and understand the Level 1 and Level 3 stakeholder maps. Just as with any system analysis, understanding one level above and one level below the baseline system can provide a richer understanding of the context within which the system operates as well as the finer details of the inner workings of the system (Crawley 2006).

2.3 Stakeholder Objectives, Specific Needs, and Inputs

Performing a rigorous stakeholder analysis involves developing an appreciation for the interests and objectives of each stakeholder as well as an in-depth understanding of how each stakeholder contributes to and derives value from the system. The importance of this is emphasized by many of the stakeholder analysis methods described previously in Section 1.6. However, I felt there lacked a rigorous methodology for capturing this information and presenting it in a format that provides traceability between the interactions among stakeholders and the satisfaction of each stakeholder's needs and objectives.

To address this, I developed a stakeholder characterization template, shown below in Figure 15, that can be used to succinctly articulate the role, objectives, and specific needs of each stakeholder. The template also indicates the inputs that the stakeholder receives from other stakeholders. The template in the figure has been populated with information for the Scientists stakeholder group. The completion of this template for each of the 13 stakeholders in the model is included in Appendix A.

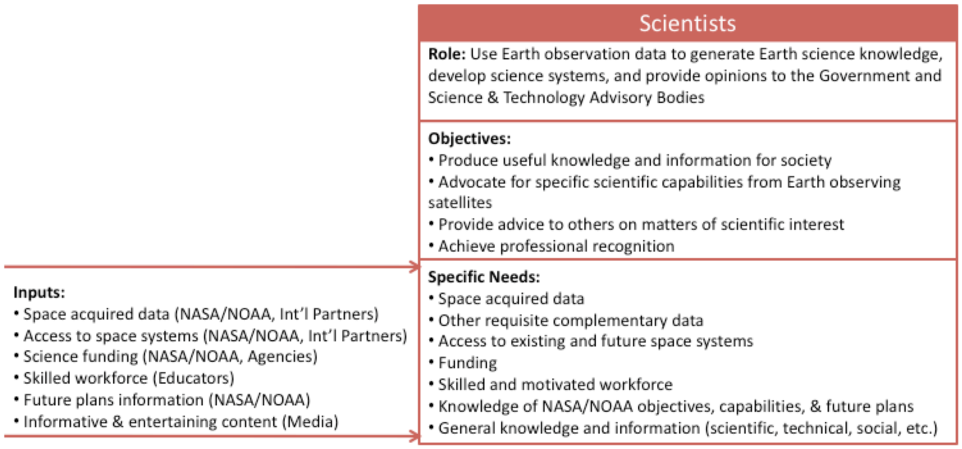


Figure 15.Stakeholder characterization template, shown for Scientists

The upper box in the template describes the role of each stakeholder within the context of the Earth Observations Program. Initially, the role assigned to each stakeholder was based on a preliminary assessment of the stakeholder's primary functions within the program. As the model progressed, more information became available regarding the high-value outputs provided by each stakeholder, and the templates were updated accordingly. The templates in Appendix A include the final assessments of the primary role of each stakeholder based on the results of the value network analysis.

The center box in the template shows the stakeholder's objectives, which are goal statements that are often published on a stakeholder's website or can be found in policy and strategy documents, mission statements, or other official documents. I determined many of the stakeholder objectives from information contained in the decadal survey, CCSP reports, the Space Act, stakeholder websites, and stakeholder policy and strategy documents.

The lower box in the template contains the stakeholder's specific needs required to satisfy its stated objectives. I use the term "specific needs" because the term "needs" can have multiple uses. "Needs" is often used as a synonym for "objectives;" for example: "A Scientist needs to achieve professional recognition" could also be phrased, "One of a Scientist's objectives is to achieve professional recognition." To avoid potential ambiguity, I use the term "specific needs" to indicate the resources that a stakeholder requires in order to satisfy its objectives. I determined the specific needs in the same manner as the objectives described above.

The left side of the template lists the inputs that the stakeholder receives from other stakeholders. Each input fulfills, either partially or wholly, a specific need of the stakeholder. To create the list of inputs to a stakeholder, I examined each specific need and determined which of the other stakeholders in the model produce outputs that satisfy that need. I also used this method to check the stakeholder list for completeness, by assessing whether any of the needs could be satisfied by stakeholders not included in the model. Using this method to determine the inputs to each stakeholder ensures that the stakeholder model will capture all the stakeholder interactions necessary to fulfill each stakeholder's objectives. Each of the inputs to a stakeholder becomes a "value flow" in the value network model, as described further in the next section.

An example of how to interpret the information contained in the template is as follows: One of the scientist's objectives is to produce useful knowledge and information for society. To do so, the scientist needs data, funding, skilled graduate students, and general knowledge related to the particular field of science. To fulfill these specific needs, Scientists receive space-acquired data from NASA/NOAA and International Partners; science funding from Federal Agencies; skilled students from Educators; and relevant knowledge and information from the Media.

Using this template provides a succinct way of articulating each stakeholder's objectives, specific needs, and inputs from other stakeholders. It also provides traceability between the inputs a stakeholder receives and the satisfaction of its objectives. Additionally, accumulating the information required to populate the framework helps ensure that the interests of each stakeholder will be fully appreciated and captured by the model.

2.4 Value Flows and the Stakeholder Value Network Model

After articulating the objectives, specific needs, and inputs of each stakeholder, the next step was to create the stakeholder value network model by connecting each stakeholder using the inputs identified in the stakeholder characterization templates. Each identified input to a stakeholder became an output of the originating stakeholder. Theoretically, the sum of all the inputs articulated in the stakeholder characterization templates provides a complete set of the value-delivering interactions within the stakeholder network. Therefore, it is unnecessary to complete a separate exercise determining each stakeholder's outputs to other stakeholders. Also, it is generally easier to identify a stakeholder's required inputs than it is to identify which of its outputs provide value to other stakeholders. Some stakeholder outputs may not actually provide value to any of the other stakeholders, and these should not be included in the model.

In the value network model I use the term *value flow* to indicate the output of one stakeholder as the input to another – it represents the delivery of value from one stakeholder to another. Figure 16 below shows the value flows into and out of each stakeholder. For example, S&T Advisory Bodies—the last stakeholder pictured Figure 16—receives funding from NASA/NOAA; science knowledge from scientists; and future plans information from NASA/NOAA, International Partners, Agencies, Commercial Data Users, and Commercial Industry. Likewise, S&T Advisory Bodies give science policy advice to NASA/NOAA and the Government; and science policy reports to Scientists, NGOs, and the Media. The four colors used for the stakeholders in Figure 16 correspond to the colors used in the four quadrants of the Level 1 stakeholder map shown previously in Figure 12. The model contains many value flows of the same type; for example, there are ten "funding" flows occurring as inputs to six separate stakeholders. The table in Appendix B provides the definition of each type of value flow.

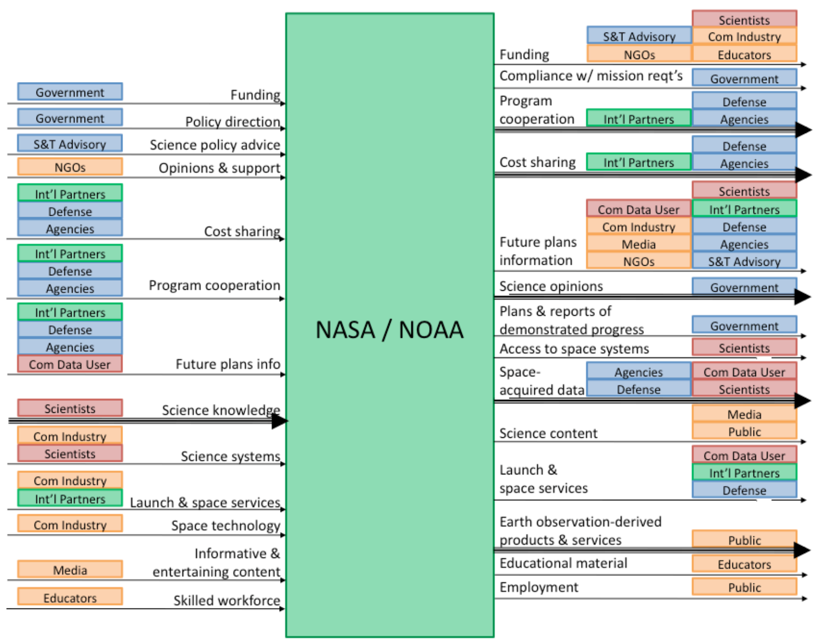


Figure 16. Value flows into and out of each stakeholder

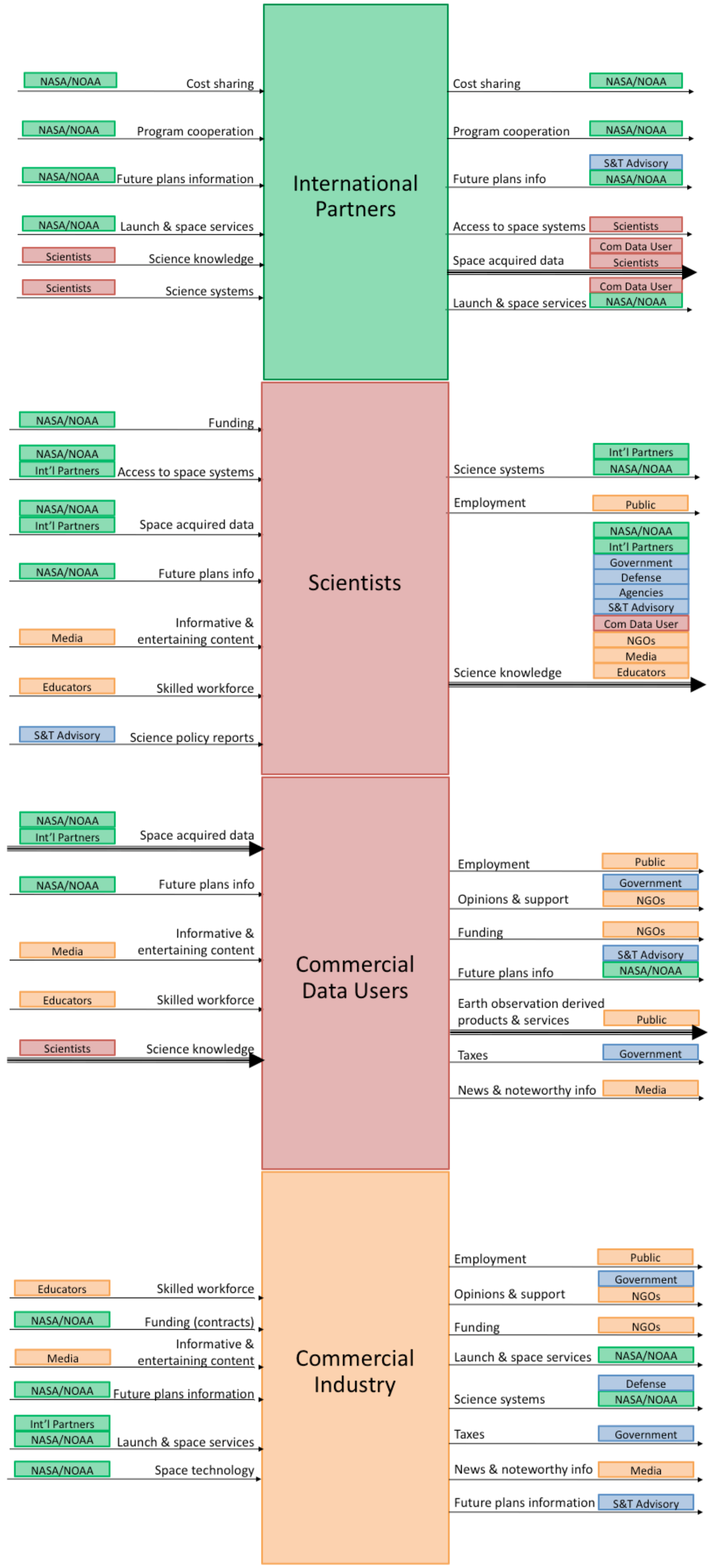


Figure 16. (continued)

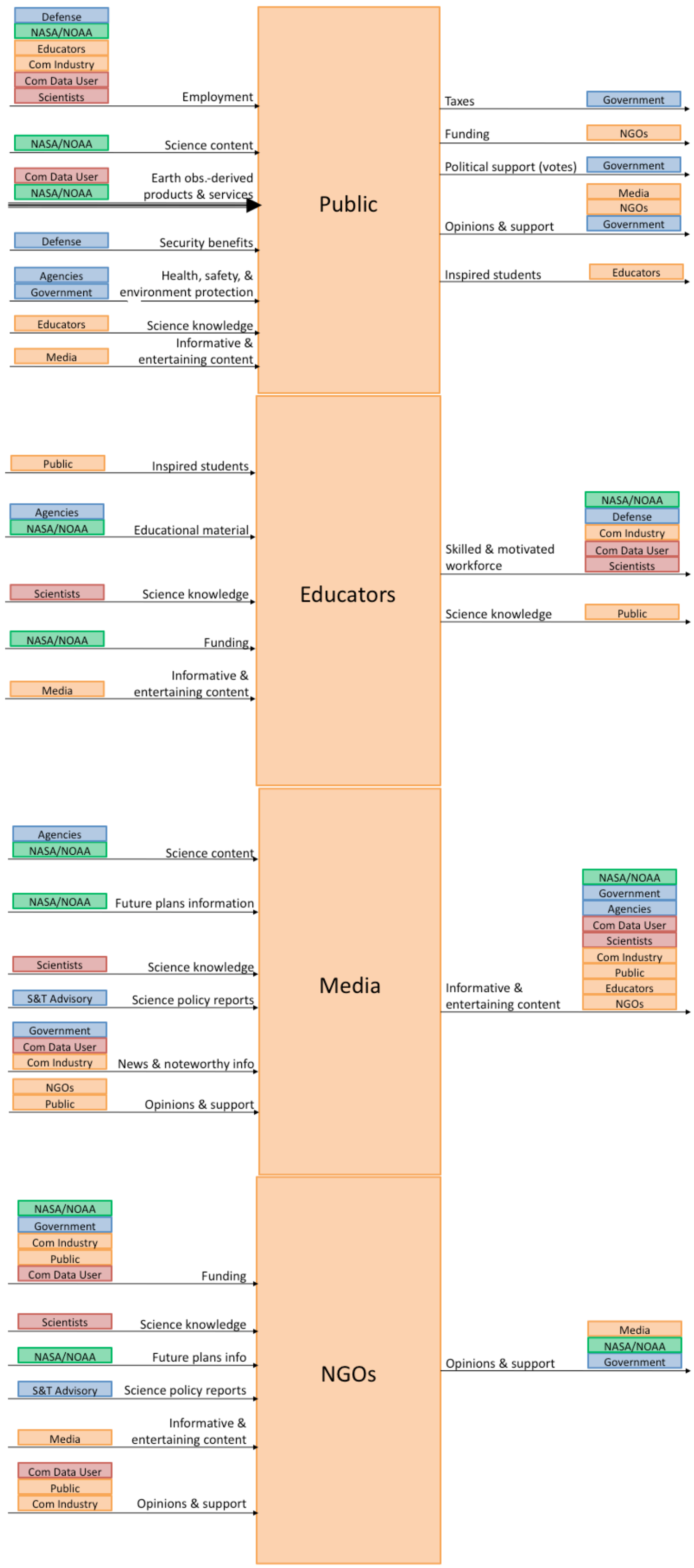


Figure 16. (continued)

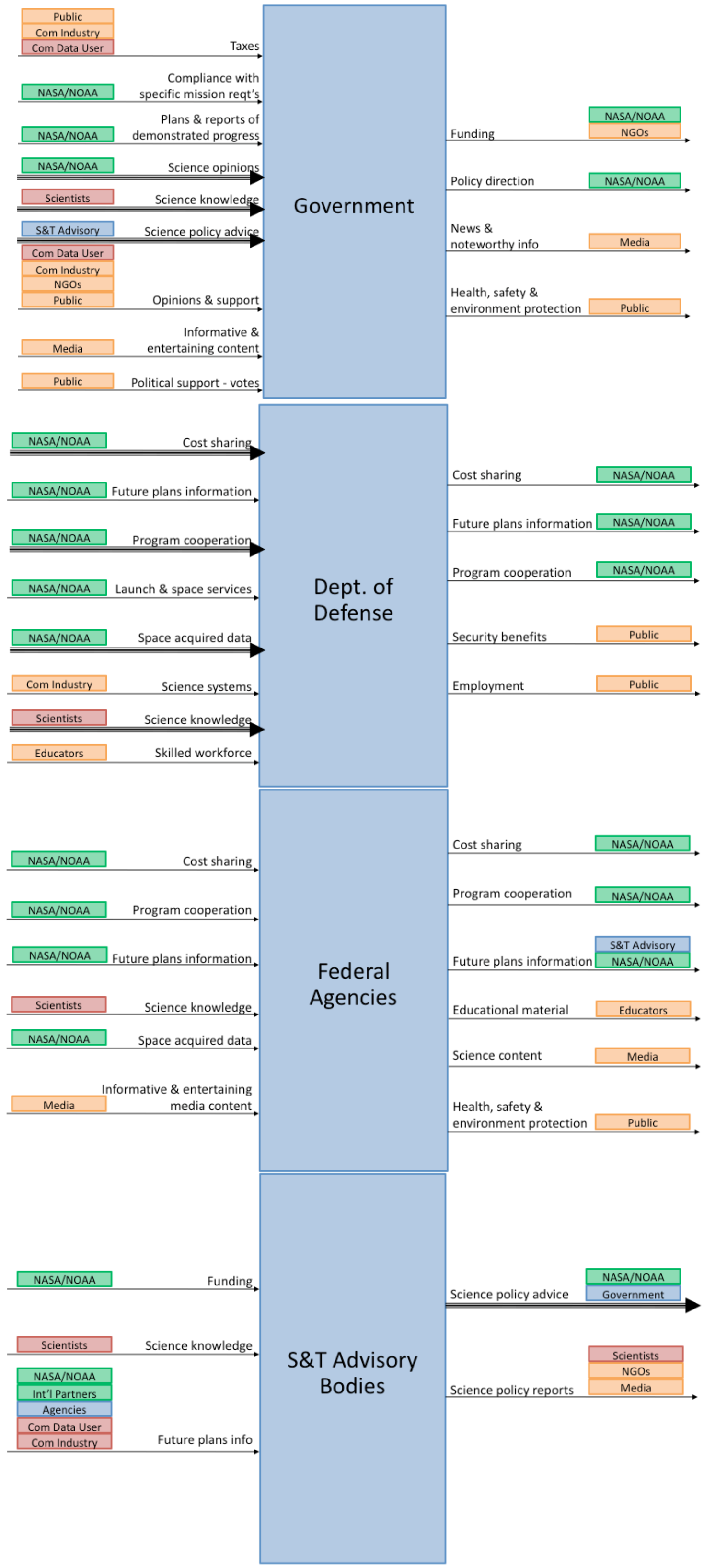


Figure 16. (continued)

Some of the science-related value flows in the model, such as science knowledge from Scientists to the Government, were modeled as six separate value flows corresponding to the categories of the six science-themed decadal survey panels: (1) human health and security, (2) land use, ecosystems, and biodiversity, (3) solid earth hazards, resources, and dynamics, (4) climate variability and change, (5) weather, and (6) water resources and hydrologic cycle. These particular value flows are designated as double-thickness arrows in Figure 16 above. Figure 17 below illustrates the notation used for these value flows.

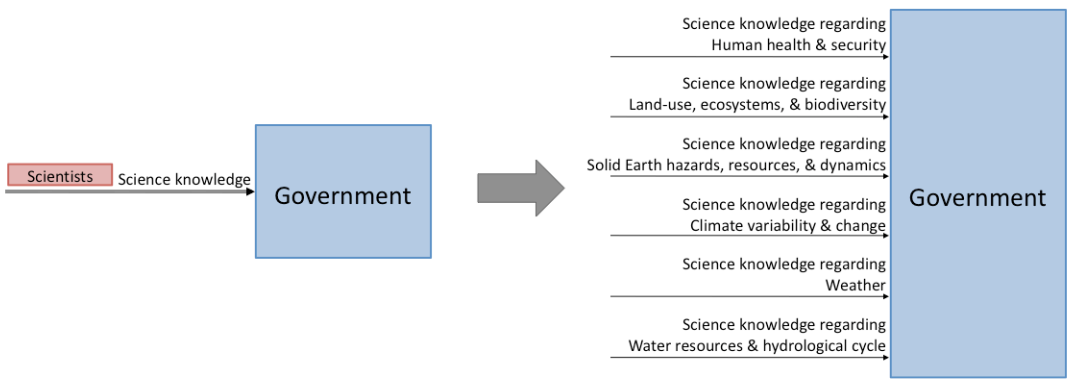


Figure 17. Notation used for science-related value flows

I chose to separate some of the flows in this way because certain stakeholders place widely different value on inputs related to the six different science categories. For example, the Department of Defense may value weather data much more highly than data regarding ecosystems & biodiversity. Similarly, the Government may need science knowledge regarding climate change much more than it needs science knowledge about solid Earth hazards. Separating these science-related value flows within the model produced results that are more architecturally distinguishing and can be used to make more specific policy recommendations.

The next step in creating the stakeholder value network model was to overlay the value flows onto the Level 2 stakeholder map. Figure 18 below shows the value flows into and out of NASA/NOAA. There are five categories of value flows, which are color-coded on the map: policy & opinion (blue), monetary (green), knowledge & information (red), goods & services (purple), and jobs & public benefit (orange). The stakeholders are arranged in approximately the positions suggested by the Level 1 and Level 2 stakeholder maps shown previously in Figure 12 and Figure 13.

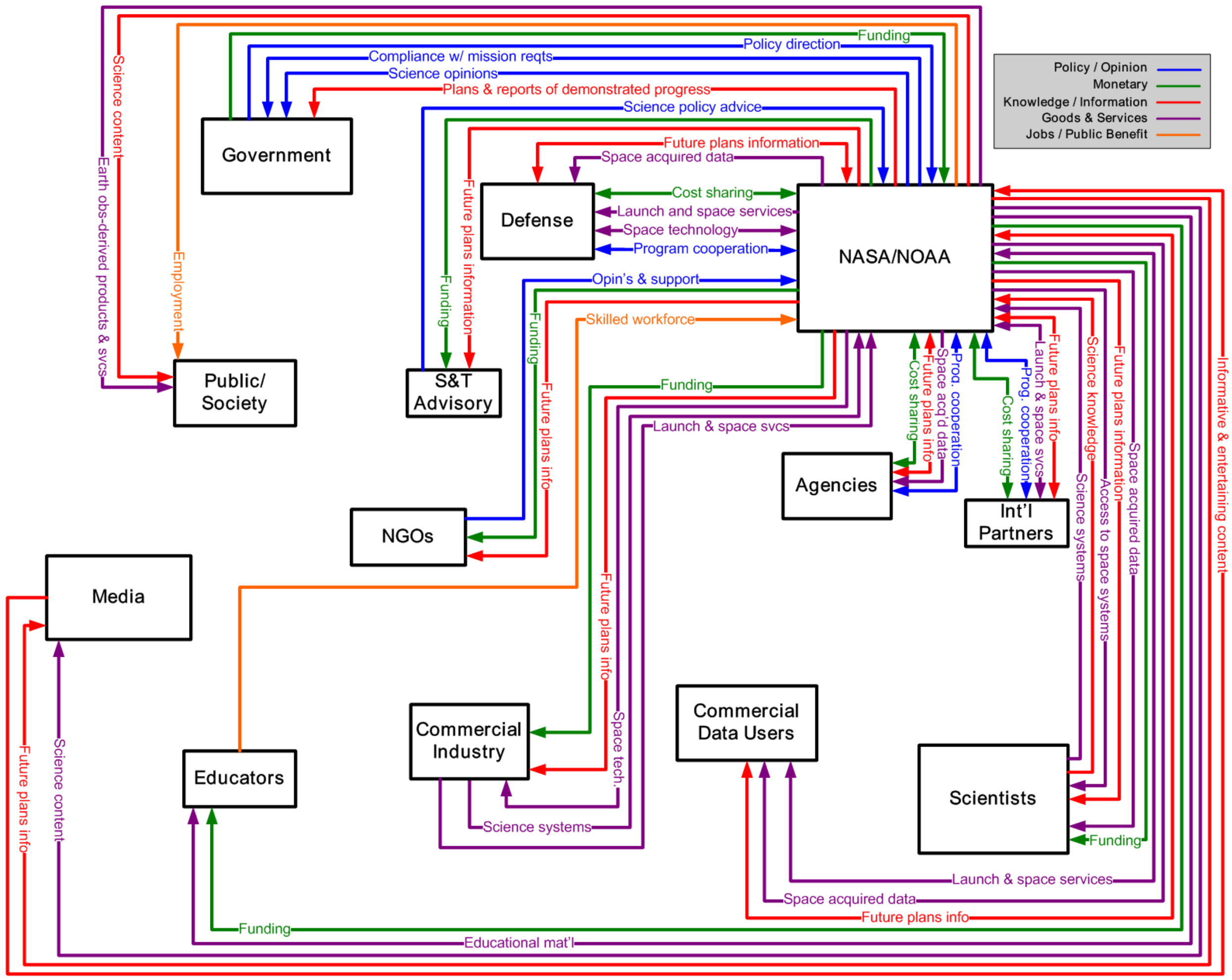


Figure 18. Value flows into and out of NASA/NOAA

Figure 19 below shows the value flows into and out of all 13 stakeholders in the model. The model contains 190 value flows. This complete value flow map illustrates the complexity of the model and reinforces the justification for completing this analysis using the Level 2, rather than the Level 3, stakeholder map. The individual value flows are difficult to read on the condensed diagram, but in general the value flows tend to flow counterclockwise through the stakeholder map. This is indicative of the Level 1 abstraction of the cyclical process by which an Earth observation campaign delivers value to its stakeholders, as shown previously in Figure 12.

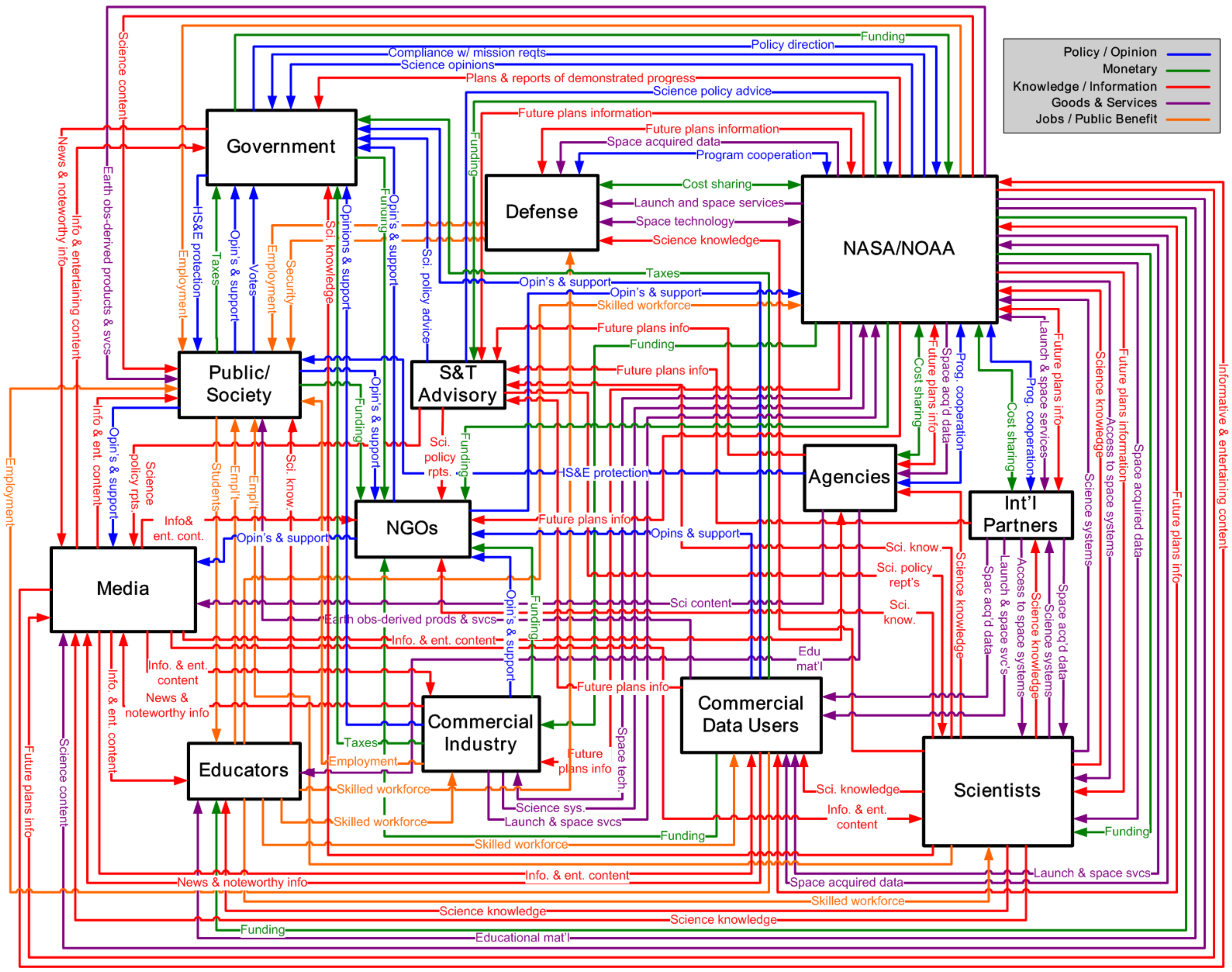


Figure 19. Complete stakeholder value flow map containing 13 stakeholders and 190 value flows

Another way to visualize the value flow map shown in Figure 19 is to display the value flows by category. This helps to simplify the diagram by making it easier to track value flows of the same type, as well as by making the diagram generally more legible. It can also be useful to help identify any potential missing value flows during the creation of the model, since it is sometimes easier to consider a single type of value flow in the network, such as the flow of money. Figure 20 through Figure 24 below show each of the five categories of value flows.

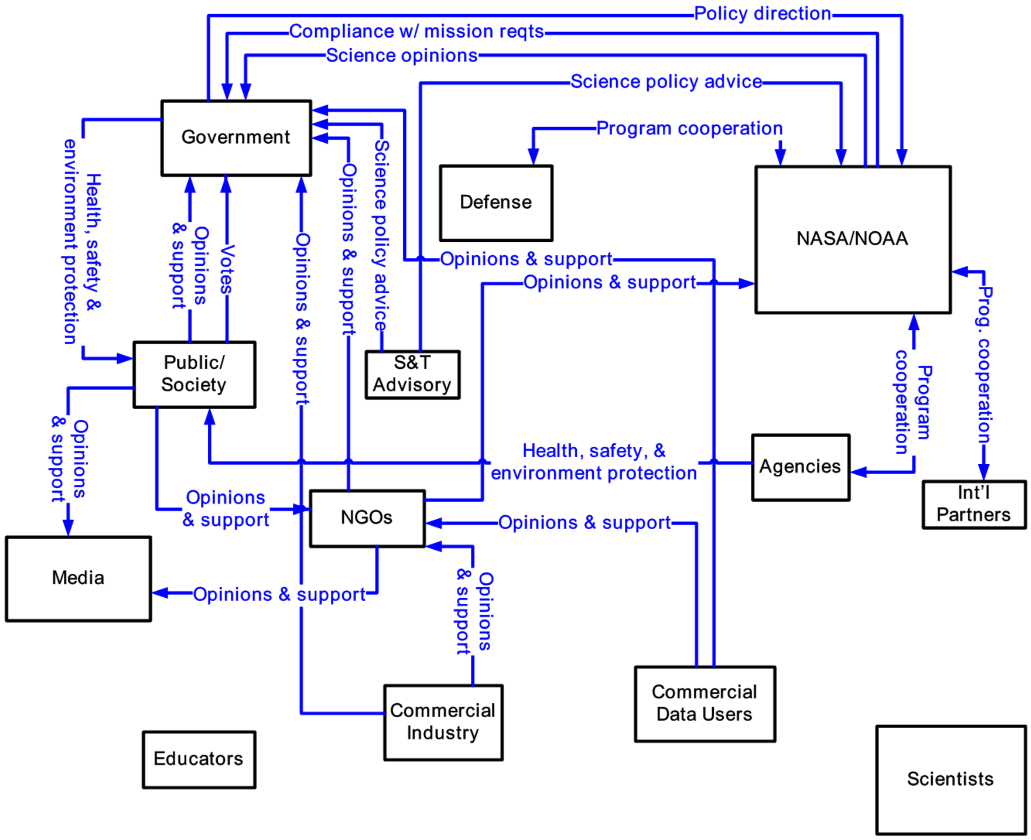


Figure 20. Policy & opinion value flows

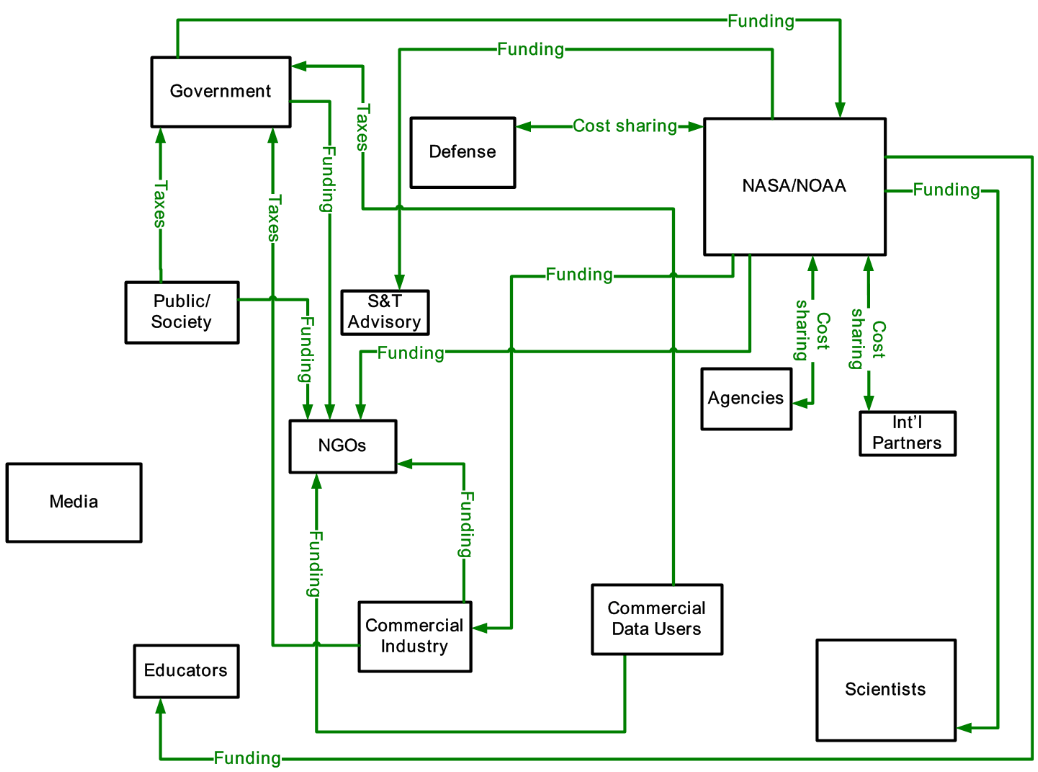


Figure 21. Monetary value flows

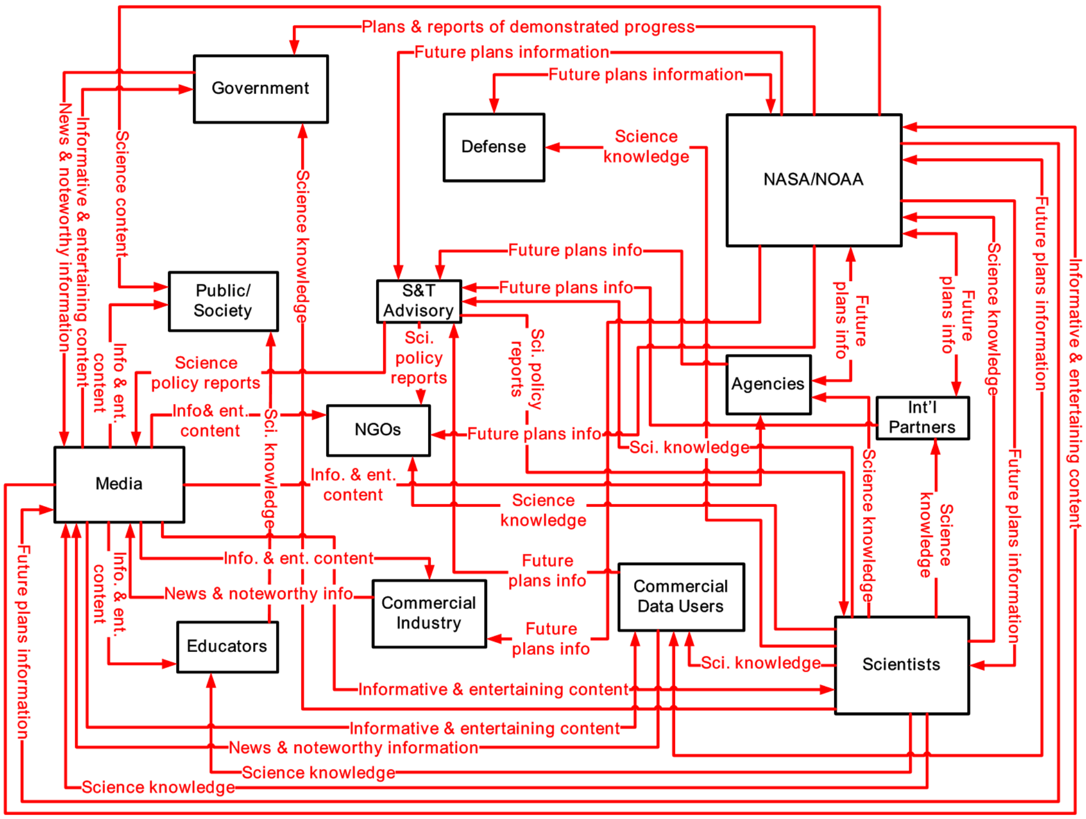


Figure 22. Knowledge & information value flows

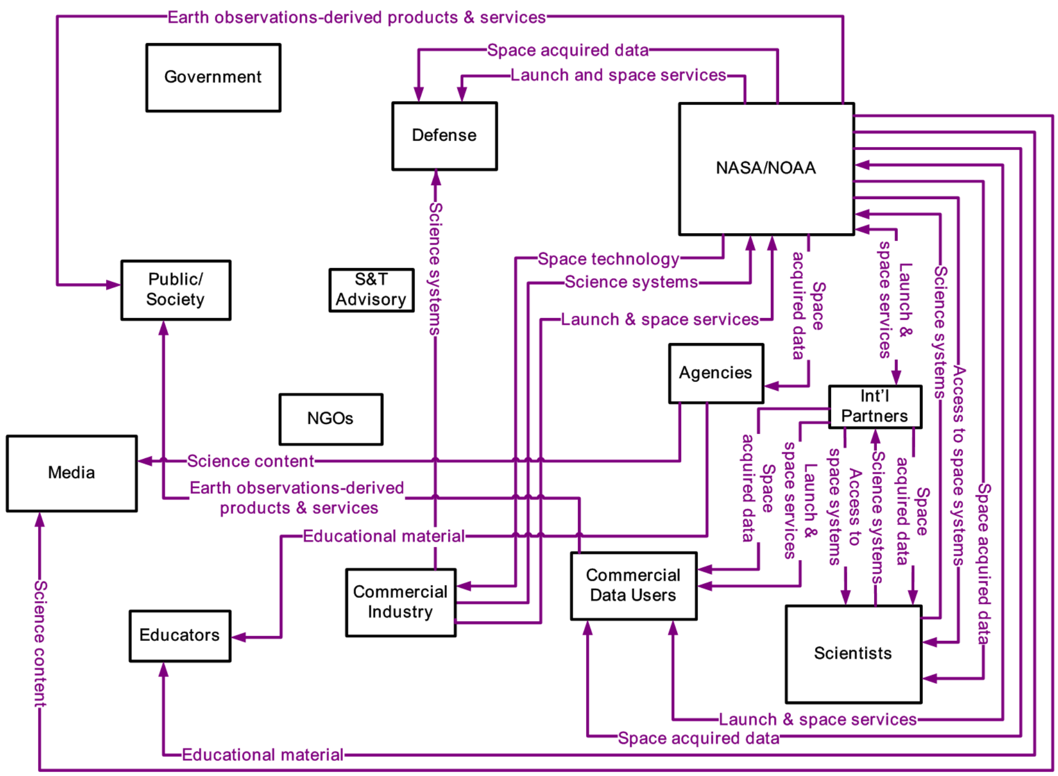


Figure 23. Goods & services value flows

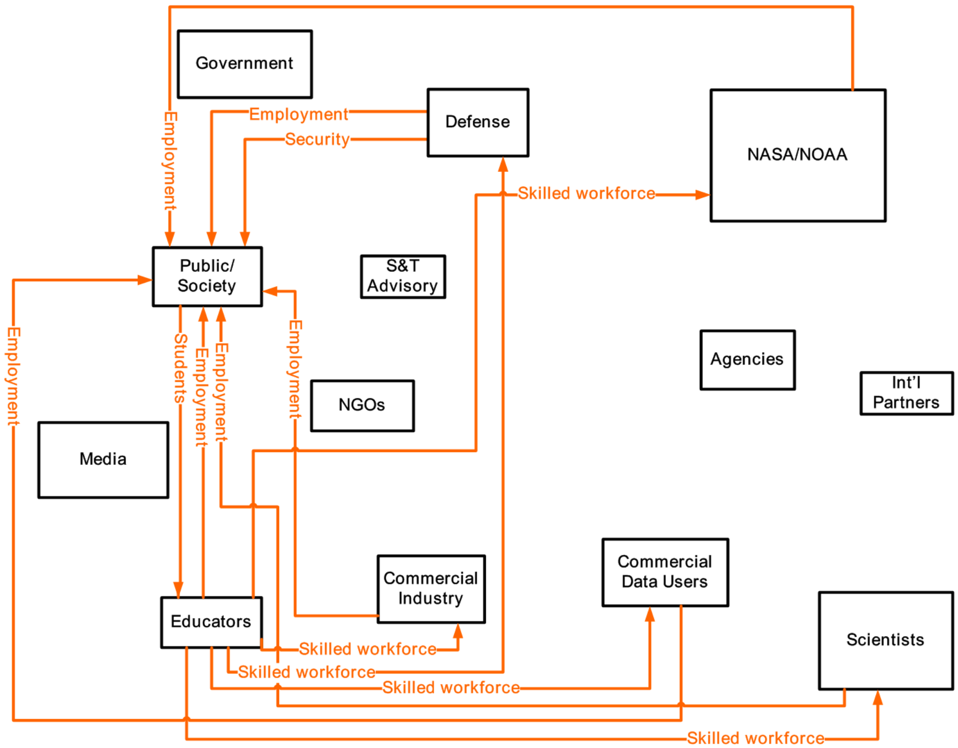


Figure 24. Jobs & public benefit value flows

The categorized value flow maps correlate strongly with the quadrants of the Level 1 stakeholder map shown previously Figure 12. Figure 25 below shows a simplified view of each type of value flow overlaid onto the Level 1 stakeholder map. The diagram shows how value generally flows counter-clockwise throughout the network.

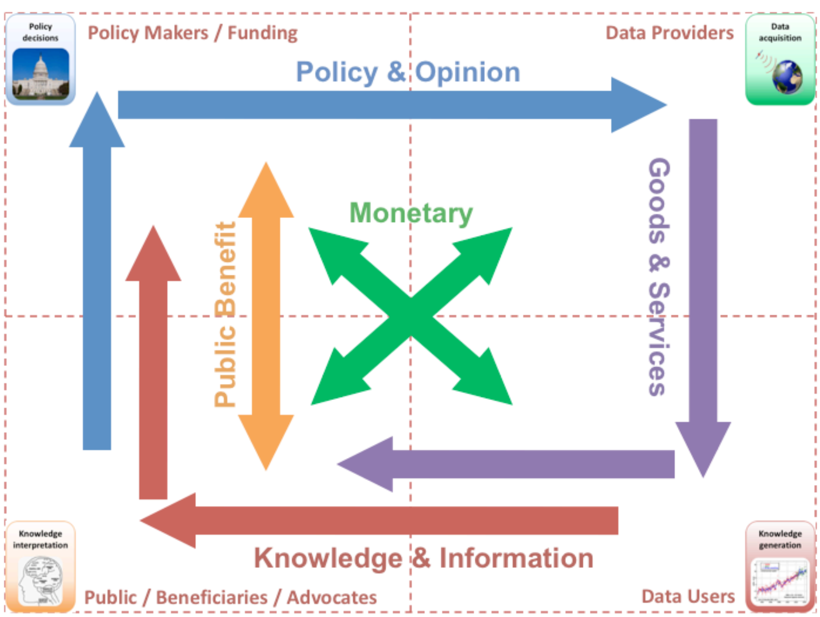


Figure 25. Simplified value flow categories overlaid onto the Level 1 stakeholder map

The figures above show that policy and opinion value flows generally flow from the Public quadrant to the Government quadrant, and from the Government to the NASA/NOAA quadrant. Monetary flows tend to be fairly evenly distributed throughout the stakeholder network. Knowledge and information flows are most highly concentrated within the lower two quadrants, representing the flow of knowledge from the Scientists to the Public and other beneficiaries. Goods and services are most highly concentrated within the two right quadrants, which represent strong links between NASA/NOAA and Scientists as well as NASA/NOAA and the Commercial sectors. Finally, jobs and public benefit flows are concentrated around the Public in the lower left quadrant.

These value flow maps provide a qualitative indication of nearly all the ways in which NASA/NOAA's Earth Observations Program delivers value to the stakeholder network. The model shows not only the direct interactions between NASA/NOAA and each stakeholder, but also the relevant direct interactions among the other stakeholders. By displaying every value flow on the stakeholder map, the model provides a sense of the general counter-clockwise flow of value within the network. We can instantly determine the source and recipient of every value flow. We can also instantly determine the connectedness of each stakeholder to the rest of the network and how "close" or "far" each stakeholder is from the others in the model.

The complete stakeholder flow map shown in Figure 19 provides a much more comprehensive understanding of each stakeholder's role and interactions within the network than other stakeholder analysis techniques would provide. NASA's stakeholder analysis method presented in Section 1.6.2 requires the definition of stakeholder interests and expectations of the system, but this predominantly yields only the direct transactions between NASA and each other stakeholder. The transactions between non-NASA stakeholders can be just as important, however. The maps above show that certain stakeholders, such as the Government and Scientists, have numerous direct interactions with NASA/NOAA. Other stakeholders, such as the Public, have few direct interactions with NASA/NOAA but are highly connected to other stakeholders and play a crucial role in the delivery of value throughout the network.

The categorized value maps also include value flows that are non-monetizable or difficult to quantify, such as knowledge & information, policy & opinions, and certain public benefits such as "security." Typically, these types of value flows would be excluded by other techniques such as cost-benefit analysis or system dynamics models. Including them in this analysis provides a more complete understanding of the ultimate value delivered by the Earth Observations Program.

2.5 Summary of Qualitative Stakeholder Model

The qualitative model described in this chapter provides a comprehensive understanding of how the Earth Observations Program delivers value to the entire network of stakeholders. The qualitative analysis yielded the following:

- An initial list of 33 stakeholders was simplified using hierarchy and aggregation into a revised list of 13 stakeholder groups.
- A three-level stakeholder map was developed, showing the stakeholders arranged according to their primary functions within the network.
- The objectives and specific needs of each stakeholder were rigorously articulated, as well as the inputs to each stakeholder from the other stakeholders in the model.
- The inputs to each stakeholder were used to develop a value flow map that includes 13 stakeholders and 190 value flows. The value flow map shows the all the ways in which NASA/NOAA's Earth Observations Program delivers value to the stakeholder network.
- Five categories of value flows were identified, representing both monetizable and non-monetizable types of value flows.

The qualitative stakeholder model yields a great deal of information about how value is created by the Earth Observations Program and delivered to each stakeholder in the model. At this point in the analysis, the value flows are still qualitative in nature. The stakeholder value flow model described in this chapter provides the foundation for the quantitative stakeholder model described next in Chapter 3.

3 Quantitative Stakeholder Model

The quantitative stakeholder model described in this chapter yields a substantial amount of additional information beyond the results of the qualitative model described in Chapter 2. The qualitative stakeholder model provides an in-depth description of the stakeholders and their interactions within the stakeholder value network. The quantitative model allows us to identify the most important stakeholders, value flows, and value chains within the stakeholder network. It can identify the most important outputs from NASA/NOAA that deliver the greatest value to the network and return the greatest value to NASA/NOAA. The analysis can also be used to establish priorities among the six different science categories from the decadal survey. Some of the results from the quantitative model may be non-intuitive, and thus would not be apparent by using the qualitative model alone. Ultimately, the quantitative model yields useful insights that can be used to make recommendations and establish priorities for the Earth Observations Program.

This chapter describes in detail the development of the quantitative value network model. The results from the analysis of the model are presented in Chapter 4. As previously mentioned in the Chapter 1, the objective of this portion of the analysis is as follows:

Objective of Quantitative Stakeholder Analysis:

- **To** identify the most important stakeholders, the highest value-producing interactions among stakeholders, and most important NASA & NOAA outputs **by** conducting a rigorous quantitative stakeholder analysis **using** the stakeholder value network analysis approach.

Like the qualitative stakeholder analysis, the techniques presented here build upon those developed in Cameron's Master's thesis (Cameron 2007). Refinements of Cameron's method are discussed in the individual sections that follow. This chapter presents a description of the methodology used to quantify the stakeholder model, which includes the following steps:

- Using a rubric to guide the assignment of quantitative scores to each value flow
- Soliciting value flow scores from individual scorers using a formal questionnaire
- Validating the relative rankings of the value flow scores
- Calculating all possible value loops within the stakeholder network

This chapter is organized according to the process flow described above. As with the previous chapter, the quantitative model presented here is specific to the Earth Observations

Program. A generalized description of this methodology, which is broadly applicable to any stakeholder value network, is presented in Chapter 5.

This chapter is organized into the following sections:

- **Section 3.1: Value Flow Scoring Method.** This section describes the rubric used to assign numeric scores to each value flow, as well as the process that was used to solicit value flow scores from experts in the field.
- **Section 3.2: Validation of Value Flow Scores.** This section describes the techniques used to validate the relative rankings of the value flows after assigning each a numeric score.
- **Section 3.3: Calculation of Value Loops.** This section describes the technique used to calculate the score of every "value loop" within the stakeholder value network.
- **Section 3.4: Reducing OPN Value Loops to a Unique, Valid Set.** This section describes the value loops identified by the OPN model and the process of reducing the initial set of value loops to a unique, valid set.
- **Section 3.5: Summary of Quantitative Stakeholder Model.** This section provides a summary of the quantitative model developed in this chapter.

3.1 Value Flow Scoring Method

Developing a quantitative stakeholder model requires quantifying the actual benefit to the recipients of the qualitative value flows in the model, derived previously in Section 2.4. This section provides a description of the method used to assign numeric scores to each value flow. This method is based on a refinement of Cameron's technique (Cameron 2007), which draws inspiration from Kano's methods for understanding how consumers define quality in the goods and services they purchase (Walden 1993). The differences between the method described here and Cameron's method are as follows: (1) this method uses a somewhat refined set of attributes to score each value flow; and (2) the questionnaire used to assign numeric scores to each value flow have been refined.

The technique used to assign numeric scores to the value flows requires evaluating two attributes of each value flow:

1. The intensity of the specific need, on the part of the recipient, that the value flow satisfies
2. The importance of a particular source in fulfilling the specific need

We felt that these were the two most important attributes needed to assign scores to each value flow. The following two sections describe the questionnaires and scoring method used for each of these two attributes.

3.1.1 Value Flow Attribute – Intensity of Need

To categorize the intensity of the specific need that each value flow fully or partially satisfies, Cameron initially developed a questionnaire based on Kano's Customer Requirement Questionnaire, shown below in Figure 26 (Walden 1993).

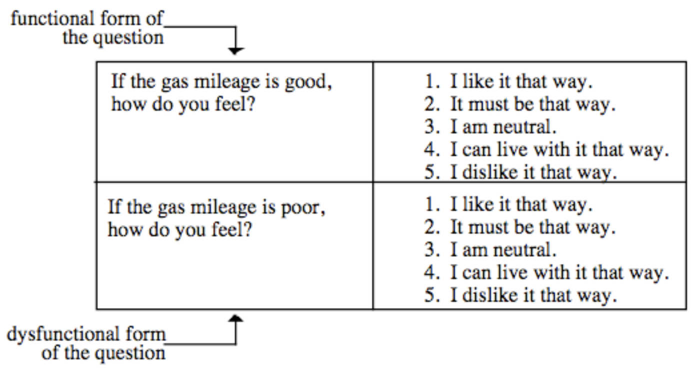


Figure 26. A pair of customer requirement questions in a Kano Questionnaire (Walden)

Using the Kano method, both a functional and dysfunctional form of a question are asked to elicit the customer's sense of satisfaction when the need is fulfilled and the sense of regret when the need goes unfulfilled. Based on the responses to the two parts of the question, the product feature is classified into one of six categories: attractive, must-be, one-dimensional, indifferent, reversal, or questionable. Figure 27 below shows the Kano Evaluation Table used to classify each feature based on the customer's responses (Walden 1993).

Customer Requirements		Dysfunctional 1. like	2. must-be	3. neutral	4. live with	5. dislike
Func-tional	1. like	Q	A	A	A	O
	2. must-be	R	I	I	I	M
	3. neutral	R	I	I	I	M
	4. live with	R	I	I	I	M
	5. dislike	R	R	R	R	Q

Customer Requirement is:
A: Attractive
M: Must-be
R: Reverse
O: One-dimensional
Q: Questionable result
I: Indifferent

Figure 27. Kano evaluation table (Walden)

One of the drawbacks to using Kano's method is that the customer's responses can produce "questionable" results or "indifferent" results that do not yield clear, logical expectations. These results are not useful to incorporate into the model. Kano's method can also produce "reverse" results, which indicate the presence of negative attributes; i.e. undesirable features or inputs. The method presented in this thesis considers only those inputs that generate positive benefit; therefore, only Kano's positive responses need to be considered. Using Kano's method as described would require asking twice as many questions for each value flow than is necessary for the value network analysis technique. Also, Kano's questions may seem confusing to individuals answering the questionnaire. Cameron found that not only were individuals confused by the questions, but also the answers obtained from multiple individuals were inconsistent due to differing interpretations of the Kano questions.

Kano's technique is useful, however, for determining three categories of needs: attractive (or "delighter"), one-dimensional, and must-be. These three can be illustrated using Kano's customer requirement diagram shown in Figure 28 below. The x-axis measures the degree to which the specific need is fulfilled, and the y-axis measures the customer satisfaction as a function of how well the specific need is fulfilled.

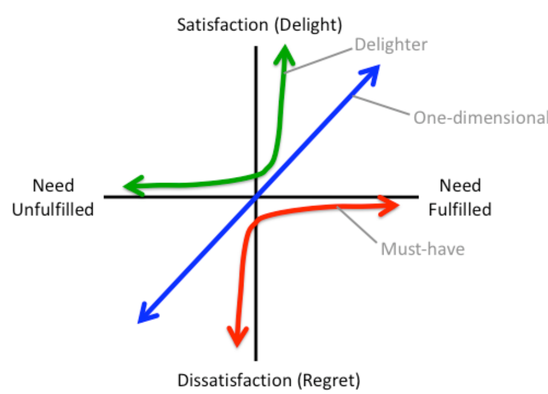


Figure 28. Kano diagram for customer requirements (Adapted from Walden 1993)

The three arrows in the diagram above represent three distinct categories of specific needs. The green arrow represents a specific need that would be considered a "delighter." An example of this might include an automobile driver's need for a sunroof. Fulfilling this need is delightful, but if the need goes unfulfilled the driver would not experience much regret. The blue arrow represents a "one-dimensional" specific need. Fulfilling more of the need provides increasing levels of satisfaction, and fulfilling less of the need provides increasing levels of dissatisfaction or regret. An example of this might include the fuel efficiency of a car: More is better and less is worse. Finally, the red arrow represents a "must-have" specific need. An example of this would include brakes in an automobile. Fulfilling this need is mandatory (but does not necessarily provide satisfaction), whereas not fulfilling this need would provide an extreme level of dissatisfaction.

To improve on Cameron's technique, we developed a new "satisfaction/regret" questionnaire that is simpler than Kano's questionnaire shown previously in Figure 26. This questionnaire, shown below in Figure 29, provides a rubric for categorizing the intensity of each specific need. In developing this rubric, we carefully chose words that closely modeled the important attributes in Kano's questionnaire and evaluation table. The responses in the questionnaire, which differ by their degree of satisfaction and regret, represent the categories of needs shown above in Figure 28.

Satisfaction / Regret Questionnaire

How would you characterize the presence or absence of fulfillment of this need?

A. I would be satisfied by its presence, but I would not regret its absence
B. I would be satisfied by its presence, and I would somewhat regret its absence
C. I would be satisfied by its presence, and I would regret its absence
D. Its presence is necessary, and I would regret its absence
E. Its presence is absolutely essential, and I would regret its absence

Figure 29. Modified Kano satisfaction/regret questionnaire for categorizing the intensity of each specific need

The satisfaction/regret questionnaire asks the scorer to evaluate the presence or absence of a value flow that fulfills a specific need. For example, using the Scientists' specific needs shown in Figure 15, this questionnaire for Scientists would include the following:

- Space-acquired data
- Access to existing and future space systems
- Funding
- Skilled and motivated workforce
- Knowledge of NASA/NOAA objectives, capabilities, and future plans
- General knowledge and information

The questionnaire asks, "How would you describe the presence or absence of fulfillment of your specific need for *space-acquired data*?" A response of A, B, C, D, or E would be chosen. Response A corresponds to a "delighter" need, response C corresponds to a "one-dimensional" need, and response E corresponds to a "must-have" need. Responses B and D fall midway between the other responses. A five-point scale was chosen to provide a greater degree of variation among value flow scores than a three-point scale would provide. This helps distinguish the scores of the calculated value loops, as described later in Section 3.3. I translated the responses of the satisfaction/regret questionnaire using the conversions shown in Table 4 below.

Table 4. Conversion table for Satisfaction/Regret Questionnaire responses

Questionnaire response	Numeric score
A	0.11
B	0.19
C	0.33
D	0.57
E	0.98

Note that I used a ratio, or log, scale for the satisfaction/regret score conversion. This provides greater differentiation between the "absolutely essential" needs (response E) and the less-essential "necessary" needs (answer D) than a linear scale would provide. This ensures that value flows that are absolutely necessary will score significantly higher than other value flows that may be important, but not critical. The scale begins with a score of 0.11 for response A, which is based on the lowest response score used by Cameron. Each successive response is a factor of approximately 1.7 higher than the next-lowest response.

We decided to use a score of 0.98 rather than 1.0 for the highest response E. We chose this because a value loop containing three links (each with a score of 1.0) would have the same score as a value loop with six links (each with a score of 1.0), using the value loop calculation technique described later in Section 3.3.1. We felt that it would be unreasonable for these two value loops to have the same score because delivering value through a chain of six stakeholders should be much harder than delivering value through a chain of three stakeholders, and the scores should reflect this. Using a maximum value flow score of 0.98 addresses this problem—under the same scenario, the three-link value loop would have a score of $(0.98)^3 = 0.94$; whereas the six-link value loop would have a score of $(0.98)^6 = 0.89$.

3.1.2 Value Flow Attribute – Source importance

The second value flow attribute categorizes the importance of a particular source in fulfilling a stakeholder's specific needs. Using the example of the Scientists' specific need for space-acquired data, this need can be fulfilled by either NASA/NOAA or International Partners. Scientists may have a preference for the supplier of space-acquired data; perhaps NASA/NOAA data would be provided at no cost, or there may be export- or timeliness-related issues with obtaining data from International Partners. The questionnaire shown in Figure 30 below provides a rubric for categorizing the importance of a particular source in fulfilling each specific need:

Source Importance Questionnaire

If this need were to be fulfilled, how important would this source be in fulfilling the need?

1. Not important – I do not need this source to fulfill this need
2. Somewhat important – It is acceptable that this source fulfills this need
3. Important – It is desirable that this source fulfills this need
4. Very important – It is strongly desirable that this source fulfills this need
5. Extremely important – It is indispensible that this source fulfills this need

Figure 30. Questionnaire for categorizing the importance of a particular source in fulfilling a specific need

Using the same Scientists example, the questionnaire asks, "If your need for *space-acquired data* were to be fulfilled how important would *NASA/NOAA* be in fulfilling this need?" A response of 1, 2, 3, 4, or 5 can be chosen. Response 1 corresponds to "not important", and response 5 corresponds to "extremely important." I translated the responses of the source importance questionnaire using the conversions shown in Table 5 below.

Table 5. Conversion table for Source/Importance Questionnaire responses

Questionnaire response	Numeric score
1	0.11
2	0.33
3	0.55
4	0.78
5	0.98

The source importance score conversion uses a linear scale beginning at 0.11 for the lowest response. We used a score of 0.98 rather than 1.0 for the highest response for the reasons described above. Cameron showed that the results of the quantitative stakeholder model were largely insensitive to the choice of scale used for the attribute scores (Cameron 2007).

Both the satisfaction/regret and source importance questionnaires use scales that range from least to greatest, but we deliberately used a scale of A through E for satisfaction/regret and a scale of 1 through 5 for source importance. Using an alphabetic scale for satisfaction/regret and a numeric scale for source importance helps reinforce to the individuals assigning scores that the two scales measure different attributes, and helps prevent the scorer from confusing the two. We used the alphabetic scale for the satisfaction/regret questionnaire because the numeric scale corresponded more naturally to the linear nature of the source importance questionnaire.

3.1.3 Determination of Final Value Flow Scores

Following Cameron's method, I multiplied the "satisfaction/regret" and "source importance" scores for each value flow to produce a *value flow score*, as shown below in Table 6.

Table 6. Table for determining value flow scores based on attribute scores

		Satisfaction/Regret Score				
		A = 0.11	***B = 0.19***	***C = 0.33***	***D = 0.57***	***E = 0.98***
Source Importance Score	***1 = 0.11***	0.01	0.02	0.04	0.06	0.11
	2 = 0.33	0.04	0.06	0.11	0.19	0.32
	3 = 0.55	0.06	0.10	0.18	0.31	0.54
	4 = 0.78	0.09	0.15	0.26	0.44	0.76
	5 = 0.98	0.11	0.19	0.32	0.56	0.96

To obtain scores for each value flow, I created Satisfaction/Regret and Source Importance Questionnaires, attached in Appendix C, for every value flow in the model and asked the following individuals acutely familiar with the decadal survey to assign scores to each flow:

- Deputy Director for the Sciences and Exploration Directorate (NASA)
- Chief Engineer of Earth Sciences Division (NASA)
- Associate Director for Flight Programs in Earth Science Division (NASA)
- Professor of Aeronautics & Astronautics and Engineering Systems (MIT)
- Graduate students in the System Architecture group involved with the project (MIT)

Completing the questionnaires for the entire list of value flows requires approximately one hour of time. When completing this exercise, I asked the scorers to think of themselves as the receiving stakeholder for each value flow. Each scorer first answered the Satisfaction/Regret Questionnaire, followed by the Source Importance Questionnaire. We preferred this method, rather than asking them to assign both satisfaction/regret and source importance scores simultaneously for each value flow, for two reasons: (1) assigning all the satisfaction/regret scores together helps keep the scorer's mind focused on one scoring rubric rather than alternating back and forth between the satisfaction/regret and source importance scales; and (2) if the satisfaction/regret and source importance scores are assigned simultaneously, we found that the scorer tends to couple the two responses together, as indicated in Figure 31 below. Equally valid, however, are uncoupled scores, as indicated in Figure 32 below. Coupled responses produce less variation among the value flow scores, which removes some of the useful texture in the final results of the value network analysis.

Satisfaction/ Regret Score	Source Importance Score	Satisfaction/ Regret Score	Source Importance Score	Satisfaction/ Regret Score	Source Importance Score
A	1	A	1	A	1
B	2	B	2	B	2
C	3	C	3	C	3
D	4	D	4	D	4
E	5	E	5	E	5

Figure 31. Coupled responses to value flow scoring questionnaires

Satisfaction/ Regret Score	Source Importance Score	Satisfaction/ Regret Score	Source Importance Score	Satisfaction/ Regret Score	Source Importance Score
A	1	A	1	A	1
B	2	B	2	B	2
C	3	C	3	C	3
D	4	D	4	D	4
E	5	E	5	E	5

Figure 32. Uncoupled responses to value flow scoring questionnaires

After the completed questionnaires from each individual were tallied, we used a modified Delphi method with one round of revision to reconcile major differences among scores for particular value flows (Rowe and Wright 1999). In most cases, there were still small discrepancies between the five scores for each value flow, so the final value flow score was determined by taking the average of the five individual scores. Table 7 below shows the combined value flow scores for the Scientists, which include any revisions made after the one round of discussion. The combined scores for all the value flows in the model are presented in Appendix D.

Some of the value flow scores were ignored if they differed significantly from the average. In most cases, this was the result of a misunderstanding of the definition of the value flow. Other flows, such as “science policy reports” from S&T Advisory Bodies, were added to the model after the initial questionnaires were distributed, and only a subset of the initial scorers were able to provide scores for these flows.

Table 7. Combined value flow scores for Scientists

To: Stakeholder	Value Flow	From: Stakeholder	Final Scores from Scorers					Combined Value Flow Score
			#1	#2	#3	#4	#5	
Scientists	Access to space systems	Int'l Partners	0.18	0.31	0.31	0.56	0.54	**0.38**
Scientists	Access to space systems	NASA/NOAA	0.44	0.44	0.44	0.56	0.96	**0.57**
Scientists	Funding	NASA/NOAA	0.56	0.56	0.18	0.56	0.18	**0.47**
Scientists	Future plans information	NASA/NOAA	0.44	0.44	0.31	0.44	0.32	**0.37**
Scientists	Informative content	Media	0.18	0.18	0.02	0.10	0.06	**0.10**
Scientists	Skilled workforce	Educators	0.56	0.44	-	0.56	0.56	**0.62**
Scientists	Space-acquired data	Int'l Partners	0.76	0.54	0.31	0.44	0.76	**0.57**
Scientists	Space-acquired data	NASA/NOAA	0.96	0.76	0.44	0.56	0.96	**0.74**
Scientists	Science policy reports	S&T Advisory	0.44	0.44	-	-	-	**0.44**

We used a separate process to assign scores to the science-related value flows that were split into the six science categories, such as the example shown previously in Figure 17. Rather than ask the questionnaire scorers to evaluate each science category separately for each value flow, we asked them to assign a single score based on the *most important* type of science to the receiving stakeholder. This prevented the questionnaire scorers from having to assign scores to dozens of additional value flows. For example, there are six types of "science knowledge" that flow from NASA/NOAA to Scientists. We asked each scorer to assign a score for "science knowledge" based on the type of science knowledge that NASA/NOAA would find most important. I call this score the "maximum science" score, as shown below in Table 8.

Table 8. Example of assigning scores to science-related value flows

To: Stakeholder	Value Flow	From: Stakeholder	Final Scores from Scorers					Combined Value Flow Score
			#1	#2	#3	#4	#5	
NASA/NOAA	Science knowledge	Scientists	0.44	0.44	0.44	0.96	0.98	**0.65 (max)**

For those stakeholders in the model who receive science-related value flows, we assigned each stakeholder a preference of High, Medium, or Low for each science category. These rankings were inferred from policy documents, evidence provided in the literature, and analyses of various information sources, as described in detail in Section 3.2.2. Scores for science-related value flows of medium importance were reduced by a factor of (1/1.7) = 0.59, which corresponds to a one-step drop in the satisfaction/regret attribute scale shown previously in Table 4. Thus, using the example above in Table 8, the medium importance science-related value flows received a score of 0.65(max) x 0.59 = 0.38. Scores for science-related value flows of low importance were reduced by a factor of $(0.59^2) = 0.35$, corresponding to a two-step drop in the satisfaction/regret attribute scale.

The rationale for using this method to reduce the scores is the following: If NASA/NOAA were to assign climate-related science knowledge a score of D ("Its presence is necessary, and I would regret its absence"), it would likely assign a score of C ("I would be satisfied by its presence, and I would regret its absence") to land-use, solid Earth, weather, and water-related climate knowledge. Likewise, it would likely assign a score of B ("I would be satisfied by its presence, and I would somewhat regret its absence") to human health-related climate knowledge. This method seemed to work well as an alternative to asking the questionnaire scorers to evaluate each individual science category for every science-related value flow in the model. Table 9 below shows an example of the technique used to assign value flow scores to the individual science-related value flows for Scientists using the maximum science score from Table 8.

Table 9. Technique used to assign value flow scores to science-related value flows

Science Category	Stakeholder Preference	Science-related Value Flow	Value Flow Score
Human health	Low	Science knowledge – human health	0.22
Land use & ecosystems	Med	Science knowledge – land use / ecosystems	0.38
Solid Earth hazards & resources	Med	Science knowledge – solid earth	0.38
Climate change	**High**	**Science knowledge – climate change**	**0.65**
Weather	Med	Science knowledge – weather	0.38
Water resources	Med	Science knowledge – water	0.38

In this example, the five questionnaire scorers assigned value flow scores for "science knowledge" to NASA/NOAA from Scientists, considering the type of science that NASA/NOAA needs the most. The average of these scores was 0.65, which was designated the "maximum science" score. Separately, stakeholder preference rankings of High, Medium, and Low were assigned to each type of science knowledge for NASA/NOAA. These were obtained from NASA policy documents, as described further in Section 3.2.2. The type of science knowledge that NASA/NOAA requires the most is climate change knowledge, so the value flow of "science knowledge – climate change" received the maximum science score of 0.65.

As mentioned previously, the combined scores for all the value flows in the model are presented in Appendix D. The following section describes the techniques that were used to validate the relative rankings of the some of the value flows within the model.

3.2 Validation of Value Flow Scores

The previous section described the process for assigning value flow scores to each value flow within the model. This process was completed by five individuals with a keen familiarity of the decadal survey and fairly broad knowledge of the Earth Observations Program. To validate the relative rankings of some of these value flow scores, I used the two methods described in the next two sub-sections.

The first validation method involved interviewing representatives of each stakeholder group and asking them to provide anecdotal validation of the relative ranking of the value flow inputs to that particular stakeholder. For the second validation method, I determined proxy data sources that could be used to validate the relative rankings of the value flows for each stakeholder. I compared the relative rankings suggested by the proxy data sources to the combined value flow scores in the model, and made adjustments where necessary. The value flow scores remained unchanged if the differences between the proxy data sources and the value flow scores could be rationalized.

The objective of the validation process was not to rigorously prove the validity of each stakeholder’s value flow scores. Rather, it was to perform enough verification to establish general confidence in the model and in our method for assigning numeric scores to value flows. Thus, only a subset of all the value flows in the model were validated using these two techniques, as described in detail below. The table of value flows in Appendix D indicates the “combined scores” that were determined by the five questionnaire scorers as well as the “final scores” that were used for the model after applying the verification techniques.

3.2.1 Validation Using Stakeholder Representatives

As mentioned above, the five individuals who completed the value flow questionnaires possessed an in-depth understanding of the decadal survey and a fairly broad knowledge of the Earth Observations Program. One of the advantages of having individuals assign scores to every value flow in the model is that we achieve a level of consistency, since each scorer applies his or her interpretation of the scoring rubrics across the entire model. However, each questionnaire scorer may not have detailed knowledge regarding the specific needs of each of the 13 stakeholders within the model. Therefore, once the combined set of value flow scores has been determined, it is useful to validate the relative rankings of the value flows by consulting with stakeholder representatives from each stakeholder group. In addition to the stakeholder representatives from NASA/NOAA, Scientists, and Educators who participated in the initial value flow scoring exercise, I conducted an interview with a former Secretary of the Air Force to validate the value flows for the Defense stakeholder (Widnall 2008).

During the stakeholder interview, I provided the individual with an overview of the qualitative stakeholder model, including the stakeholder maps and value flow maps. I also created a diagram showing the *inputs* to that stakeholder in rank order based on the combined value flow scores assigned by the questionnaire scorers. I asked the individual to evaluate the *relative* rankings of the value flows to provide an anecdotal validation of the value flow scores. To avoid the need to explain the entire methodology to the interviewees, I did not ask them to validate the absolute numeric scores. Figure 33 below shows an example of the diagram I used for the Defense interview. The diagram shows the value flow scores before and after the interview.

To:	Value Flow	From:	Score Before:	Score After:	greater importance
Defense	Skilled workforce	Educators	0.60	0.60	
Defense	Space-acquired data	NASA/NOAA	0.54	0.54	
Defense	Science systems	Com Industry	N/A	0.54	
Defense	Launch and space services	NASA/NOAA	0.49	0.49	
Defense	Space technology	NASA/NOAA	0.38	(deleted)	
Defense	Science knowledge	Scientists	0.24	0.24	
Defense	Future plans information	NASA/NOAA	0.22	0.22	
Defense	Program cooperation	NASA/NOAA	0.17	0.17	
Defense	Cost sharing	NASA/NOAA	0.09	0.09	less importance

Figure 33. Diagram used for Defense validation interview

Initially, the list of value flows included "space technology" from NASA/NOAA, shown above in red font. However, we had struggled to understand the direct connections between NASA/NOAA and the Department of Defense. The interviewee clarified that in the realm of Earth observations, the direct link between NASA/NOAA and Defense is weak or non-existent; rather, the sharing of technology occurs through Commercial Industry. Based on this feedback I eliminated the "space technology" value flow between NASA/NOAA and Defense and added a "science systems" link between Commercial Industry and Defense, shown above in green font.

With guidance from the interviewee, we assigned a score of 0.54 to the new value flow, equivalent to the existing flow of "space-acquired data" from Scientists. I also made the equivalent changes to the Commercial Industry value flows. Other than these changes, the interviewee was satisfied that this represented the approximate relative rankings of the inputs to Defense.

The Defense stakeholder interview was valuable in providing insights that were not apparent from the perspective of the original five questionnaire scorers. Representatives from NASA/NOAA, Scientists, and Educators participated in the value flow scoring process, so I have high confidence in the validity of those scores. While I was unable to conduct interviews with representatives from all the stakeholder groups, the changes made to value flow scores after the Defense interview were relatively minor, providing general confidence in the validity of the model.

3.2.2 Validation Using Literature and Data-Gathering Techniques

This section describes the second method for validating the value flow scores. This method involved comparing the value flow rankings to evidence presented in various literature and data sources. I was able to use this technique for two purposes: (1) to validate the relative ranking of the value flows into a stakeholder, and (2) to validate or inform the high, medium, or low science category preferences for stakeholders that receive science-related value flows. This validation method represents a unique contribution of this thesis to the overall stakeholder modeling process. As mentioned previously, the objective of this was to perform enough verification to establish general confidence in the model, rather than to rigorously prove the validity of every value flow in the model. The following sub-sections describe in detail the value flow rankings that were validated for NASA/NOAA, Defense, Commercial Data Users, Media, Public, S&T Advisory Bodies, and the Government.

NASA/NOAA

For NASA/NOAA, I was able to use the data-gathering technique to validate the science category preferences for science-related inputs. For this, I consulted the most recent version of NASA's Science Plan for 2007-2016 (NASA 2007). The research objectives for Earth Science heavily emphasize climate change. Somewhat less emphasis is placed on weather, land-use/ecosystems, water resources, and solid earth; and little or no emphasis is placed on human health. Based on this, I assigned the following science category preferences to NASA/NOAA, shown below in Table 10:

Table 10. Science category preferences for NASA/NOAA

Science category	Preference to NASA/NOAA
Human health	Low
Land use & ecosystems	Med
Solid Earth hazards & resources	Med
Climate change	**High**
Weather	Med
Water resources	Med

Defense

For Defense, I was also able to use the data gathering technique to validate the science category preferences for science-related inputs. For this, I consulted the 2008 report published by the Climate Change Science Program (CCSP 2007), the 2005 Strategic Plan for the U.S. Integrated Earth Observation System (Interagency Working Group on Earth Observations 2005), and a 2007 report by the CNA Corporation titled *National Security and the Threat of Climate Change* (CNA Corporation 2007). Based on the emphasis placed by these documents on the six areas of science, I assigned the following science category preferences to Defense, shown below in Table 11:

Table 11. Science category preferences for Defense

Science category	Preference to Defense
Human health	Low
Land use & ecosystems	Med
Solid Earth hazards & resources	Low
Climate change	**High**
Weather	**High**
Water resources	**High**

Commercial Data Users

I was also able to use the data-gathering technique to validate the science category preferences for Commercial Data Uses. Many commercial users of space-acquired data belong to industry associations such as the Management Association for Private Photogrammetric Surveyors (MAPPS). MAPPS is the only national association exclusively comprised of private commercial geospatial users (MAPPS 2008). Using the list of member firms on the MAPPS website, I identified firms that use satellite data and visited those firms' websites to determine the type of products and services offered by each. Nearly all the firms use satellite imagery data for land-use applications.

Weather is also an important science category for Commercial Data Users. Weather forecasting is a major industry with commercial companies dependant on weather-related satellite data. Most commercial weather companies rely on data provided by the National Weather Service, a division of NOAA, either exclusively or to supplement their proprietary weather forecasts. Weather data is also becoming more important to the energy sector. Solar and wind energy providers require accurate forecasts of solar and wind conditions in order to manage electricity production. NASA Langley Research Center provides free access to global-scale data on insolation (incoming sunlight), wind speed and direction, and a range of meteorological variables for private companies looking to develop renewable energy sources (Herring 2001).

There is a modest demand for solid Earth data by Commercial Data Users. I found several reports detailing the use of solid Earth satellite data for commercial natural resource exploration. According to one NOAA report, all the major petroleum companies use satellite altimeter gravity data from Geosat and ERS-1 satellites to locate offshore sedimentary basins in remote areas (Sandwell and Smith 2008). Insurance companies also use Earth observation data. In addition to data related to solid Earth hazards (e.g. earthquakes), insurance companies use satellite data to indentify homes at risk of fire damage due to their proximity to brush (Associated Press 2004). Based on these reports and data sources for Commercial Data Users, I assigned the following science category preferences to Commercial Data Users, shown below in Table 12:

Table 12. Science category preferences for Commercial Data Users

Science category	Preference to Commercial Data Users
Human health	Low
Land use & ecosystems	**High**
Solid Earth hazards & resources	Med
Climate change	Low
Weather	**High**
Water resources	Low

Media

In the stakeholder model, the Media receives information from nine other stakeholders. The final value flow scores for the Media stakeholder are shown below in Table 13. These scores reflect any changes that may have been made after the initial questionnaires were completed.

Table 13. Final value flow scores for Media

To: Stakeholder	Value Flow	From: Stakeholder	Final Value Flow Score
Media	Future plans information	NASA/NOAA	**0.11**
Media	News & noteworthy information	Com. Data Users	**0.48**
Media	News & noteworthy information	Com. Industry	**0.48**
Media	News & noteworthy information	Government	**0.48**
Media	Opinions & support	NGOs	**0.15**
Media	Opinions & support	Public	**0.22**
Media	Science content	Agencies	**0.19**
Media	Science content	NASA/NOAA	**0.28**
Media	Science knowledge	Scientists	**0.32**
Media	Science policy reports	S&T Advisory	**0.17**

To validate the value flow scores for the Media, I assumed that the Media's preference for various types of information corresponds to the popularity of each type of information among media consumers. A 2003 research paper examined online news-viewing data available from Nielsen NetRatings, which monitors the Internet usage of at-home and at-work panels of users (Tewksbury 2003). Table 14 below shows the news content selection patterns from this paper.

Table 14. News content selection patterns (adapted from Tewksbury 2003)

News Category	% of All Page Views
Sports	26.0%
Business & money	**13.4**
Arts & entertainment	10.9
Features	10.7
U.S National	**10.2**
Technology & Science	**7.0**
World	6.1
Politics	5.4
Weather	3.6
Health	1.5
Opinion & Editorial	**1.4**
State & local	1.2
Other news	2.6

Since these news categories do not perfectly correlate with the sources of "news and noteworthy information" value flows to the media in the stakeholder model, I made the following approximations to assign each stakeholder to a news category, shown in Table 15 below.

Table 15. Stakeholders corresponding to each relevant news category from the Tewksbury paper

Relevant News Categories	Stakeholders Belonging to Category
Business & money	Commercial Industry, Commercial Data Users
U.S National	Government
Technology & Science	NASA/NOAA, Scientists, Agencies, S&T Advisory
Opinion & Editorial	Public, NGOs

As shown below in Table 16, I compared the relative rankings of the news categories from the Tewksbury paper with the relative rankings of the value flows from the stakeholders listed above. The left side of the table shows the news categories and their relative rankings according to Table 14. The right side of the table shows the Media value flows from the model that correspond to each news category—based on Table 15 above—and the final value flow scores. The table indicates that the relative rankings of the value flow scores largely reproduce the relative rankings of the news categories. This provides a high degree of confidence in the value flow scores for the Media.

Table 16. Comparison of relevant news content rankings with value flow rankings

News Category	Relative Ranking	To: Stakeholder	Value Flow	From: Stakeholder	Final Value Flow Score
Business & money	1	Media	News & info	Com. Industry	0.48
		Media	News & info	Com. Data Users	0.48
U.S. National	2	Media	News & info	Government	0.48
Technology & science	3	Media	Science knowledge	Scientists	0.32
		Media	Science content	NASA/NOAA	0.28
		Media	Science content	Agencies	0.19
		Media	Science policy reports	S&T Advisory	0.17
		Media	Future plans info	NASA/NOAA	0.11
Opinion & editorial	4	Media	Opinions & support	Public	0.22
		Media	Opinions & support	NGOs	0.15

Public

I also validated the relative value flow rankings for the Public using the data-gathering technique. Table 17 below shows the final value flow scores for the Public. These scores reflect any changes that may have been made after the initial questionnaires were completed. Note that the science-related value flows indicate the "maximum science" score, as described previously in Section 3.1.3.

Table 17. Final value flow scores for the Public

To: Stakeholder	Value Flow	From: Stakeholder	Final Value Flow Score
Public	Earth observation-derived products & services	Com. Data Users	**0.42 (max)**
Public	Earth observation-derived products & services	NASA/NOAA	**0.32 (max)**
Public	Employment	Com. Data Users	**0.32**
Public	Employment	Com. Industry	**0.54**
Public	Employment	Defense	**0.44**
Public	Employment	NASA/NOAA	**0.37**
Public	Employment	Scientists	**0.46**
Public	Health, safety, & environmental protection	Agencies	**0.29**
Public	Health, safety, & environmental protection	Government	**0.34**
Public	Informative & entertaining content	Media	**0.33**
Public	Science knowledge	Educators	**0.29 (max)**
Public	Security benefits	Defense	**0.43**

I validated the "employment" value flows separately from the other value flows into the Public. To validate the employment value flows, shown below in Table 18, I used a variety of sources to obtain estimates on the number of employees within each stakeholder group relevant to Earth science and observations. I used corporate and government websites to obtain employment figures for Commercial Industry, Commercial Data Users, Defense, and NASA/NOAA; and a report from the Department for Professional Employees (DPE) to obtain employment figures for Scientists in fields relevant to the decadal survey (DPE 2002). The table is ranked by the total number of employees within each stakeholder group.

Table 18. Comparison of Public Employment Figures to Value Flow Scores

Stakeholder	# Employees	Relative Ranking	Employment Value Flow Score
Defense (Civilian Workforce)	**700,000**	1	0.44
Commercial Industry	**528,300**	2	0.54
Ball Aerospace	3,000		
Boeing	160,000		
Jet Propulsion Laboratory	5,000		
Lockheed Martin	140,000		
Northrop Grumman	120,000		
Orbital Sciences	3,300		
Raytheon	80,000		
Swales	17,000		

Table 18. (continued)

Stakeholder	# Employees	Relative Ranking	Employment Value Flow Score
Scientists	**296,000**	3	0.46
Atmospheric & Space Scientists	14,000		
Geologists & Geodesists	50,000		
Physical Scientists	45,000		
Agricultural & Food Scientists	35,000		
Biological & Life Scientists	126,000		
Forestry & Conservation Scientists	26,000		
Commercial Data Users	**< 100,000** (estimated)	4	0.32
NASA/NOAA	**25,000**	5	0.37
NASA	18,000		
NOAA	7,000		

The relative value flow score rankings largely reproduce the employment rankings, with two exceptions. First, the Defense workforce of 700,000 scores slightly lower than the Scientist workforce of roughly 300,000. This is reasonable because only a portion of the Defense civilian workforce works in areas related to the decadal survey. Second, NASA/NOAA's score of 0.37 is comparatively high given that it only employs 25,000 workers. This is also reasonable because although the total number of employees is relatively low, NASA/NOAA projects employ many workers from the other stakeholder groups. Also, NASA/NOAA has a major economic and political impact, as well as high visibility, in the cities and states where its centers are located.

For the remaining group of value flows, I validated the scores by examining the relative importance of national issues to the Public. To do this, I tabulated results from major national polls conducted periodically during the period 2002-2008, which were aggregated at a single website (Polling Report Inc. 2008). The results are presented below in Table 19. There were generally two types of polls: The first type, designated Type 1, asks respondents to name their single top issue of importance. The second type, designated Type 2, asks respondents to rate the level of importance of each issue using a four- or five-point scale. Responses from both types of surveys are presented in the table below. The table shows the rank order of each issue for both survey types.

Table 19. Survey Results for Public Issues (Polling Report Inc. 2008)

Issue	Type 1: % Respondents Declaring as Most Important Issue	Type 2: Avg. Importance Score (using 1-4 scale)	Type 1 Rank	Type 2 Rank
Security / Defense / War	39%	3.3	1	3
Economy / Budget / Taxes	27%	3.5	2	1
Health Care	12%	3.3	3	4
Energy / Environment	6%	3.0	4	5
Domestic Issues	4%	-	-	-
Knowledge / Education	2%	3.4	5	2
Other	10%	-	-	-

As Table 19 shows, there is a mismatch between the Type 1 and Type 2 rankings for each issue. Most notably, the issue of knowledge and education ranks fifth in the Type 1 surveys, but second in the Type 2 surveys. This indicates that while knowledge and education may not be the most important issue for many respondents, it is the second-most important issue for a large majority of respondents.

Table 20 below compares the value flow score rankings to the Type 1 and Type 2 rankings derived above in Table 19. The left side of the table shows the relevant public issue categories from Table 19 above and their Type 1 and Type 2 rankings. The right side of the table shows a subset of the Public value flows from the model that correspond to each public issue category, as well as the final value flow scores. The table is ranked according to the Type 1 survey rankings.

Table 20. Comparison of Public value flow rankings to Type 2 survey results

Public Survey Issue Category	Rank from Type 1 Surveys	Rank from Type 2 Surveys	To: Stakeholder	Value Flow	From: Stakeholder	Final Value Flow Score
Security	1	3	Public	Security benefits	Defense	0.49
Health / Environment	3/4	4/5	Public	Health, safety, & environmental protection	Government	0.34
			Public	Health, safety, & environmental protection	Agencies	0.29
Knowledge / Education	5	2	Public	Informative & entertaining content	Media	0.33
			Public	Science content	NASA/NOAA	0.31
			Public	Science knowledge	Educators	0.29

The relative value flow score rankings largely reproduce the Type 1 rankings from the surveys. The Type 2 rankings show less agreement. This could be an indication that future stakeholder analyses should validate Public value flow scores using data from Type 1 surveys.

Science & Technology Advisory Bodies

In the model, the S&T Advisory Bodies receive funding, future plans information, and science knowledge from six other stakeholders. In reality, S&T Advisory Bodies receive information from the committee and panel members comprising each study, as well as independent experts in science and technical fields related to each study. To validate the relative value flow rankings, I examined the decadal survey (National Research Council 2007) and two recent Earth observations-related reports published by the National Research Council (National Research Council 2007, National Research Council 2005). For each study I classified the committee or panel members listed in the Table of Contents by the stakeholder groups they represented. Table 21 below shows the total number of representatives from each stakeholder group and the relative importance ranking of each stakeholder for the three NRC reports. For this validation technique, I assume that the number of representatives from each stakeholder group is proportional to the importance of that stakeholder group as a source of information to S&T Advisory Bodies.

Table 21. Stakeholder representation in NRC Earth observation reports

Stakeholder Group	Total Number of Stakeholders from NRC Reports	Rank
Scientists	85	1
Commercial Industry	15	2
Commercial Data Users	11	3
Federal Agencies	8	4
NASA/NOAA	5	5
International Partners	2	6

Next, I compared the ranking of each stakeholder from Table 21 above to the relative ranking of the S&T Advisory value flows in the model, shown below in Table 22.

Table 22. Comparison of source rankings from NRC reports with value flow rankings to S&T Advisory Bodies

To: Stakeholder	Value Flow	From: Stakeholder	Source Ranking from NRC reports	Value Flow Score
S&T Advisory	Science knowledge	Scientists	1	0.53
S&T Advisory	Future plans information	Commercial Industry	2	0.36
S&T Advisory	Future plans information	Commercial Data Users	3	0.33
S&T Advisory	Future plans information	Federal Agencies	4	0.36
S&T Advisory	Funding	NASA/NOAA	5	0.21
S&T Advisory	Future plans information	NASA/NOAA	5	0.57
S&T Advisory	Future plans information	International Partners	6	0.31

There is strong agreement between the relative rankings of the value flows and the rankings according to the three NRC reports. One exception is the "future plans information" value flow from NASA/NOAA. In Table 21, NASA/NOAA ranks fifth based on the number of NASA/NOA representatives in the NRC reports. However, there are many more inputs from NASA/NOAA to the NRC committees other than membership on the committee, in the form of reports, presentations, and both formal and informal discussions with NASA/NOAA representatives. Also, the premise of the decadal survey is to assess the current state of NASA and NOAA and provide recommendations for the future. For these reasons, it is appropriate that the "future plans information" value flow from NASA/NOAA scores highest in the model.

Government

For the Government, I was able to use data-gathering techniques to validate the information-related value flow scores and the relative rankings of the science category preferences. For the value flow scores, I referenced a survey conducted by Kingdon on the importance of various actors in informing Congressmen's voting decisions (Kingdon 1989). Table 23 below reproduces Kingdon's survey results.

Table 23. Actor/Source importance in influencing Congressmen's voting decisions (Kingdon)

Importance	Constituency	Fellow Congressmen	Party Leadership	Interest Groups	Administration	Staff	Reading
Determinative	7%	5%	0%	1%	4%	1%	0%
Major importance	31	42	5	25	14	8	17
Minor importance	51	28	32	40	21	26	32
Not important	12	25	63	35	61	66	52
Total %	*101%*	*100%*	*100%*	*101%*	*100%*	*101%*	*101%*
Total n	*222*	*221*	*222*	*222*	*222*	*221*	*221*

Kingdon conducted the survey by asking 222 U.S. Congressmen to rate the importance of various actors, or sources, in providing information that ultimately affects voting decisions. This method is similar to the scoring method used to assign source importance scores to information value flows to the Government in the stakeholder model. For this analysis, I ignored the results for Party Leadership, Administration, and Staff because they do not correspond to any of the stakeholders in my model. Based on these survey results, I approximated the relative ranking of each source as shown below in Table 24:

Table 24. Relative rankings of the relevant actors/sources from Kingdon surveys

Actor (Source)	Rank
Fellow Congressmen	1
Constituency	2
Interest Groups	3
Reading	4

Since these actor/source categories do not perfectly correlate with the sources of value flow inputs to the Government in the stakeholder model, I made the following approximations to assign each stakeholder to one of Kingdon's actor/source categories, shown in Table 25 below.

Table 25. Stakeholders in the model corresponding to Kingdon's actor categories

Kingdon's Actor Category	Stakeholders Belonging to Category
Fellow Congressmen	Scientists, S&T Advisory, NASA/NOAA
Constituency	Public
Interest Groups	NGOs, Commercial Data Users, Commercial Industry
Reading	Media

One thing to note is that in Kingdon's survey, Fellow Congressmen are important sources because they provide information that was conveyed during testimony in Congressional committee hearings. In committee hearings related to Earth observations, Scientists, S&T Advisory Bodies, and representatives from NASA/NOAA often provide scientific testimony, which is why I have grouped these stakeholders with Kingdon's Fellow Congressman actor in Table 25.

I compared the rankings of Kingdon's sources from Table 24 to the relative rankings of the information-related value flow inputs to the Government stakeholder, as shown below in Table 26. The final value flow scores reflect any changes that may have been made after the initial questionnaires were completed. Note that the science-related value flows indicate the "maximum science" score, as described previously in Section 3.1.3.

Table 26. Comparison of Government information-related value flow inputs to Kingdon survey results

Actor (source) in Kingdon survey	Approx. Rank from Kingdon Survey	To: Stakeholder	Value Flow	From: Stakeholder	Final Value Flow Score
Fellow Congressmen	1	Government	Science knowledge	Scientists	**0.43 (max)**
		Government	Science policy advice	S&T Advisory	**0.43 (max)**
		Government	Science opinions	NASA/NOAA	**0.42 (max)**
Constituency	2	Government	Opinions & support	Public	**0.34**
Interest groups	3	Government	Opinions & support	NGOs	**0.30**
		Government	Opinions & support	Com. Data Users	**0.29**
		Government	Opinions & support	Com. Industry	**0.26**
Reading	4	Government	Informative content	Media	**0.24**

Table 26 shows remarkable similarity between Kingdon's responses and the value flow scores in the stakeholder model. This validates the relative rankings of the information-related value flows to the Government.

To validate the science category preferences for the Government, I recognized that in the Legislative branch, Congressmen most often obtain science information through testimony at committee hearings. I examined the written testimony for hearings held during the 110th Session of Congress by the following five House of Representatives Committees that deal with Earth science-related issues:

- House Committee on Science & Technology
- House Committee on Agriculture
- House Committee on Energy and Commerce
- House Committee on Natural Resources
- House Select Committee on Energy Independence and Global Warming

A total of 39 out of 536 hearings contained Earth science-related testimony. For each science hearing, I noted the science category (or categories) to which the testimony related. The results are shown below in Table 27 along with the science category preferences I assigned to the Government.

Table 27. Science category preferences assigned to Government based on House Committee hearings

Science category	Number of Hearings	Preference to Government
Human health	11	Med
Land use & ecosystems	17	Med
Solid Earth hazards & resources	3	Low
Climate change	**26**	**High**
Weather	10	Med
Water resources	12	Med

Climate was by far the most important science category; followed by human health, land use & ecosystems, weather, and water resources. Solid Earth hazards & resources had the lowest importance.

Summary

This section of Chapter 3 demonstrated the usefulness of using stakeholder interviews and proxy data-gathering techniques to validate the value flow scores and science category preferences within the model. In general, the value flow scores showed strong agreement with the anecdotal validation and the proxy data sources, providing confidence in the model and the technique used to assign the value flow scores. Table 28 below summarizes the type of validation performed for each stakeholder within the model.

Table 28. Summary of validation techniques used for each stakeholder in the model

Stakeholder	Anecdotal Validation by Stakeholder Representative	Proxy Data Sources for Value Flows	Proxy Data Sources for Science Category Preferences
Agencies			N/A
Commercial Data Users			X
Commercial Industry			N/A
Defense	X		X
Educators	X		N/A
Government		X	X
International Partners			N/A
Media		X	N/A
NASA/NOAA	X		X
NGOs			N/A
Public		X	
S&T Advisory Bodies		X	N/A
Scientists	X		N/A

Stakeholder representatives were consulted to provide anecdotal validation for the value flows scores for Defense, Educators, NASA/NOAA, and Scientists. Proxy data sources were used to provide validation of the value flow scores for the Government, Media, Public, and S&T Advisory Bodies. Proxy data sources were also used to provide validation of the science category preferences for Commercial Data Users, Defense, Government, and NASA/NOAA. Future work could be done to interview additional stakeholder representatives and to find proxy data sources to validate the remaining value flow scores within the model.

3.3 Calculation of Value Loops

As described previously in Chapter 2, many traditional stakeholder analysis techniques consider the direct exchanges between the central stakeholder and each other stakeholder. The stakeholder analysis method presented in this thesis considers not only direct transactions, but also longer value chains involving three or more stakeholders. Value loops that begin and end with the central stakeholder—in this case, NASA/NOAA—provide the foundation for the quantitative stakeholder analysis. This section describes the method used to calculate all the possible value loops within the stakeholder value network.

At this point, it is useful to clarify the terminology used. A *value flow* is the output of one stakeholder and the input of another. A *value chain* is a string of value flows. For example, "NASA/NOAA provides data to Scientists, who provide knowledge to the Public, who provide policy support to the Government" would be a value chain starting at NASA/NOAA and ending at the Government. A *value loop* is a value chain that begins and ends with the same stakeholder. For this stakeholder analysis, value loops were defined as starting and ending with NASA/NOAA, since this analysis is being conducted from NASA/NOAA's perspective.

Value loops can be used to understand the indirect transfer of benefit among three or more stakeholders. They can help illustrate which stakeholder needs are satisfied by strong feedback loops, and which needs are not well satisfied. Value loops also provide the means for developing an in-depth understanding of how value is created and delivered throughout the stakeholder network, which may not be immediately obvious or intuitive to Earth Observations Program planners. The results of the value loop calculations are presented in Chapter 4.

3.3.1 Value Loop Calculation

The value loop method described here is the same method developed in Cameron's Master's thesis. (Cameron 2007). Our method for calculating value loops involves multiplying the value flow scores of each value flow within a loop. As Cameron describes, using a multiplicative rule with a [0, 1] range ensures that each value loop score will remain bounded within the [0, 1] range. One minor difference between this analysis and Cameron's method is that the value flows in this model are bounded within a [0, 0.96] range, as described previously in Section 3.1.3. Using this method, longer value loops are likely to have lower scores than shorter value loops, which is intuitive—delivering value through a chain of four or five stakeholders is often more difficult than delivering value through a chain of just two or three stakeholders. Figure 34 below illustrates the calculation of a single value loop: Space acquired data flows from NASA/NOAA to Scientists; science knowledge flows from Scientists to Media; Media information flows from Media to Public; opinions and support flow from Public to Government; and funding flows from Government back to NASA/NOAA. The individual scores for each value flow are listed in Appendix D. Using these, the value loop score is calculated by multiplying the scores of each individual value flow:

$$0.74 \times 0.32 \times 0.33 \times 0.59 \times 0.53 = \mathbf{0.024}$$

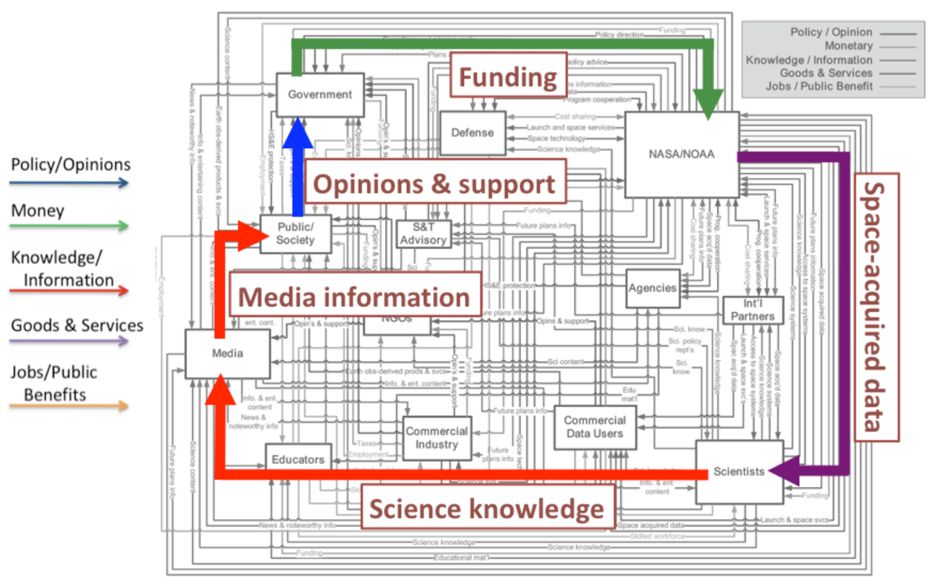


Figure 34. Example of value loop score calculation

Figure 34 illustrates how value loops can be used to understand how value flows change from one type to another throughout the value loop. Within the value loop, a goods & services output from NASA/NOAA becomes a knowledge & information flow to the Media and Public, which becomes a policy flow to the Government, and finally returns to NASA/NOAA as a monetary flow. By illustrating how value loops contain different types of flows, this technique provides additional insight than the diagrams shown earlier in Figure 20 through Figure 24, which show how value flows of the same type travel throughout the stakeholder network. Those diagrams do not convey the fact that inputs to a stakeholder of one type of flow may lead to outputs of another type of flow. For example, Figure 35 below, which is an excerpt of Figure 23, shows the goods and services value flows into and out of the Scientists. This diagram implies that inputs of space acquired data and access to space systems result in outputs of science systems. However, in reality this is not the case—space acquired data and access to space systems result in outputs of science knowledge, which is a knowledge & information value flow. Similarly, the outputs of science systems are generated by inputs of funding, which is a monetary value flow. Value loops provide a more representative indication of how value is actually delivered throughout the stakeholder network by allowing connections between value flows of different types. The connection of value flow inputs to value flow outputs using "internal assets" is described further in the following sub-section.

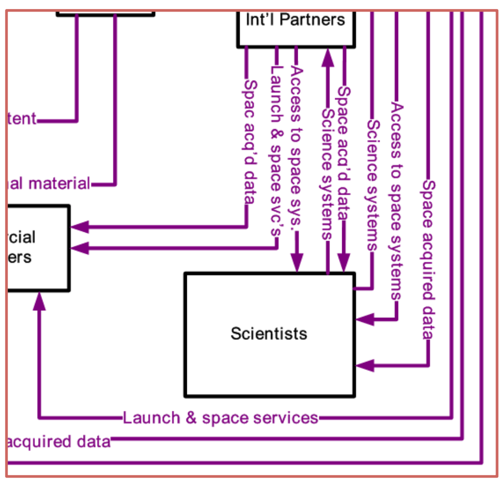


Figure 35. Goods and services value flows into and out of Scientists (excerpt of Figure 23)

Cameron developed the multiplicative method for calculating value loops without developing a rigorous mathematical theory to support the method. The MIT System Architecture research group is currently working to develop the theory to support this calculation method. Our theory is based on network utility theory, and the multiplicative method used here closely resembles the formula that maximizes the net benefit to a central stakeholder, which in this case is NASA/NOAA. Work in this area is ongoing and will strengthen the theoretical justification for our value loop calculation method.

3.3.2 Internal Assets

The stakeholder value network analysis described in this thesis requires the calculation of all possible value loops within the stakeholder network. Using an unrestricted model, each input to a stakeholder would connect with every output from that stakeholder. In reality, though, each input to a stakeholder affects only a subset of the outputs. An example of this was illustrated in the discussion above regarding Figure 35.

To capture the idea that not all inputs to a stakeholder have an affect on all outputs, I used Cameron's concept of "internal assets" to link each input to a stakeholder with the appropriate outputs (Cameron 2007). Figure 36 below shows three internal assets for the Public stakeholder: financial wellbeing, knowledge base, and quality of life. Each internal asset represents a stakeholder characteristic that can be affected by one or more inputs and have an effect on one or more outputs. For most stakeholders, I used the same internal assets from Cameron's model. For stakeholders that were not included in Cameron's model, I generated a small number of internal assets that reasonably and appropriately restricted the input and output connections. The internal assets and value flow connections used for all 13 stakeholders are shown in Appendix E.

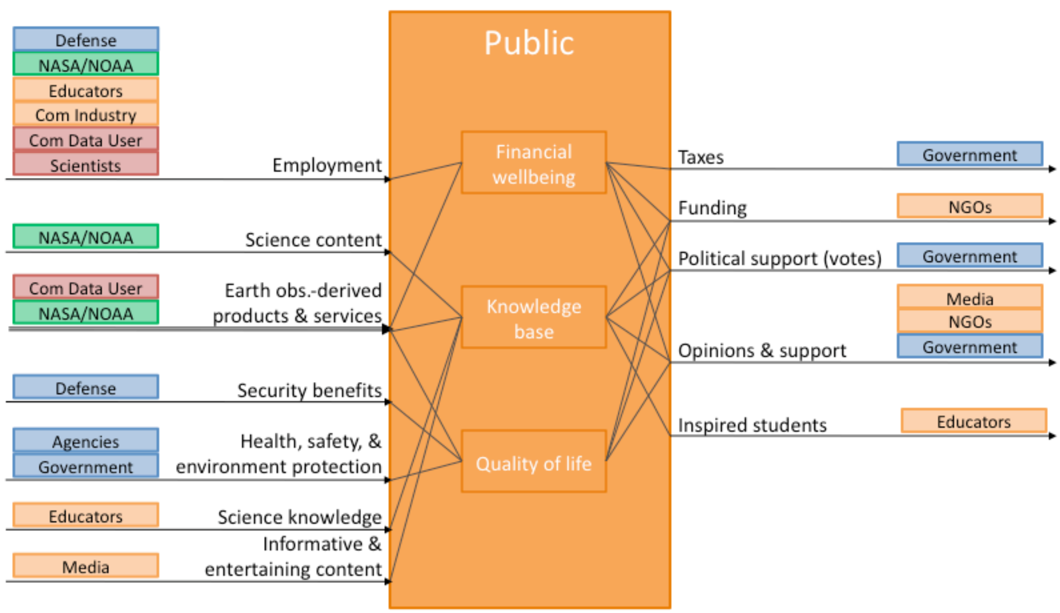


Figure 36. Internal assets of the Public stakeholder

Using internal assets helps to dramatically reduce the total number of possible links within the stakeholder network, which reduces the computational resources needed to compute all the value loops. However, using internal assets may create duplicate links when a value flow input connects through more than one internal asset, as described further in Section 3.4.1.

3.3.3 Using OPN to Calculate Value Loops

This section describes the software program used to calculate the value loops. I used a computer software program developed by our research group called Object Process Network (OPN) to compute the value loop scores for every feasible value loop within the stakeholder network. OPN is a domain-neutral, executable meta-language designed to represent, generate, and manipulate simulation models. As a model generation tool, OPN is particularly suitable for enumerating and analyzing large, complex system architectures or networks such as this stakeholder value network model (Koo 2005).

I developed the OPN model based on the stakeholder value network map shown previously in Figure 19. Within the model, stakeholders and internal assets are modeled as objects (rectangles) and value flows are modeled as processes (ovals), as shown below in Figure 37.

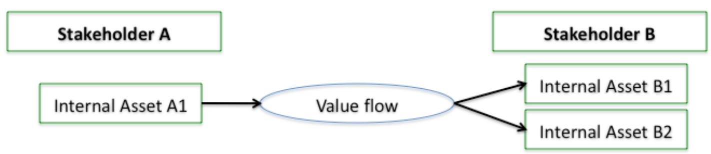


Figure 37. OPN representation of stakeholders and value flows

Following Cameron's approach, there are three logical rules built into the connections within the OPN model:

1. Each value loop begins and ends with NASA/NOAA.
2. A stakeholder may only appear once in any given value loop.
3. Value loops with scores below a certain threshold are eliminated. I used a threshold score of 0.01; however this was arbitrary. Some of the final results are somewhat sensitive to the choice of threshold value, as discussed further in Section 4.8.1.

Implementing these rules into the OPN model required just a few lines of code for each process link, as indicated in Figure 38 below. I created a variable [STAKEHOLDER] for each stakeholder to track whether it has already appeared in a value loop. The multiplication process to compute the value loop scores occurs in the process ovals. To enforce rules #2 and #3, OPN allows the user to encode "pre-conditions" and "post-conditions" as criteria for invoking a process or changing an object's state. I used a post-condition rule to eliminate value loop scores that fell below the threshold score and to prevent a stakeholder from appearing twice in a single value loop. The OPN model also contains a global script containing the desired threshold score and the scores for each individual value flow, which are accessed by the lines of code shown below in Figure 38.

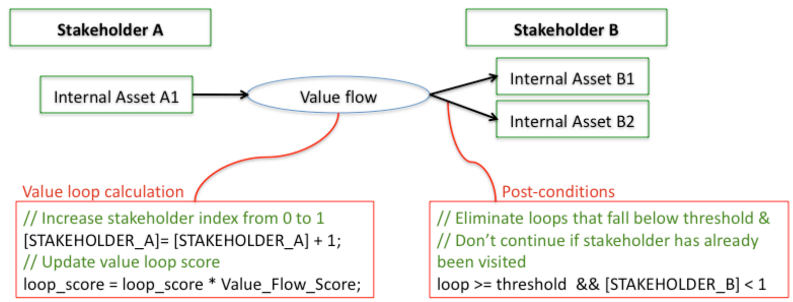


Figure 38. OPN code showing value loop calculation and post-condition criteria

A screenshot of the entire OPN model is shown below in Figure 39. A portion of the figure has been enlarged to show the stakeholder and value flow connections in detail.

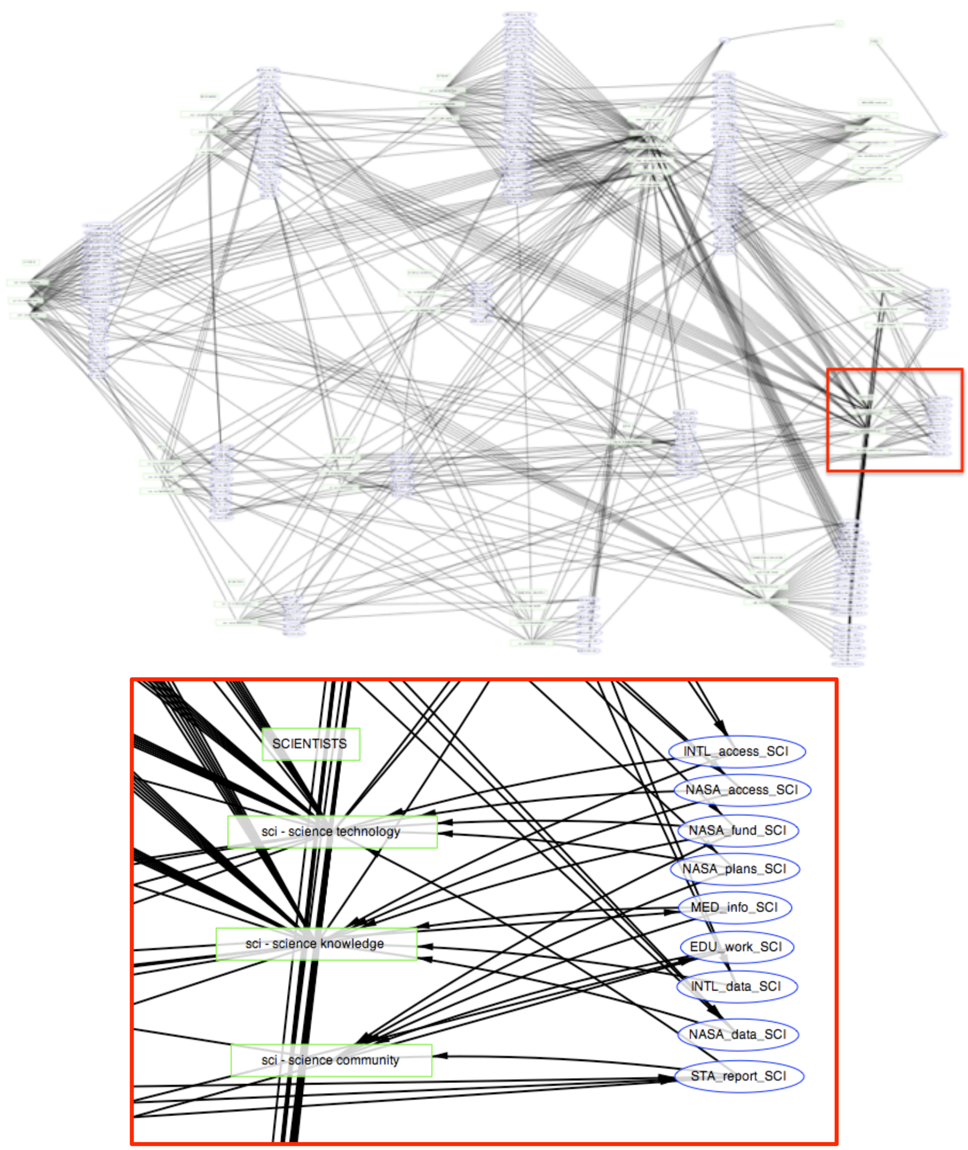


Figure 39. (Top) Complete OPN model; (Bottom) Detail showing stakeholder and value flow connections in OPN

Within the OPN model, objects (rectangles) containing the stakeholder names are non-functional labels within the diagram. Objects containing the internal assets function as the nodes connecting each value flow input to the appropriate value flow outputs. Value flows are modeled as processes (ovals) within the model.

This model seems to be near the maximum feasible size for an OPN stakeholder model. The model contains 13 stakeholder labels, 44 internal asset objects, and 190 value flow processes. Using a threshold value of 0.01, the model required approximately three hours of execution time and approximately 1.5 GB RAM. The output produced 43,388 rows of data, and 11,207 value loops were identified.

3.4 Reducing OPN Value Loops to a Unique, Valid Set

This section describes the value loops identified by the OPN model and the process of reducing the initial set of value loops to a unique, valid set.

The OPN model identified a total of 11,207 value loops. Figure 40 below shows an example of the value loop data imported into Excel. I used the notation STAKEHOLDER(A)_valueflow(1)_STAKHOLDER(B) for each value flow, which can be interpreted as a value flow of Type 1 flowing from Stakeholder A to Stakeholder B. Table 29 below the figure shows the abbreviations used for each stakeholder and each type of value flow, sorted alphabetically by the abbreviations.

Score	Start	NASA internal asset	NASA output	Stakeholder internal asset	Value Flow	Stakeholder internal asset	End
0.48	Start	nasa - mission support	NASA_data_SCI	sci - science knowledge	SCI_know_climate_NASA	nasa - educational outreach - exit	Exit
0.48	Start	nasa - mission support	NASA_data_SCI	sci - science knowledge	SCI_know_climate_NASA	nasa - science missions - exit	Exit
0.48	Start	nasa - science missions	NASA_data_SCI	sci - science knowledge	SCI_know_climate_NASA	nasa - educational outreach - exit	Exit
0.48	Start	nasa - science missions	NASA_data_SCI	sci - science knowledge	SCI_know_climate_NASA	nasa - science missions - exit	Exit
0.48	Start	nasa - collaborative efforts	NASA_data_SCI	sci - science knowledge	SCI_know_climate_NASA	nasa - educational outreach - exit	Exit
0.48	Start	nasa - collaborative efforts	NASA_data_SCI	sci - science knowledge	SCI_know_climate_NASA	nasa - science missions - exit	Exit
0.41	Start	nasa - science missions	NASA_comp_GOV	gov - domestic political capital	GOV_dir_NASA	nasa - science missions - exit	Exit
0.40	Start	nasa - collaborative efforts	NASA_plans_STA	sta - issue awareness	STA_advice_NASA	nasa - science missions - exit	Exit
0.38	Start	nasa - science missions	NASA_access_SCI	sci - science technology	SCI_sys_NASA	nasa - mission support - exit	Exit

Figure 40. Sample of original output from OPN identifying 10,912 value loops

Table 29. Abbreviations used for stakeholders and value flows in the OPN model

Stakeholder	Abbreviation	Value Flow Type	Abbreviation
Federal Agencies	AGN	Access to space systems	access
Commercial Data Users	DATA	Science policy advice	advice
Defense	DEF	Compliance with policy direction	comp
Educators	EDU	Concerns (Opinions & support)	concerns
Government	GOV	Science content	cont / content
Commercial Industry	IND	Program cooperation	coop
International Partners	INTL	Cost sharing	cost
Media	MED	Space-acquired data	data
NASA/NOAA	NASA	Policy direction	dir
NGOs	NGO	Educational material	edu
Public	PUB	Employment	emp
Scientists	SCI	Funding	fund
S&T Advisory	STA	Health, safety, & environmental protection	hse
		Informative & entertaining content	info
		Science knowledge	know
		Launch & space services	launch
		News & noteworthy info	news
		Opinions & support	opin
		Future plans information; Plans & reports of demonstrated progress	plans
		Earth observation-derived products & services	products
		Science policy reports	report
		Science opinions	sci
		Security	sec
		Inspired students	stud
		Science systems	sys
		Taxes	tax
		Space technology	tech
		Votes	votes
		Skilled workforce	work

The 11,207 value loops identified by OPN contained two classes of inconsistencies that required correction prior to analysis: duplicate loops and non-causal loops. The following sub-sections describe the process of eliminating the duplicate and non-causal loops from the OPN output.

3.4.1 Elimination of Duplicate Value Loops

This section describes the process used to eliminate the duplicate value loops from the OPN output. Duplicate loops appeared as a result of using internal assets to connect a stakeholder's inputs with its outputs. As shown below in Figure 41, which is a subset of Figure 36, duplicate value loops occur when a value flow input connects to two internal assets that both connect to a single value flow output. The internal asset connections that resulted in duplicate value loops are indicated with dashed lines in Appendix E.

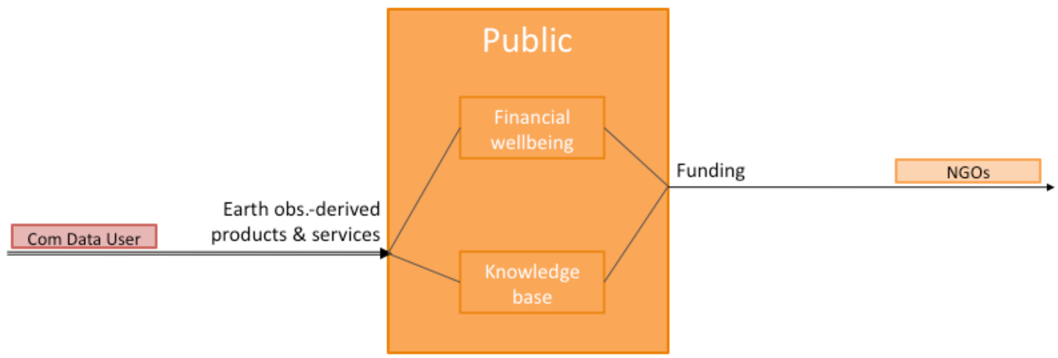


Figure 41. Example of duplicate value flows created by internal assets (subset of Figure 36)

Duplicate loops must be deleted to avoid double-counting value loops in the final analysis. A simple way to eliminate the duplicate loops is to ignore the internal assets data and check for loops containing identical value flows. This was done by examining the entire list of value loops in Excel. Of the 11,207 identified value loops, 8777, or 78%, were found to be duplicates, reducing the model to 2430 unique value flows. Although a significant fraction of the original value loops were duplicates, using internal assets still provided a dramatic improvement over the thousands of non-causal loops that would have been created otherwise. Additionally, duplicate value loops can be eliminated with a single operation in Excel, whereas deleting non-causal loops requires manually assessing each value loop individually. Despite the use of internal assets, some non-causal loops still remained, as described in the next section.

3.4.2 Elimination of Non-causal Value Loops

This section describes the process used to eliminate non-causal value loops. A non-causal value loop is one that contains a connection between a stakeholder input and output, where in reality the input would have no direct affect on the output. An example of this is shown below in Figure 42. Note that the internal assets included in the original data output have been hidden in the figure. Non-causal links can appear in the model when a stakeholder input and output, which are not directly related, connect through the same internal asset. In Figure 42 below, the non-causal link between NASA/NOAA, Commercial Data Users, and the Government was created by the Commercial Activity internal asset.

Score	Start	NASA output	Value Flow	Value Flow	End
0.07	Start	NASA_plans_DATA	DATA_tax_GOV	GOV_fund_NASA	Exit

Figure 42. Example of a non-causal value loop

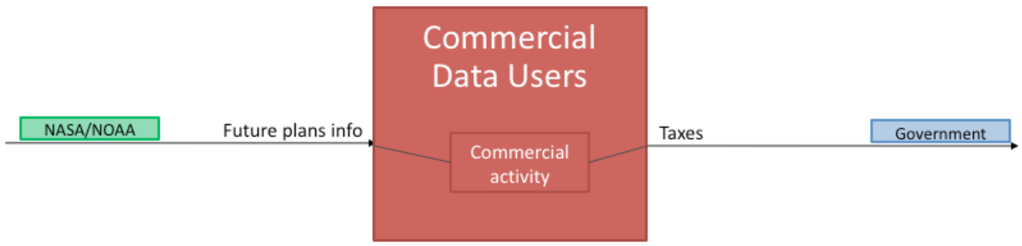


Figure 43. Example of non-causal link created by internal asset connection

This value loop in Figure 42 can be interpreted as follows: NASA/NOAA provides "future plans information" to Commercial Data Users, who provide "taxes" to the Government, which provides "funding" to NASA/NOAA. In reality, the sharing of NASA/NOAA's future plans information with Commercial Data Users is unlikely to have a strong direct effect on the taxes paid by Commercial Data Users to the Government. Therefore, value loops that contained the combination NASA_plans_DATA and DATA_tax_GOV were deleted. I identified a total of six non-causal links in the list of unique value flows:

- MEDIA_information_COM INDUSTRY → COM INDUSTRY_launch services_NASA
- NASA_access to space systems_SCIENTISTS → SCIENTISTS_space systems_INTL-PARTNER
- NASA_access to space systems_SCIENTISTS → SCIENTISTS_space systems_NASA
- INTL PARTNER_access to space systems_SCIENTISTS → SCIENTISTS_space systems_NASA
- NASA_future plans info_COM DATA USERS → COM DATA USERS_taxes_GOVERNMENT
- NASA_future plans info_COM INDUSTRY → COM INDUSTRY_taxes_GOVERNMENT

These non-causal links appeared in 13 value flows, which were deleted. This reduced the OPN model output to 2417 unique value flows.

The appearance of non-causal links indicates that the internal asset involved in the connection is too broad. Using a greater number of more precise internal assets would help prevent non-causal links from occurring.

3.4.3 Elimination of Value Loops Containing Multiple Science Categories

This section describes the process used to eliminate value loops that contained value flows representing more than one science category. For example, in the value loop shown below in Figure 44, the NASA/NOAA output of weather-related data to Commercial Data Users leads to the output of land-related products and services from to the Public. In reality, this connection would not exist. Only connections involving the same science category were permitted.

Score	Start	NASA output	Value Flow	Value Flow	Value Flow	End
0.06	Start	NASA_data_weather_DATA	DATA_products_land_PUB	PUB_votes_GOV	GOV_fund_NASA	Exit

Figure 44. Example of a value loop containing links from two science categories

The OPN model created these types of value flows because I did not include a rule to ensure that each value flow contained links from only one science category. Doing so would have eliminated the need for the manual deletion of these loops later. I identified 537 value loops containing links from more than one science category, which were deleted. This reduced the OPN model output to the final list of 1880 unique, valid value loops.

3.4.4 Final List of Value Loops

This section describes the final list of value loops used for the quantitative analysis. Deleting the duplicate, non-causal, and multiple science category value loops resulted in 1880 unique and valid value loops. Table 30 below shows the highest-scoring top 30 value loops.

Table 30. Top 30 value loops from the set of 1880 unique, valid value loops

Score	Start	NASA output	Value Flow	Value Flow	End
0.48	Start	NASA_data_SCI	SCI_know_climate_NASA	Exit	-
0.41	Start	NASA_comp_GOV	GOV_dir_NASA	Exit	-
0.40	Start	NASA_plans_STA	STA_advice_NASA	Exit	-
0.37	Start	NASA_access_SCI	SCI_know_climate_NASA	Exit	-
0.34	Start	NASA_plans_GOV	GOV_dir_NASA	Exit	-
0.31	Start	NASA_fund_SCI	SCI_sys_NASA	Exit	-
0.31	Start	NASA_fund_SCI	SCI_know_climate_NASA	Exit	-
0.30	Start	NASA_sci_climate_GOV	GOV_dir_NASA	Exit	-
0.30	Start	NASA_comp_GOV	GOV_fund_NASA	Exit	-
0.28	Start	NASA_plans_IND	IND_launch_NASA	Exit	-
0.28	Start	NASA_data_SCI	SCI_know_solid_NASA	Exit	-
0.28	Start	NASA_data_SCI	SCI_know_land_NASA	Exit	-
0.28	Start	NASA_data_SCI	SCI_know_water_NASA	Exit	-
0.28	Start	NASA_data_SCI	SCI_know_weather_NASA	Exit	-
0.27	Start	NASA_data_SCI	SCI_know_STA	STA_advice_NASA	Exit
0.27	Start	NASA_fund_IND	IND_launch_NASA	Exit	-
0.25	Start	NASA_plans_IND	IND_sys_NASA	Exit	-
0.25	Start	NASA_plans_GOV	GOV_fund_NASA	Exit	-
0.25	Start	NASA_plans_SCI	SCI_sys_NASA	Exit	-
0.24	Start	NASA_plans_SCI	SCI_know_climate_NASA	Exit	-
0.24	Start	NASA_fund_IND	IND_sys_NASA	Exit	-
0.23	Start	NASA_data_SCI	SCI_know_climate_GOV	GOV_dir_NASA	Exit
0.22	Start	NASA_data_SCI	SCI_know_EDU	EDU_work_NASA	Exit
0.22	Start	NASA_sci_climate_GOV	GOV_fund_NASA	Exit	-
0.22	Start	NASA_access_SCI	SCI_know_solid_NASA	Exit	-
0.22	Start	NASA_access_SCI	SCI_know_land_NASA	Exit	-
0.22	Start	NASA_access_SCI	SCI_know_water_NASA	Exit	-
0.22	Start	NASA_access_SCI	SCI_know_weather_NASA	Exit	-
0.21	Start	NASA_access_SCI	SCI_know_STA	STA_advice_NASA	Exit
0.18	Start	NASA_sci_health_GOV	GOV_dir_NASA	Exit	-

The scores for the 1880 value loops range from 0.48 to 0.01. The lower bound of 0.01 represents the arbitrarily chosen lower threshold used to retain value loops in the OPN model. Table 31 below shows the number of value loops within each given range, as well as the sum of the scores of all value loops within the range. Cumulative totals are also shown. The total sum of all the computed value loop scores is 60.11.

Table 31. Characteristics of computed value loop scores

Score Range	Number of Value Loops Within Range	Cumulative Number	Sum of All Value Loop Scores Within Range	Cumulative Sum	Cumulative Percent
0.40 – 0.49	3	3	1.29	1.29	2.1%
0.30 – 0.39	6	9	1.93	3.22	5.4
0.20 – 0.29	20	29	4.93	8.15	13.6
0.10 – 0.19	82	111	10.66	18.81	31.3
0.05 – 0.09	197	308	12.76	31.57	52.5
0.03 – 0.04	334	642	11.12	42.69	71.0
0.01 – 0.02	1238	1880	17.42	60.11	100.0%
TOTAL	**1880**		**60.11**		

Figure 45 below shows the distribution of value loop scores with key thresholds indicated.

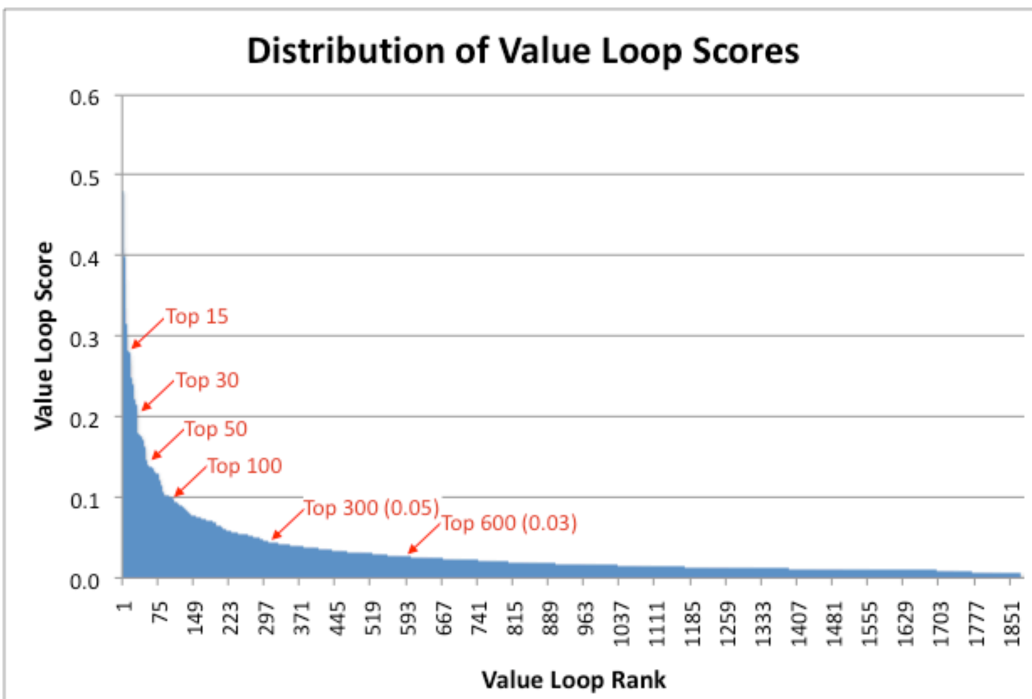


Figure 45. Distribution of value loop scores showing key threshold points

The top 600 scores have a lower bound of approximately 0.03, and the top 300 scores have a lower bound of approximately 0.05. It is worth noting that 1572 out of 1880 loops lie within the range of 0.01 – 0.05. The sum of the computed value loops scores within this range is 28.54, which is 47% of the total sum of all value loop scores—a significant fraction of the value flows within the model. The sensitivity of the analysis results to the choice of lower threshold is discussed further in Section 4.8.1.

3.5 Summary of Quantitative Stakeholder Model

This chapter described the step-by-step process used to create the quantitative stakeholder model. This model uses, and improves upon, the method developed by Cameron for assigning numeric scores to value flows and computing value loops. A different set of attributes was used to evaluate each stakeholder's needs, and a revised questionnaire was developed for soliciting the numeric value flow scores from individual scorers. This chapter also described several new techniques for validating the relative ranking of value flow scores and science category preferences. The quantitative stakeholder model yielded 1880 unique and valid value loops. The analysis of these value loops is described next in Chapter 4. Many of the insights and recommendations yielded from the value loop analysis are presented in Chapter 5.

4 Quantitative Stakeholder Analysis Results

After using OPN to identify the 1880 unique and valid value loops in the stakeholder value network, I conducted a rigorous analysis of the value loops to fulfill the objective presented at the beginning of Chapter 3:

Objective of Quantitative Stakeholder Analysis:

- **To** identify the most important stakeholders, the highest value-producing interactions among stakeholders, and most important NASA & NOAA outputs **by** conducting a rigorous quantitative stakeholder analysis **using** the stakeholder value network analysis approach.

This chapter describes in detail the results from the quantitative stakeholder analyses for the NASA/NOAA Earth Observations Program. I performed an analysis of the value loops to identify the following:

- Most important stakeholders
- Most important value loops
- Most important value flows

From this I developed a simplified version of the stakeholder map that shows only the most important stakeholders and associated value flows. I further analyzed the value loops to determine the following:

- Highest value NASA/NOAA outputs
- Highest value NASA/NOAA inputs
- Value potential for each of the six science categories

I also investigated the sensitivity of the results to various parameters in the model and discuss some possible directions for future work on this topic. This chapter is organized into the following sections:

- **Section 4.1: Most Important Stakeholders.** This section describes the value loop analysis conducted to identify the most important stakeholders in the network.
- **Section 4.2: Most Significant Value Flows.** This section describes the value loop analysis conducted to identify the most significant individual value flows within the stakeholder value network.
- **Section 4.3: Most Significant Value Loops.** This section describes the highest-scoring value loops in the stakeholder value network.

- **Section 4.4: Simplified Stakeholder Model.** This describes the simplified stakeholder model that was created based on the results of the analyses conducted in the first three sections.
- **Section 4.5: Most Significant NASA/NOAA Outputs.** This section describes the value loop analysis conducted to identify the most significant outputs from NASA/NOAA.
- **Section 4.6: Most Significant NASA/NOAA Inputs.** This section describes the value loop analysis conducted to identify the top affectable inputs to NASA/NOAA.
- **Section 4.7: Most Important Science Categories.** This section describes the value loop analysis conducted to identify the science categories that create the greatest amount of value throughout the stakeholder value network.
- **Section 4.8: Sensitivity Studies.** This section describes five sensitivity studies conducted on the stakeholder model: (1) investigating the sensitivity of overall results to choice of threshold value loop score, (2) investigating the sensitivity of science category rankings to individual value flow scores, (3) investigating the effect of increasing the importance of International Partners, (4) modeling NOAA as an individual stakeholder, and (5) investigating the effect of using a modified formula for calculating value loops.
- **Section 4.9: Summary of Stakeholder Analysis Results.** This section provides a brief summary of the results of the quantitative stakeholder analysis.
- **Section 4.10: Future Work.** This section discusses some possible directions for future work on this topic.
- **Section 4.11: Conclusions.** This section presents a brief set of conclusions from the entire stakeholder analysis. The conclusions complement the insights and recommendations presented in Chapter 5.

4.1 Most Important Stakeholders

This section describes the analysis conducted to identify the most important stakeholders in the stakeholder network. I define "important" stakeholders as those who contribute the most value to the entire network. In the stakeholder model, important stakeholders may be included in high-scoring value loops, or in a large number of lower-scoring value loops. Figure 46 below shows the most important stakeholders in the model. The numeric scores for each stakeholder are listed in Appendix F. To calculate the importance of each stakeholder, I used the weighted sum of the stakeholder's occurrence in all value loops. Each time a stakeholder appears in a value loop, the score for that loop is added to the stakeholder's total. I normalized the final values by the sum of all value loop scores included in the set. By definition, NASA/NOAA has a score of 1.0 because it appears in every value loop.

$$\text{Weighted Stakeholder Occurrence} = \frac{\textit{Sum of all value loops containing Stakeholder}}{\textit{Sum of all 1880 value loop scores}}$$

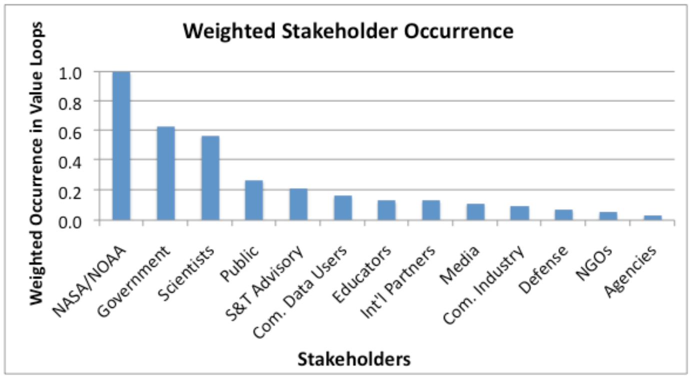


Figure 46. Weighted stakeholder occurrence scores

Using this method, the two most important stakeholders after NASA/NOAA are the Government and Scientists. Following them are the Public, S&T Advisory Bodies, and Commercial Data Users. The remaining seven stakeholders contribute comparatively little value—the sum of their weighted occurrence scores is 18% of the total sum of the weighted occurrence scores of all stakeholders.

Another method for determining the important stakeholders is to divide a stakeholder's weighted occurrence score from Figure 46 by the number of value loops in which the stakeholder occurs. I call this the normalized weighted stakeholder occurrence score, shown in Figure 47 below. The numeric scores for each stakeholder are listed in Appendix F. This method tends to increase the score of stakeholders that appear in a modest number of high-value loops and decrease the score of those that appear in a large number of lower-value loops. This method may provide a fairer ranking scheme since some of the more important stakeholders may only appear in a few high-value loops.

$$\text{Normalized Weighted Stakeholder Occurrence} = \frac{\textit{Stakeholder Weighted Occurrence Score}}{\textit{Number of value loops containing Stakeholder}}$$

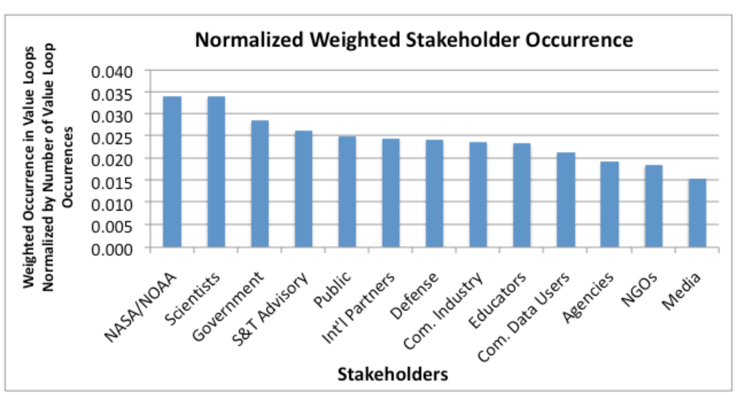


Figure 47. Normalized stakeholder occurrence scores

Using the normalized stakeholder occurrence method, the top three stakeholders remain NASA/NOAA, Scientists, and the Government, although the order of Scientists and the Government are reversed from the first method. The fourth and fifth most important stakeholders remain the Public and S&T Advisory Bodies, although their order is also reversed. The normalized method significantly increases the relative importance of Defense and significantly decreases the relative importance of Commercial Data Users and the Media compared to the original rankings. The normalized method slightly increases the rankings of International Partners, Commercial Industry, Educators, and Federal Agencies. There is no change in the ranking of NGOs.

One of the notable differences between the two methods is that the Stakeholder Importance scores in Figure 46 show a ten-fold difference in score between the highest scoring stakeholder (NASA/NOAA) and the lowest (Agencies). Whereas, using the Normalized Stakeholder Importance scores in Figure 47, there is only a two-fold difference between NASA/NOAA and the lowest scoring stakeholder (Media). This indicates that using the original Stakeholder Importance method, roughly 80% of the difference between the highest and lowest scoring stakeholders is due to the *number* of value flows passing through each stakeholder; and roughly 20% of the difference is due to the *scores* of the value loops passing through each stakeholder.

Both methods clearly show that the top five stakeholders are NASA/NOAA, Scientists, the Government, the Public, and S&T Advisory Bodies. With the exception of S&T Advisory bodies, these top stakeholders represent the four categories included in the Level 1 stakeholder map shown previously in Figure 12.

The results from the value loop analysis described above differ significantly from a more traditional type of analysis that considers only direct transactions between NASA/NOAA and each other stakeholder. As described previously in 1.6.1, Freeman's stakeholder network considers only the direct links between the central stakeholder and each other stakeholder (Freeman 1984). Figure 48 below shows the stakeholder importance rankings that would be produced by applying the stakeholder occurrence calculation to Freeman's stakeholder map.

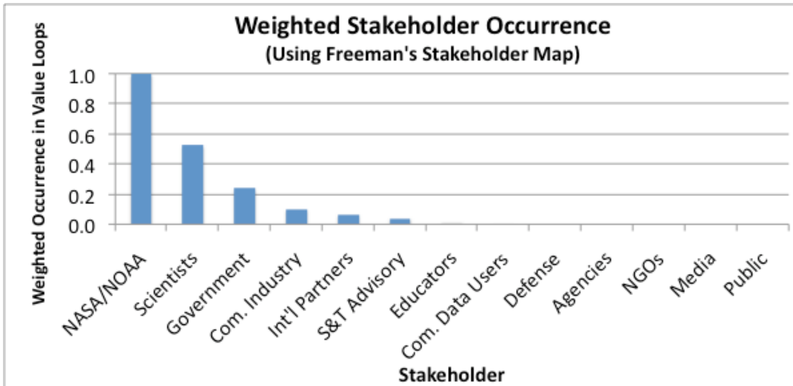


Figure 48. Stakeholder importance using Freeman's stakeholder modeling technique

Freeman's stakeholder model yields NASA/NOAA, Scientists, and the Government as the top three stakeholders. Commercial Industry and International Partners score third and fourth, however neither of these two stakeholders appears in the top five stakeholder rankings using the value loop method. Most notably, the Public receives a score of 0.0 using Cleland's model, yet the decadal survey identified the Public as one of the most important stakeholders to consider! This occurs because the stakeholder value network model does not contain any direct links from the Public to NASA/NOAA; instead, the Public provides opinions and support to the Government, which provides policy direction and funding to NASA/NOAA.

Stakeholder models such Freeman's, which contain only direct transactions between a central stakeholder and all other stakeholders, are insufficient at capturing benefits that occur through value chains involving three or more stakeholders. The method presented in this thesis incorporates all the indirect transactions and provides a more comprehensive assessment of the most important stakeholders in the network.

4.2 Most Significant Value Flows

This section describes the analysis conducted to identify the most significant value flows within the stakeholder value network. The most significant value flows are those that occur most often in the full set of value loops, weighted by the score of each value loop. These are the key value flows created by the Earth Observations Program, and they help deliver the most value throughout the stakeholder network.

To find the most significant value flows, I calculated the weighted occurrence score for each value flow using the same technique used to calculate stakeholder importance above. Each time a value flow appears in a value loop, the score for that loop is added to the value flow's total.

Figure 49 below shows the top 30 most significant value flows using this method. The numeric scores for each value flow are listed in Appendix F. Note that the value flows designated with (all) represent the sum of all six science categories for that particular value flow.

Weighted Value Flow Occurrence = *Sum of all value loops containing value flow*

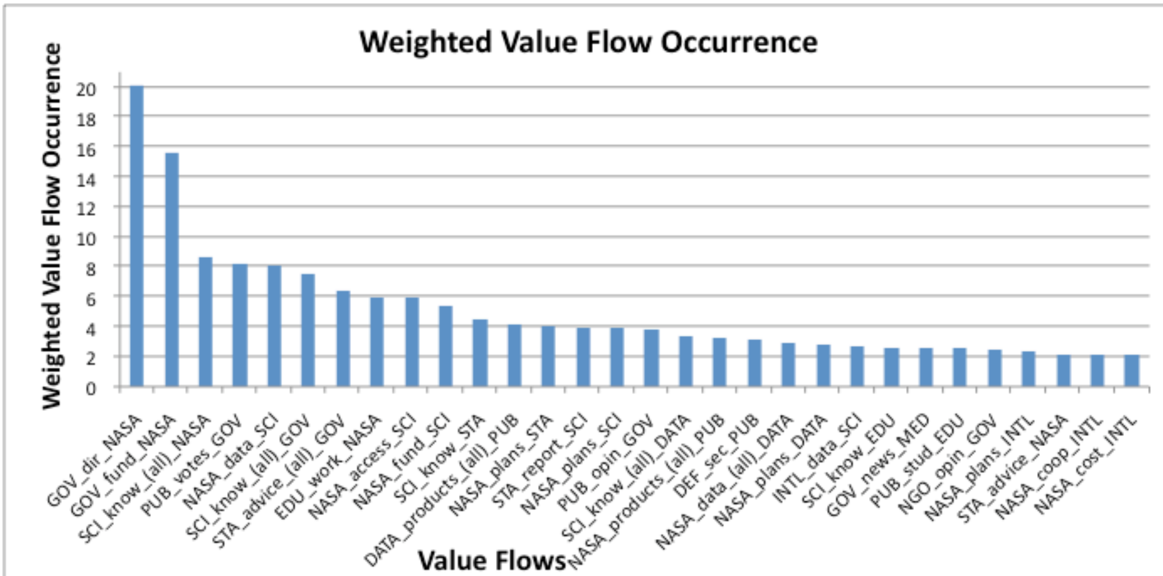


Figure 49. Top 30 most significant value flows

By far the most significant value flows are policy direction and funding from the Government to NASA/NOAA—64% of all the value loops in the model terminate with these two value flows. The flow of science data from NASA/NOAA to Scientists, which is NASA/NOAA's primary output and the focus of much the effort of the decadal survey, ranks third using this calculation method. The fourth most significant value flow is "votes" from the Public to the Government, which further reinforces the position of the Public in the top tier of stakeholders.

It is also useful to view the top value flows on the Level 2 stakeholder map, as shown below in Figure 50. This diagram provides a visualization of the most significant value flows and provides another technique for identifying important stakeholders.

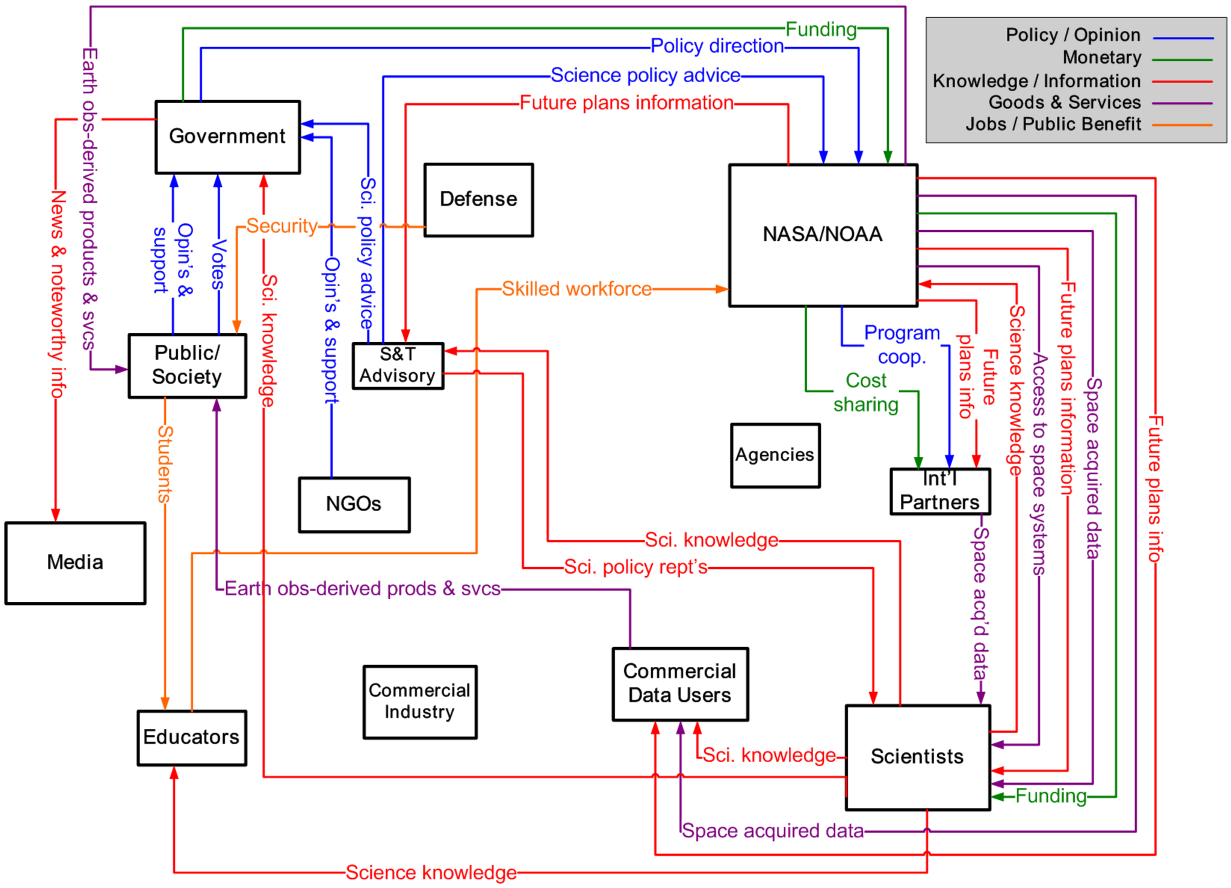


Figure 50. Stakeholder map showing top 30 value flows

To summarize Figure 50, the top value flows involve the following:

- Resources and information between NASA/NOAA and Scientists
- Program cooperation and cost sharing from NASA/NOAA to International Partners
- Space acquired data from NASA/NOAA and International Partners to Scientists and Commercial Data Users
- Science knowledge and content from Scientists to NASA/NOAA, the Government, S&T Advisory Bodies, Commercial Data Users, and Educators
- Earth observations-related products & services from NASA/NOAA and Commercial Data Users to the Public
- Science policy advice from S&T Advisory Bodies to NASA/NOAA, the Government, and Scientists
- Opinions and votes from the Public to the Government
- Students from the Public to Educators
- Skilled workforce from Educators to NASA/NOAA

In Figure 50, NASA/NOAA, Scientists, the Government, and the Public have the greatest number of value flow connections. S&T Advisory Bodies and Commercial Data Users also play important roles in the delivery of value throughout the network. Educators and International Partners play limited but important roles. Specifically, International Partners can provide space-acquired data to Scientists through program cooperation and cost sharing with NASA/NOAA. This could be an increasingly important strategy for NASA/NOAA as it tries to execute the recommendations of the decadal survey with limited budget and resources. Both the Media and NGOs have single value flow connections that are not a part of any closed value loops. This indicates that these particular value flows, while individually high-scoring, may belong to weaker value loops.

After examining the most significant value flows, it is useful to examine the most significant value loops to check for similarities and differences between the top value flows and the top value loops.

4.3 Most Significant Value Loops

This section describes the analysis conducted to identify the most significant value loops within the stakeholder value network. Identifying the important value loops provides another method for identifying the important value flows within the stakeholder network. It also provides an indication of the value loops that return the most value back to NASA/NOAA, which the stakeholder and value flow analyses described above do not provide.

I ranked the complete set of 1880 value loops according to their value loop scores. Figure 51 through Figure 60 below show the top 40 value loops pictorially, with the value loop scores indicated next to each loop. The value loops have been grouped according to the first value flow appearing in each value loop. Note that in the diagrams below, value flows appearing in brackets represent science-related value flows from the respective science categories.

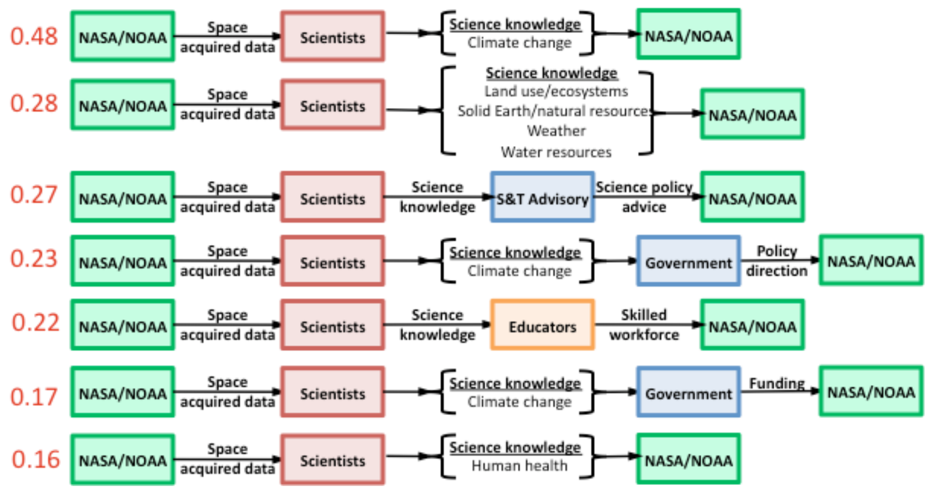


Figure 51. Top-scoring value loops beginning with "space-acquired data" to Scientists

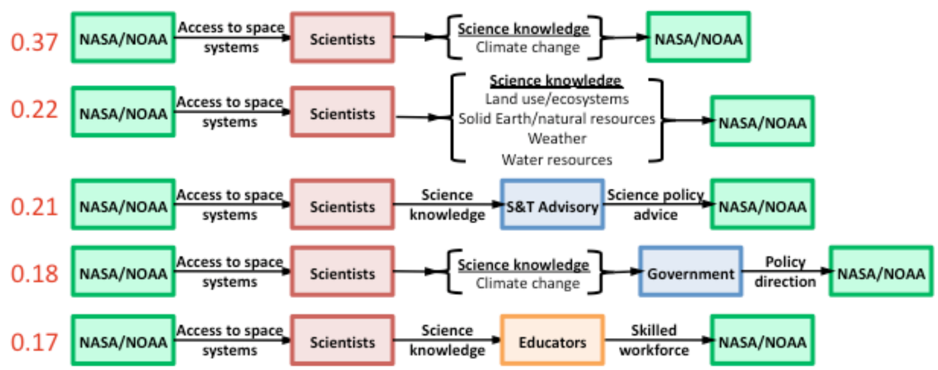


Figure 52. Top-scoring value loops beginning with "access to space systems" to Scientists

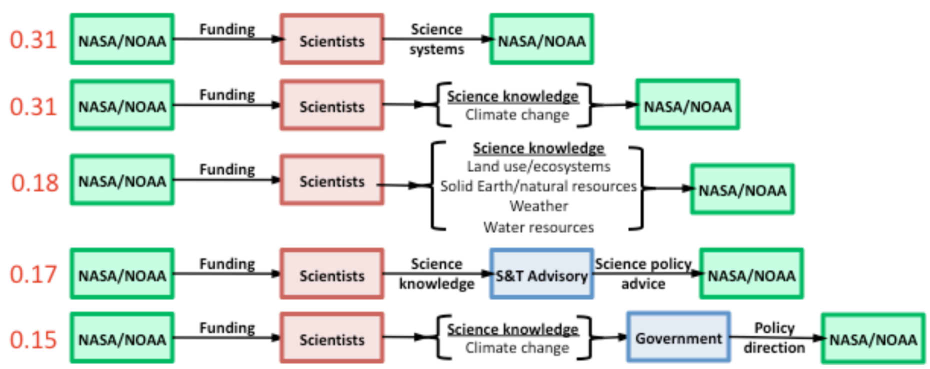


Figure 53. Top-scoring value loops beginning with "funding" to Scientists

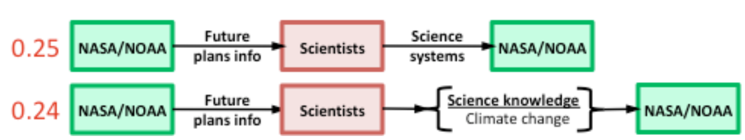


Figure 54. Top-scoring value loops beginning with "future plans information" to Scientists

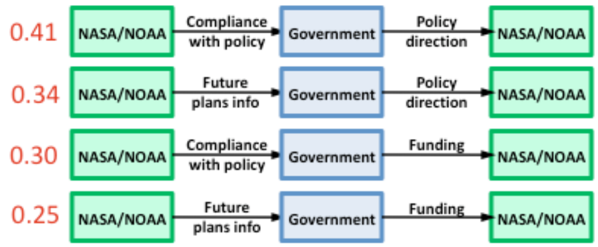


Figure 55. Top-scoring value loops beginning with "compliance with policy" or "future plans information" to the Government

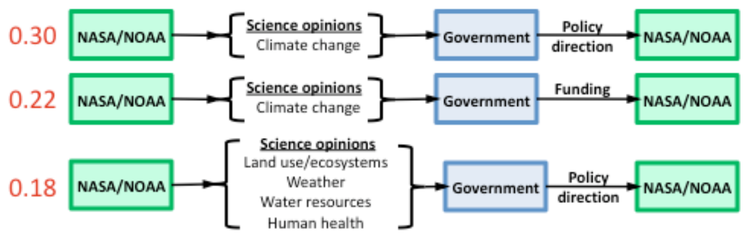


Figure 56. Top-scoring value loops beginning with "science opinions" to the Government

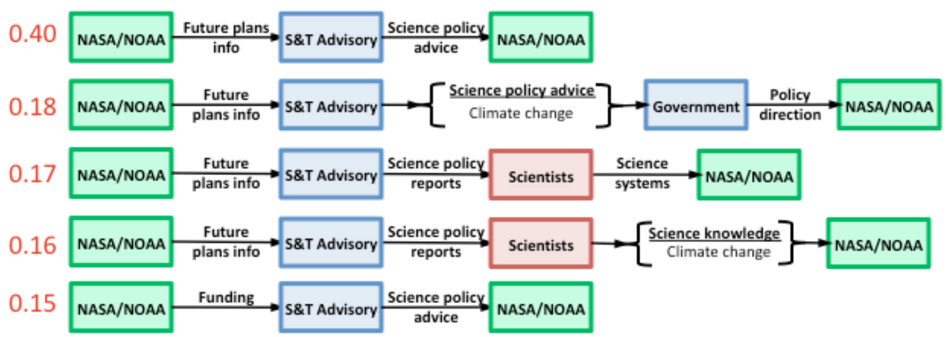


Figure 57. Top-scoring value loops beginning with "future plans information" or "funding" to S&T Advisory Bodies

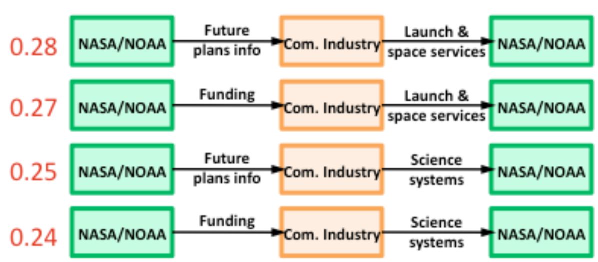


Figure 58. Top-scoring value loops beginning with "future plans information" or "funding" to Commercial Industry

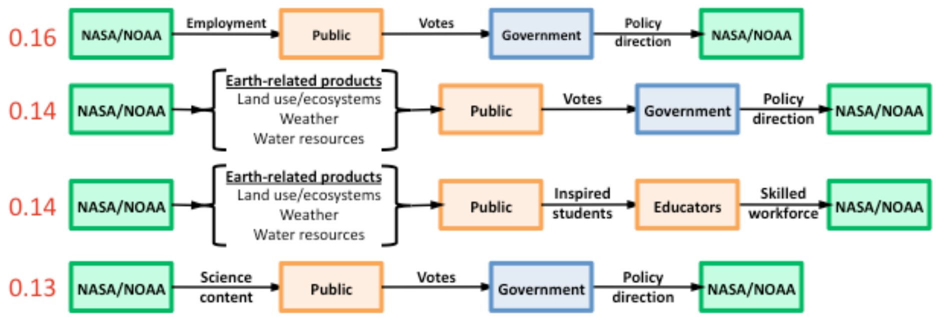


Figure 59. Top-scoring value loops beginning with "employment," "Earth observations-derived products & services," or "science content" to the Public

Figure 60. Top-scoring value loop beginning with "educational material" to Educators

Another way to examine the top value loops is to overly the value flows contained in the top loops onto the Level 2 stakeholder map, shown in Figure 61 below. This can provide a better visualization of the actual flow of value throughout the stakeholder network. Due to the large number of direct loops in the model, 30 of the top 40 value loops are direct loops. Each direct value loop contains only NASA/NOAA and one other stakeholder. Because of this, the top 40 value loops do not contain many stakeholders with indirect connections to NASA/NOAA, such as the Public. Therefore, to capture some of the important longer value loops, I identified both the top 40 direct and top 40 indirect value loops. The value flows comprising these top value loops are shown in the figure below.

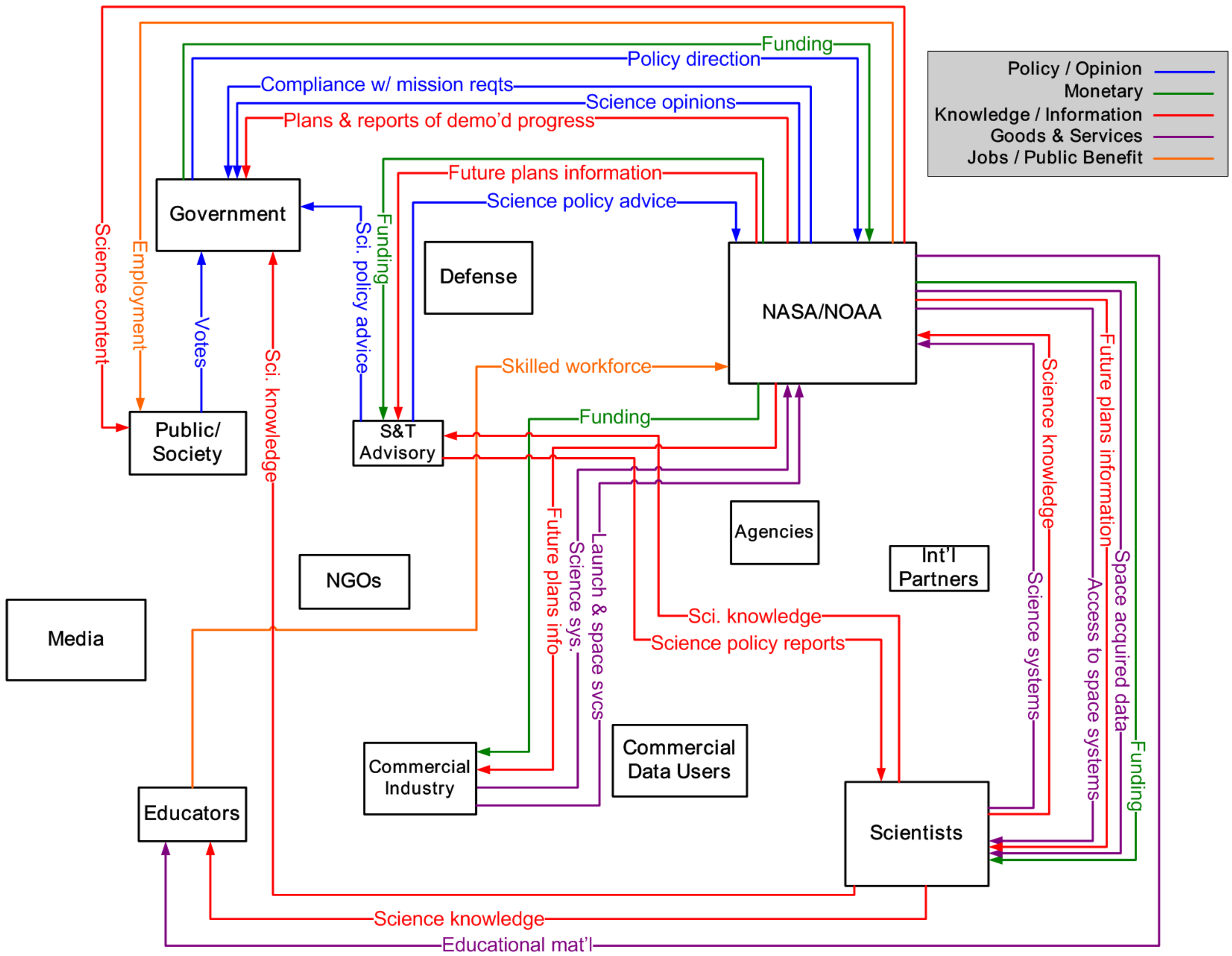


Figure 61. Value flows comprising top 40 direct and top 40 indirect value loops

To summarize Figure 61, the top value loops involve primarily the following:

- Resources and space acquired data from NASA/NOAA to Scientists
- Science knowledge from Scientists to NASA/NOAA, the Government, Educators, and S&T Advisory Bodies
- Science content from NASA/NOAA to the Public, the Government, and Educators
- Science policy advice from S&T Advisory Bodies to NASA/NOAA, the Government, and Scientists
- Funding and future plans information from NASA/NOAA to Commercial Industry
- Science systems and launch services from Commercial Industry to NASA/NOAA
- Skilled workforce from Educators to NASA/NOAA
- Employment from NASA/NOAA to the Public
- Votes from the Public to the Government

In Figure 61 above, NASA/NOAA, Scientists, the Government, and S&T Advisory Bodies have the greatest number of value loop connections. The Public, Commercial Industry, and

Educators play more limited but important roles. Notably, Commercial Industry did not appear in the list of top value flows from the previous section, and Commercial Data Users do not appear in the list of top value loops in this section. The value loop analysis indicates that Commercial Industry can provide highly valued launch services to NASA/NOAA. This is one of the key concerns currently facing NASA due to the potential retirement of the Delta II medium-lift launch vehicle (Pasztor 2007). The remaining six stakeholders in the model are not included in any of the top value loops.

One notable absence from the list of top value loops and value flows is the flow of "health, safety, & environmental protection" from the Government to the Public. We expected this value flow to have a high importance since it includes the policies that would be enacted to deal with climate change, an issue of heightened national importance. This value flow does not appear in the top list due to the structure of the model—each stakeholder may only appear once in a value loop. If a value loop flows through the Government, followed by the Public, (i.e. "health safety, & environmental protection" from the Government to the Public), there are no other paths back to NASA/NOAA other than through the Government. Therefore, the "health, safety, & environmental protection" value flow would form a recursive loop between the Government and the Public, as shown below in Figure 62. However, the Government relies on science knowledge and science opinions from Scientists, S&T Advisory Bodies, and NASA/NOAA in order to craft legislation and regulations related to health, safety, and environmental protection. Therefore, the importance of the "health, safety, & environmental protection" value flow is captured implicitly in the scores assigned to the "science knowledge" and "science opinion" value flows into the Government.

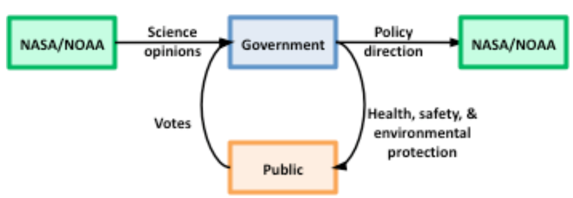


Figure 62. Recursive value loop created by "health, safety, & environmental protection" value flow

The information regarding the top-scoring value loops can be combined with information regarding the top NASA/NOAA outputs, discussed later in Section 4.5, to provide program-level recommendations for the Earth Observations Program. These recommendations are presented later in Section 5.2. In the following section, I combined the information from the analyses of the most important stakeholders, value flows, and value loops to construct a simplified stakeholder model.

4.4 Simplified Stakeholder Model

The complete stakeholder value flow map in Figure 19, which shows all 13 stakeholders and 190 value flows, is enormously complex. While it adequately demonstrates the complexity and completeness of the model, the diagram displays too much information, especially for project managers and policy-makers who are unfamiliar with our stakeholder modeling methodology. A diagram showing only the most important stakeholders and value flows would provide a more comprehensible view of the stakeholder network and would serve as a much more useful reference tool.

To produce the simplified stakeholder model, shown in Figure 63 below, I combined the information yielded from the analyses of the most important stakeholders, value flows, and value loops as described in the previous sections. I used a somewhat subjective approach to create the simplified model: Stakeholders and value flows that appeared consistently across the three analyses were included in the simplified model. I added additional stakeholders and value flows if they played a significant role in at least one of the three analyses. Certain stakeholders and value flows were deleted if their presence was minor or inconsistent across the three analyses.

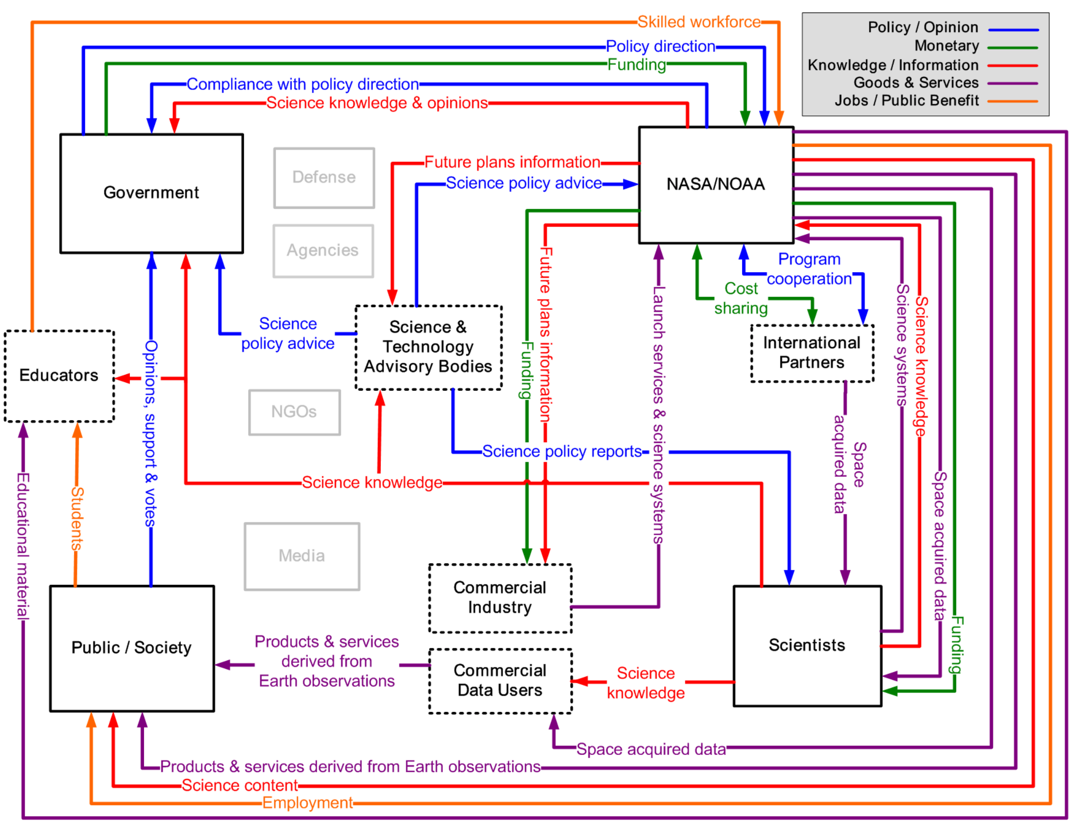


Figure 63. Simplified stakeholder model

Another way to visualize the simplified stakeholder model is to vary the thickness of each value flow line according to its relative importance in the model. Figure 64 below shows the simplified stakeholder model with the thickness of each value flow proportional to its weighted occurrence score, as calculated previously in Section 4.2.

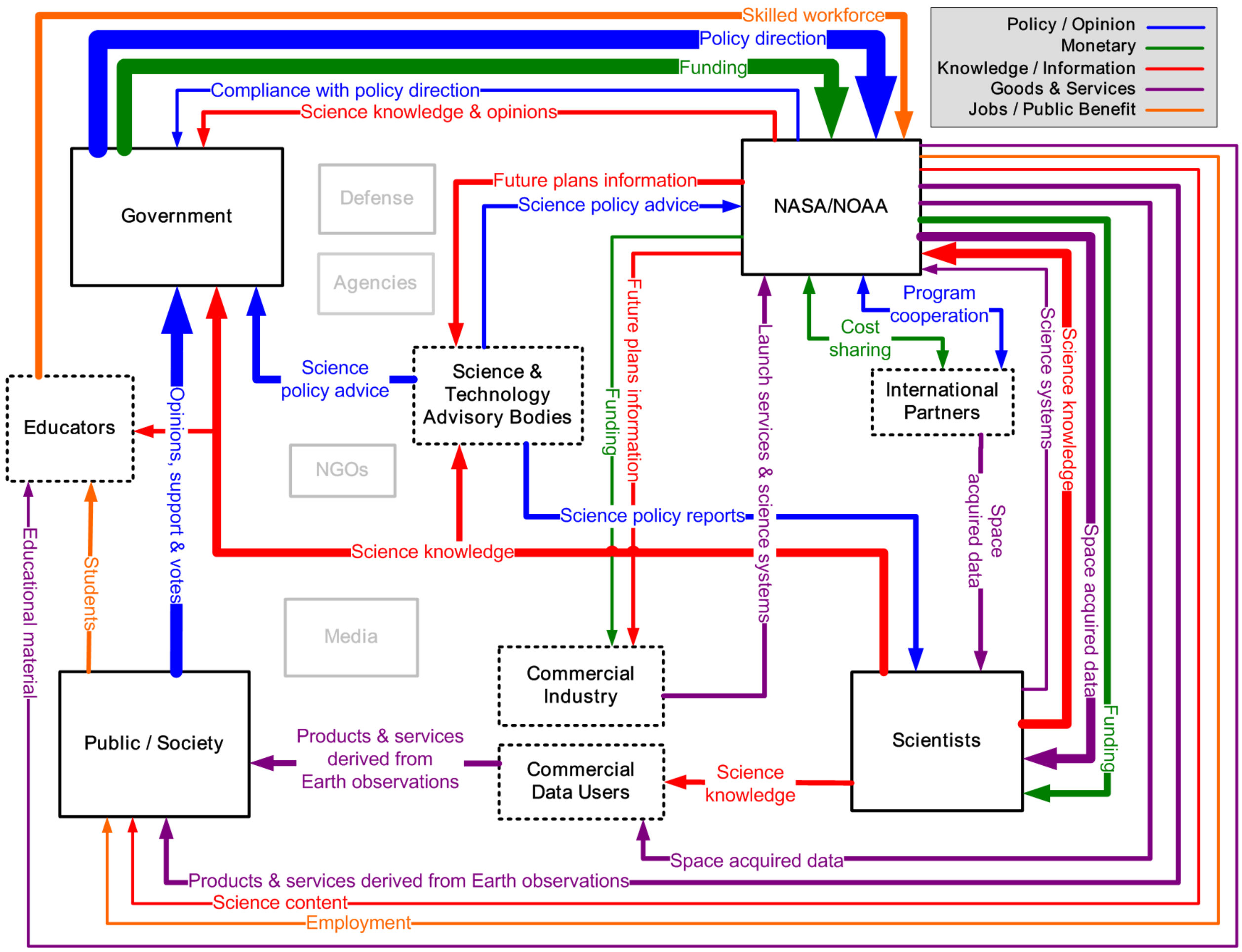


Figure 64. Simplified stakeholder map showing relative importance of each value flow

The first tier of stakeholders, indicated with solid black lines in Figure 64, includes NASA/NOAA, Scientists, the Public, and the Government. These four stakeholders and the value flows among them appeared consistently across the three analyses. These stakeholders also represent the four quadrants of the Level 1 stakeholder map shown previously in Figure 12.

The second tier of stakeholders, indicated with dashed lines in Figure 64, includes S&T Advisory Bodies, International Partners, Commercial Data Users, Educators, and Commercial Industry. Of these five stakeholders, S&T Advisory Bodies are the most important based on the analyses conducted in the previous sections. This is reflective of the deference with which NASA, NOAA, the Executive and Congress treat the decadal survey, and of the importance of the advisory process performed by the National Academies and other science- and technology-focused advisory bodies. The other four Tier 2 stakeholders are not absolutely critical to the success of the Earth Observations Program, but they each contribute to important value chains that provide high-value resources that can greatly enhance the program's success. International Partners have the capacity to provide program cooperation and cost sharing to NASA/NOAA and space acquired data to Scientists. As the decadal survey mentions, this could alleviate the need for certain missions or significantly reduce the cost to NASA and NOAA of obtaining space-acquired data. Commercial Data Users use the space-acquired data from NASA/NOAA and the knowledge from Scientists to provide Earth observations-related products and services to the Public. These include services such as weather forecasts and land-imaging products such as Google Earth and Microsoft Virtual Earth. This is discussed further in Section 4.7. Educators provide a skilled and motivated workforce, which is a key asset for NASA/NOAA to maintain its leadership position in Earth observations. Commercial Industry is the weakest of the Tier 2 stakeholders, having appeared inconsistently in the stakeholder, value flow, and value loop analyses. However, in addition to providing science systems, Commercial Industry has the capacity to provide launch services to NASA/NOAA, another key asset for the Earth Observations Program. Because of the previously mentioned uncertainty of the future of the Delta II launch vehicle, I decided to place Commercial Industry in the second tier rather than the third tier.

Finally, the third tier of stakeholders includes the Media, Defense, Federal Agencies, and NGOs. While these four stakeholders do contribute some value to the program, their overall importance to the Earth Observations Program is minimal and they should receive a lower priority than stakeholders in the first and second tiers. One of the notable differences between the NASA/NOAA Earth Observations Program and the NASA Exploration Programs is the importance of the Media. In Cameron's analysis of the Exploration Program, the Media was one of the more important stakeholders. This is because much of the value created by the Exploration Program is delivered by the Media to the Public, through photo and video imagery. In the Earth Observations Program, however, much of the value of the program is delivered through science knowledge to the Government and Earth observations-related product and services to the Public. Neither of these outputs involve value flows through the Media. While the Media does provide sensational news reports regarding weather and climate change, these are not among the high-scoring value flows within the stakeholder value network.

Section 5.1.1 provides a brief overview of the generalized role of each stakeholder in the simplified model presented in this section.

4.5 Most Significant NASA/NOAA Outputs

Another useful exercise using the value loop results is to determine the most significant outputs from NASA/NOAA and inputs to NASA/NOAA. This information can be used to establish priorities for the Earth Observations Program by aligning the outputs of NASA/NOAA with those that the analysis indicates will create the most value throughout the stakeholder network. This section presents the most significant NASA/NOAA outputs, and the following section presents the most significant inputs.

Figure 65 below shows the most significant NASA/NOAA outputs. The numeric scores for each NASA/NOAA output are listed in Appendix F. I computed the scores for each output using the weighted occurrence technique—each output's score corresponds to the sum of all value loops that begin with that output. The model contains 67 outputs from NASA/NOAA, and the top 25 outputs are shown in the figure below. The most significant outputs can be interpreted as the outputs that have the greatest potential for producing value within the stakeholder network. Since each value loop ends with NASA/NOAA, these outputs also provide an indication of how NASA/NOAA should align its outputs to create the strongest feedback loops to its own inputs.

Weighted NASA/NOAA Output Occurrence = *Sum of all value loops beginning with NASA/NOAA output*

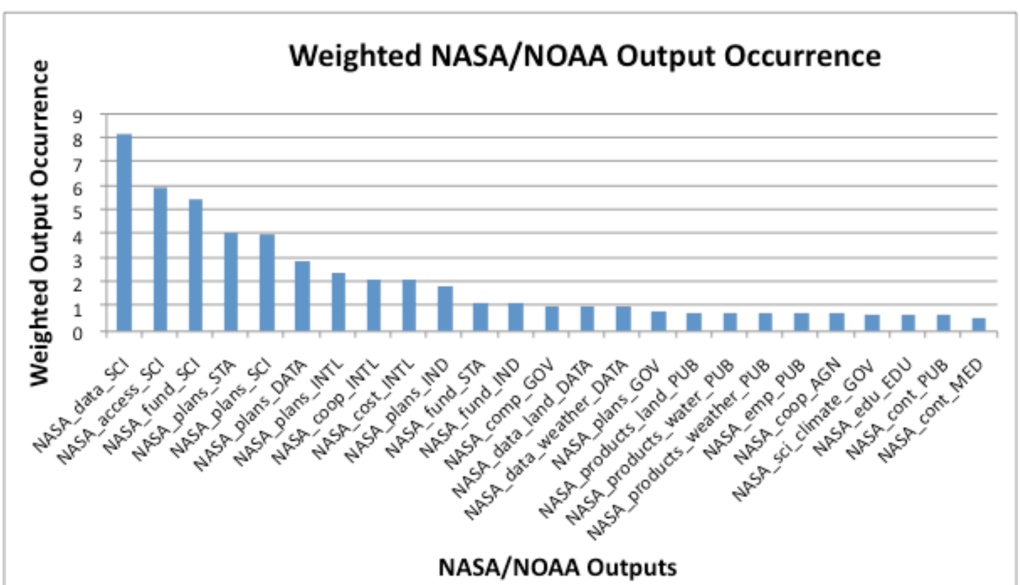


Figure 65. Most significant NASA/NOAA outputs

In general, the list of the most important NASA/NOAA outputs is intuitive, but there are a few notable surprises. The highest scoring outputs are science data, access to science system, and funding to Scientists. Following these are future plans information flows to S&T Advisory Bodies, Scientists, and Commercial Data Providers. The appearance of Commercial Data Providers here was somewhat surprising, but consistent with the earlier value loop analysis.

The next three flows are future plans information, program cooperation, and cost sharing between NASA/NOAA and International Partners. This was also somewhat of a surprise, although consistent with the earlier value flow analysis. This underscores the potential value that cooperation with International Partners can bring to the Earth Observations Program.

Following the International Partner outputs are the future plans information and funding outputs to Commercial Industry. Like the earlier value loop analysis, this underscores the potential value that launch services from Commercial Industry can provide to NASA/NOAA.

Among the next few value flows are compliance with policy direction and future plans information to the Government. Between these outputs are the land- and weather-related science data flows to Commercial Data Users. Again, it was somewhat surprising for the outputs to Commercial Data Users to score among the top 25 outputs, but this highlights the potential for Commercial Data Users to create new products, services, and markets for NASA/NOAA space-acquired data—all of which provide strong feedback loops back to NASA/NOAA.

The next four outputs in Figure 65 are Earth observations-related products and services and employment to the Public. Given the emphasis placed on societal benefits in the decadal survey, we expected to see direct outputs to the Public in the list of top NASA/NOAA outputs. This reinforces one of the primary messages of the decadal survey: The Earth Observations Program must consider societal benefits as well as scientific benefits when designing and prioritizing future missions.

Following the outputs to the Public is cooperation with Federal Agencies. The relative ranking of this output with the higher-scoring International Partner outputs further confirms the previous analyses that shows that NASA/NOAA should prioritize cooperation with International Partners over cooperation with other Federal Agencies.

Perhaps the biggest surprise was the next value flow—climate-related science knowledge from NASA/NOAA to the Government, which ranks 22nd in the list. We expected this to be one of the top ten outputs of NASA/NOAA. However, as Figure 64 above shows, science knowledge from Scientists and science policy advice from S&T Advisory Bodies provide greater value to the Government than science knowledge from NASA/NOAA.

The final three outputs in the top 25 list are educational material to Educators and science content to the Public and the Media. The analysis of the top value loops in Section 4.3 showed that the other important inputs to Educators are science knowledge from Scientists and inspired students from the Public. This means that to seriously engage the Educators, NASA/NOAA should also work closely with Scientists to develop appropriate educational science content. The analyses also indicate that the high-value NASA/NOAA outputs to the Public are goods & services value flows, rather than information value flows (e.g. science knowledge). Finally, as previously discussed, due to the nature of the beneficial outputs of the Earth Observations Program, the Media plays a relatively limited role in the stakeholder network.

The top 25 NASA/NOAA outputs contain only one value flow to Federal Agencies and none to Defense or NGOs. The lack of important outputs to Federal Agencies contradicts some of the recommendations of the decadal survey. The decadal survey recommends that NASA/NOAA increase cooperation with both International Partners and other Federal Agencies. This analysis, however, indicates that investing resources to cooperate with Agencies will not provide as many strong feedback loops as would cooperation with International Partners.

The lack of important outputs to Defense was surprising, given that both NASA/NOAA and Defense have significant Earth Observations Programs. However, after the interview with the former Secretary of the Air Force (Widnall 2008), it became clear that cooperation between NASA and the Department of Defense historically has been limited. This is in part due to cultural differences between the two organizations, and because the objectives of NASA and the Department of Defense are significantly different.

The lack of outputs to the NGOs is consistent with the previous value flow and value loop analyses, all of which indicate that NGOs play only a minor role in the stakeholder value network.

By combining the information regarding NASA/NOAA's most important outputs with the information about the top-scoring value loops, I created a prioritized list of program goals for the NASA/NOAA Earth Observations Program. These program goals are presented in Section 5.2.

In summary, the analysis of the most significant NASA/NOAA outputs indicates that NASA/NOAA should prioritize its outputs in approximately this order:

1. Data and resources to Scientists
2. Future plans information and funding to S&T Advisory Bodies
3. Program cooperation and cost-sharing with International Partners
4. Future plans information and funding to Commercial Industry
5. Compliance with policy and future plans information to the Government
6. Data and future plans information to Commercial Data Users
7. Earth observations-related products & services and employment to the Public

These priorities provide the foundation for the program-level recommendations provided in Section 5.2.

4.6 Most Significant NASA/NOAA Inputs

The previous section examined the most significant outputs from NASA/NOAA. This section describes the analysis conducted to determine the most significant inputs to NASA/NOAA.

To find the most significant inputs, I used the weighted occurrence method—each input's score represents the sum of all value loops that end with that input. Figure 66 below shows the most significant NASA/NOAA inputs. The numeric scores for each NASA/NOAA input are listed in Appendix F. The model contains 26 inputs to NASA/NOAA, all of which are shown in the figure below. The most significant inputs can be interpreted as the top "affectable" inputs to NASA/NOAA. If NASA/NOAA increased all its outputs by one unit, the weighted input occurrence is the amount each input to NASA/NOAA would increase. Therefore, the ranking of the inputs provides an indication of NASA/NOAA's ability to affect each input. Note that in the diagram, I separated the first three inputs because their weighted occurrence scores were an order of magnitude higher than the others.

Weighted NASA/NOAA Input Occurrence = *Sum of all value loops ending with NASA/NOAA input*

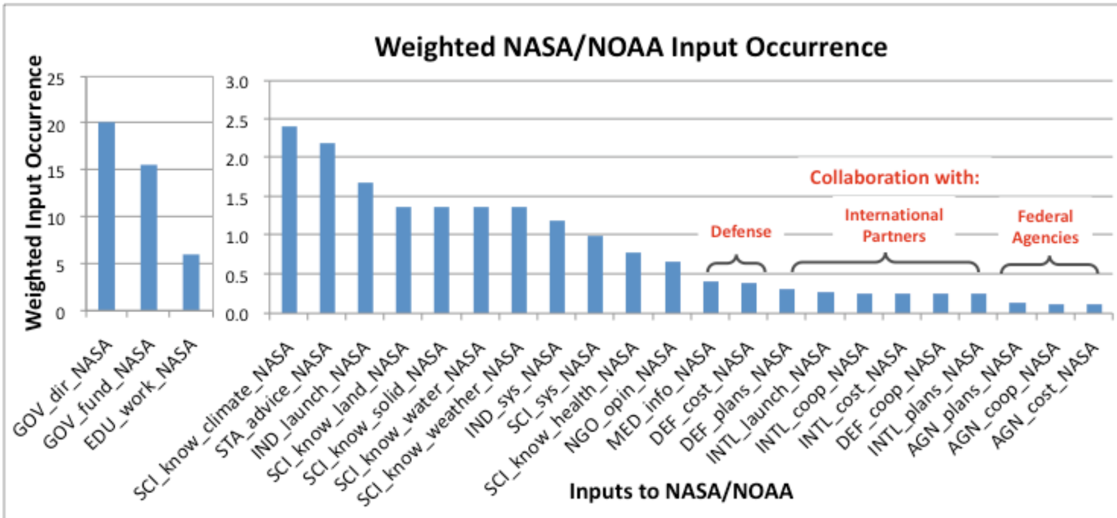


Figure 66. Most significant NASA/NOAA inputs

Not surprisingly, the most significant input is policy direction from the Government. Funding from the Government is the second most significant input, which may initially seem surprising. Recall though that the funding score is not an indication the level of funding NASA/NOAA receives; rather, it indicates that NASA/NOAA has a greater ability to affect its level of funding than most of the other inputs.

Also surprisingly, the third top input is skilled & motivated workforce from Educators. Although Educators were not included in the first tier of stakeholders in the simplified stakeholder model shown in Figure 64, Educators participate in a large number of value loops and reap many of the rewards from NASA/NOAA's outputs. In fact, the National Research Council recently issued a report reviewing and providing recommendations for NASA's elementary and secondary education program (National Research Council 2008).

The next several inputs are science knowledge from Scientists (from five of the six science categories), science policy advice from S&T Advisory Bodies, and launch services from Commercial Industry. This is consistent with the results presented earlier.

The last four significant inputs are science systems from Commercial Industry and Scientists, human health science knowledge from Scientists, and opinions from NGOs. This is only the second time the NGOs have appeared in the analysis—the first was providing opinions and support to the Government, shown previously in Figure 50. The input ranking is unsurprising though, given that there is no shortage of interest groups and other organizations offering their opinions to NASA.

The remaining inputs, which the analysis indicates are the most "unaffectable" by NASA/NOAA, are collaborative and cost-sharing inputs from Defense, International Partners, and Federal Agencies. This suggests that is inherently difficult for NASA/NOAA to achieve significant collaboration with these stakeholders, even with a renewed focus on increasing collaboration as the decadal survey recommends. This is consistent with the analyses from the previous sections, and I discuss this finding further in Chapter 5.

Another way to analyze the value flow inputs to NASA/NOAA is to compare the weighted occurrence of each input to the value flow scores assigned to each input. This provides an approximate indication of the difference between what NASA/NOAA needs and what NASA/NOAA actually receives. Figure 67 below shows the difference between the normalized weighted occurrence and the normalized value flow scores for each NASA/NOAA value flow input. I normalized the weighted occurrences and value flow scores such that the sum of all value flow inputs equals one. I excluded the top three value flow inputs (policy direction and funding from the Government, and skilled workforce from Educators) from this analysis because their weighted occurrence was an order of magnitude above all the others. The value flows are ranked from left to right according to the difference between the weighted occurrence and the weighted value flow score.

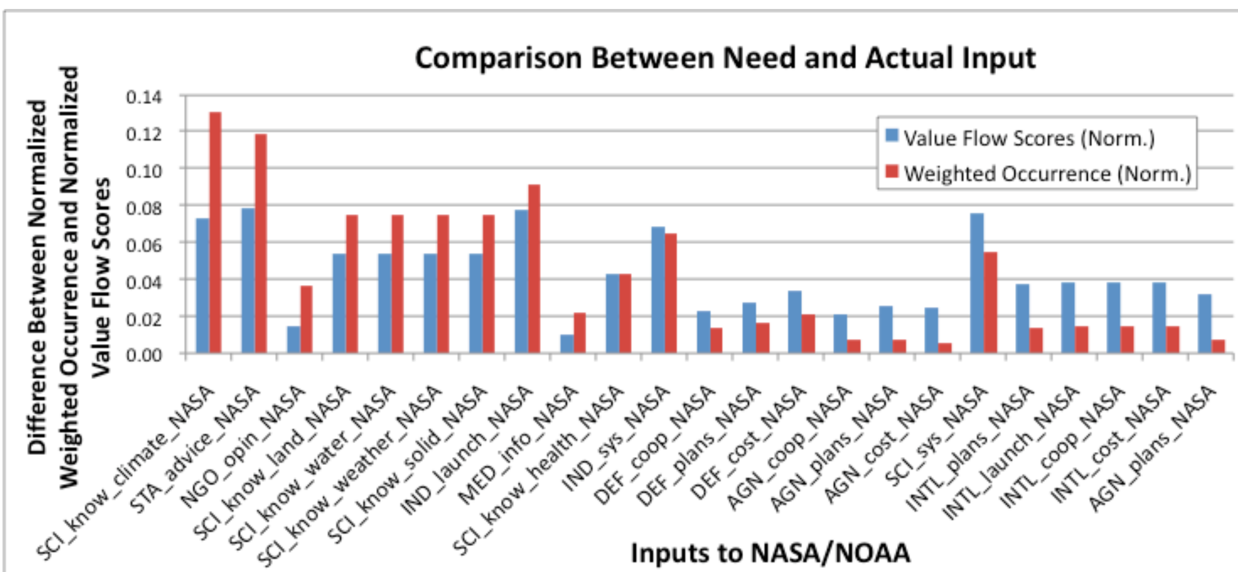


Figure 67. Comparison between weighted occurrence and value flow scores for NASA/NOAA inputs

The chart in Figure 67 can be interpreted as follows: NASA/NOAA receives an adequate amount of the value flows along the left side of the chart (where the height of the red line is equal to or greater than the blue line). Conversely, NASA/NOAA receives less value than it needs from the value flows along the right side of the chart (where the height of the red line is less than the blue line). In general, the most inadequate value flows involve cost sharing and program cooperation with International Partners, Federal Agencies, and Defense. This is consistent with the previous analyses in this chapter that suggest that NASA/NOAA should improve and prioritize its cooperative efforts with International Partners. These findings are discussed further in Chapter 5.

4.7 Most Important Science Categories

This section describes the analysis conducted to rank the relative importance of each of the six science categories from the decadal survey.

One of the difficult tasks achieved by the decadal survey was establishing priorities among the missions suggested by the six science-themed panels. As previously discussed, each decadal survey panel used a group consensus process to establish a set of recommended missions for its science category. In total, the six science-themed panels recommended 31 missions, which the decadal survey committee combined into 17 by compromising on instruments or spacecraft operational characteristics and developing synergistic missions that satisfied multiple panels (Hager 2007).

The decadal survey does not provide explicit guidance on how the committee prioritized the six science categories other than to recommend that the Earth Observations Program should seek “to achieve and maintain balance in a number of thematic areas in order to support the broad range of demands on Earth information.” In fact, the committee generally prioritized missions by placing technologically-ready and less expensive missions earlier in the sequence of implementation (National Research Council 2007).

Our research group needed a method for prioritizing the science categories for the concurrent system architecture model developed by Justin Colson (Colson 2008). In his model, Colson implemented a weighted fairness scheme for manifesting each satellite mission, which prioritized new missions from each science category based on the each category’s priority level. Initially, we determined the priorities of each science category using a consensus process.

Before analyzing the value loops, I first determined the science category rankings suggested by NASA’s most recent Science Plan (NASA 2007). A crude analysis of the NASA’s Earth Science research objectives indicates that NASA places the greatest emphasis on understanding climate change; somewhat less emphasis on understanding weather, land use, water resources, and solid Earth; and little to no specific emphasis on human health and security. These relative rankings are indicated in Table 32 below.

Table 32. Ranking of NASA science priorities based on NASA Science policy documents

Science category	Ranking Based on NASA Science Policy Documents
Human health	Low
Land use & ecosystems	Med
Solid Earth hazards & resources	Med
Climate change	**High**
Weather	Med
Water resources	Med

Next, I investigated the relative science category rankings suggested by the value loop analysis, as shown below in Figure 68. Like the previous analyses, I calculated the weighted occurrence score for each science category. Each time a value loop contained one or more value flows specific to one of the six science categories, the score for that value loop was added to the science category's total. Because of the rules I established for the value loops, discussed previously in Section 3.4.3, a value loop may contain value flows from only a single science category.

Weighted Science Category Occurrence = *Sum of all value loops containing one or more value flows from each science category*

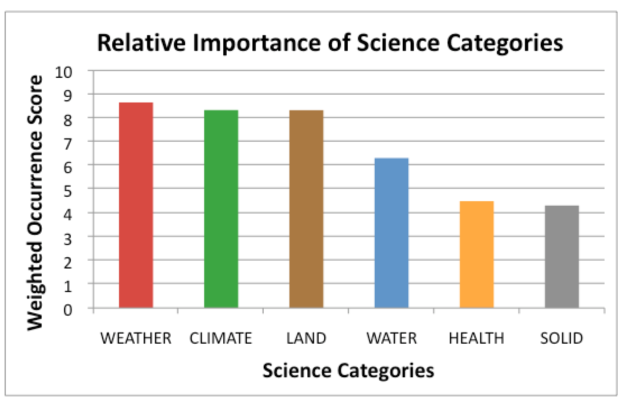


Figure 68. Relative importance of science categories using value loop analysis

Based on these rankings, I assigned a priority to each science category, shown in Table 33 below. Also shown is the comparison to the rankings shown above in Table 32.

Table 33. Comparison of science category rankings from NASA science policy documents and value loop analysis

Science category	Ranking Based on NASA Science Policy Documents	Ranking Based on Value Loop Analysis
Human health	Low	Low
Land use & ecosystems	Med	**High**
Solid Earth hazards & resources	Med	Low
Climate change	**High**	**High**
Weather	Med	**High**
Water resources	Med	Med

The relative ranking of the six science categories according to the value loop analysis was surprising. Given the recent emphasis on climate change, I expected the climate change category to outrank the other five categories. Instead, weather, climate change, and land-use have roughly equal scores, and I assigned a high priority to all three categories. The difference between the scores of these three categories is insignificant given the sensitivity of the model. The water resources category ranks fourth, and I assigned it medium priority. Human health and solid Earth categories rank fifth and sixth, with roughly equal scores, and they received the lowest priority.

Understanding why climate change, weather, and land-use have roughly equal scores requires an in-depth examination of the value loops generated by the model. For this, I constructed three individual stakeholder value flow maps showing the most important value flows created by each science category, shown in Figure 69, Figure 70, and Figure 71 below. The value flows for each category are those flows that comprise the weighted occurrence score for each science category from Figure 68 above. The thickness of each value flow is proportional to the weighted occurrence of the flow within the set of category-specific value loops.

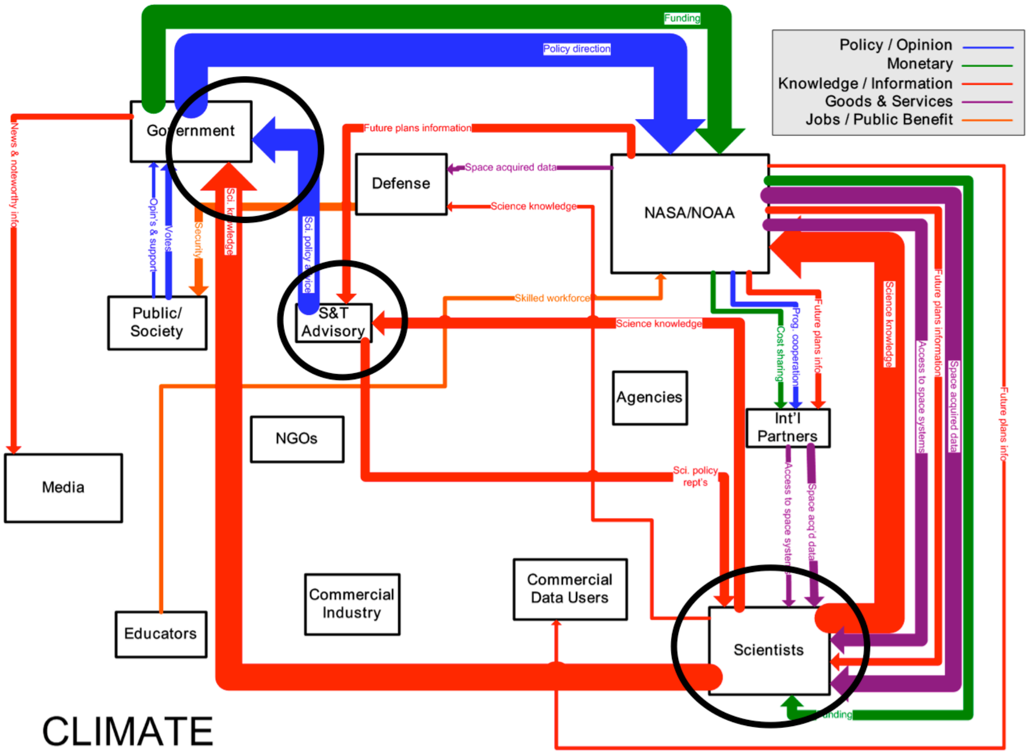


Figure 69. Top value flows created by climate missions

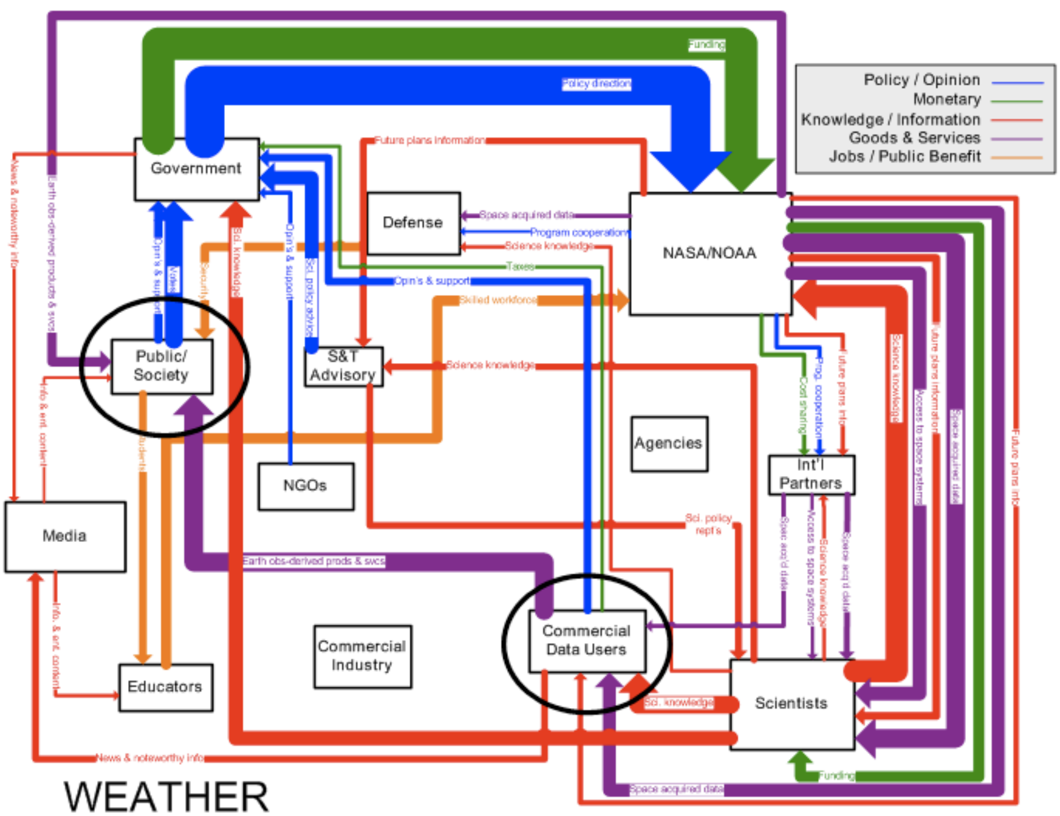


Figure 70. Top value flows created by weather missions

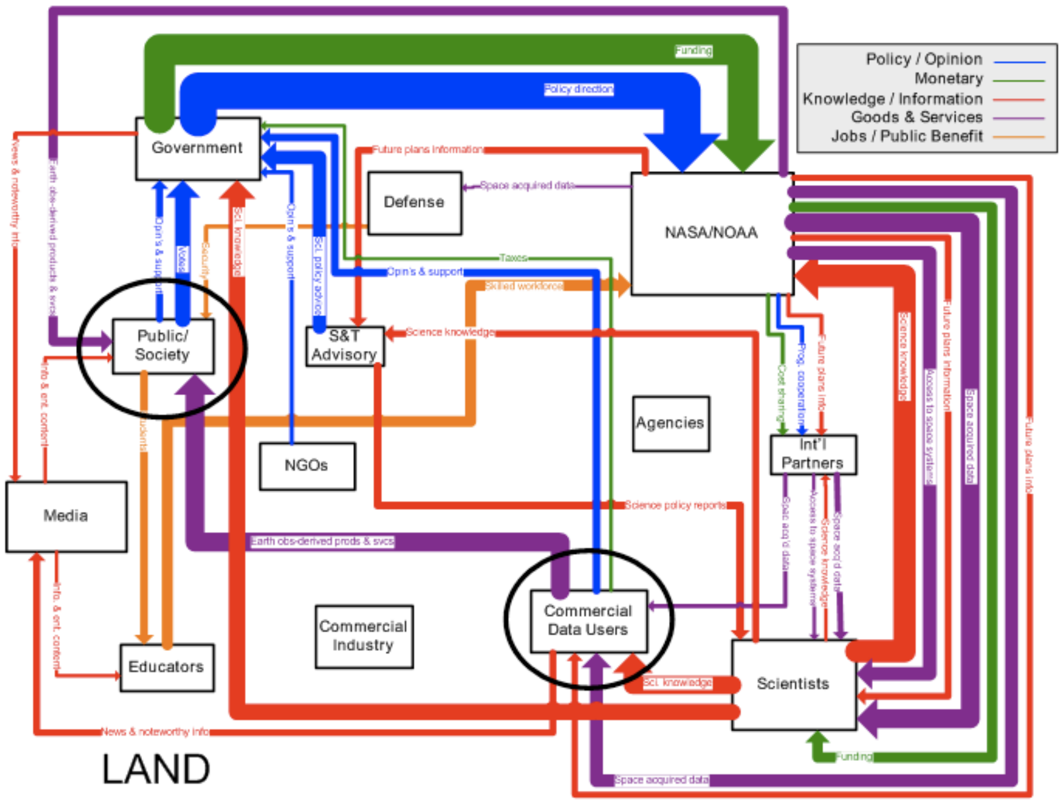


Figure 71. Top value flows created by land-use missions

The climate value flow map in Figure 69 above shows that the most significant value flows (i.e. thicker value flow lines) created by climate change missions are science knowledge from Scientists to NASA/NOAA, the Government, and S&T Advisory Bodies; as well as science policy advice from S&T Advisory bodies to the Government. However, these value flows are not as strong in the weather and land-use maps. Figure 70 and Figure 71 above show that weather and land-use missions "activate" the Commercial Data Users and Public much more than the climate missions. Weather and land-use missions create more Earth observations-derived products and services (i.e. thicker purple lines). This model indicates that because of the tremendous commercial value in weather and land-use data, missions from these two categories would produce roughly equivalent amounts of value to the stakeholder network as climate-related missions. Note that most of the value flows out of Commercial Data Users flow to the Public, as indicated in the diagrams above.

These value flow maps suggest that although NASA/NOAA may place a higher value on climate change than the other science categories, weather and land-use missions produce more products and services for the Public, such that NASA/NOAA should prioritize them equally with climate missions. This differs from much of the current consensus that climate missions should receive higher priority than all other science categories.

The analysis also concludes that the human health and solid Earth science categories provide the smallest amount of value to the network. This provides a somewhat objective rationale for assigning low priority to missions from these two categories. While solid Earth information could be useful in helping to predict natural hazards such as earthquakes, there are other more important needs to be fulfilled for the Public and other beneficiaries. Given NASA/NOAA's current lack of sufficient resources for Earth Science, it may be beneficial to assign responsibility for solid Earth missions to another Federal Agency such as the USGS. With regards to human health missions, this falls outside the traditional boundary of NASA's Earth science program. Human health is not specifically mentioned in the list of objectives for NASA's Earth Science Program (NASA 2007).

One noteworthy feature of the value flow maps shown above is that there are no important flows out of the Media in the climate map. This seems to contradict recent trends in the Media in which climate-related stories appear frequently, and climate change is an increasingly important part of the national dialogue. This finding, however, is consistent with the previous analyses that showed that the Media's role in contributing to the highest-scoring value loops within the model is limited. Most of the significant value from the Earth Observations Program is ultimately delivered through science knowledge (involving NASA/NOAA, Scientists, and the Government) and Earth observations-derived products and services (involving NASA/NOAA, Commercial Data Users, and the Public).

Finally, the science category rankings revealed by the value loop analysis provide a more justifiable input to our concurrent system architecture model, rather than using our general consensus as the basis for the science category prioritization. This analysis allows us to couple the results from the stakeholder model with the inputs to the system architecture model, since the science category rankings provide architecturally distinguishing information. Further work can be done to find additional ways to directly link the two models.

The value loop methodology presented here provides a relatively objective means for understanding the value created and delivered by missions within each science category. This information can be used to create a transparent scheme for prioritizing missions based on each mission's science category. As discussed previously, much of the effort in producing the decadal survey involved managing the communication among science communities that had rarely worked together and had competed for resources in the past. An objective, transparent metric for determining how to prioritize each science category would be a valuable tool for the Earth Observations Program planning process. At the very least, it would present a starting point for discussions among the various science communities.

The next section discusses some of the sensitivity analyses performed on the stakeholder model to investigate the effects of changing various parameters within the model.

4.8 Sensitivity Studies

This section describes five tests conducted to investigate the sensitivity of the results to certain parameters or assumptions within the model, described as follows:

- Testing the sensitivity of the results to the choice of threshold value loop score
- Testing the sensitivity of the science category rankings to individual value flow scores
- Increasing the importance of International Partners
- Modeling NOAA as an individual stakeholder
- Using a modified formula for calculating value loops

The following sub-sections describe the results of each test.

4.8.1 Choice of threshold value loop score

The results presented in this chapter are based on analyses of the value loops produced by the quantitative stakeholder model. The value loops were calculated using an OPN model, which used a threshold value of 0.01 for value loop scores. The OPN model automatically deleted any value loops whose score fell below the threshold value, which yielded 1880 unique and valid value loops. This helped keep the model computationally manageable, since the stakeholder network contains millions of possible value loops. Recall that the maximum possible score for a value loop is $(0.96)^2 = 0.92$, and the highest scoring loop generated by the model is actually $(0.74 \times 0.65) = 0.48$.

To investigate the sensitivity of the results to the choice of threshold value, I reproduced the results using threshold values of 0.03 and 0.05. As shown previously in Figure 45, using a threshold of 0.03, the model output yields 643 value loops; using a threshold of 0.05, the model output yields 310 value loops. For this sensitivity analysis, I examined the differences between the stakeholder importance rankings, important value flows, NASA/NOAA outputs and inputs, and the science category rankings for different threshold values. It is unnecessary to examine changes to the top-scoring value loops, presented in Section 4.3, because the lowest-scoring value loop from that analysis was 0.13, which would remain unchanged using threshold values of 0.01, 0.03, or 0.05.

Stakeholder Importance Rankings

This section investigates the sensitivity of the science category rankings to the choice of threshold value. Figure 72 below shows the weighted stakeholder occurrence scores using threshold values of 0.01, 0.03, and 0.05. The weighted stakeholder occurrence scores using a threshold value of 0.01 were shown previously in Figure 46. The numeric scores for each stakeholder are listed in Appendix F.

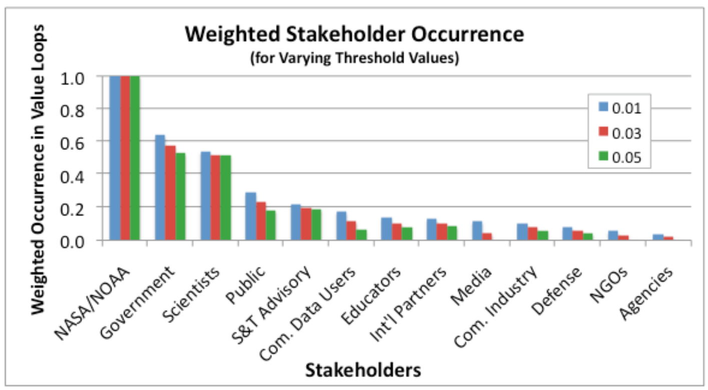


Figure 72. Most important stakeholders using different threshold values

The figure above indicates that changing the threshold value has a largely insignificant effect on the stakeholder rankings. The stakeholders most affected by the threshold value are Commercial Data Users and the Media, who both score much lower in the rankings using a threshold of 0.05 than 0.01. This indicates that Commercial Data Users and the Media appear in a large number of low-scoring value loops.

Most Important Value Flows

Figure 73 below shows the weighted value flow occurrence scores using threshold values of 0.01, 0.03, and 0.05. Figure 74 below shows the top 20 value flows using a threshold value of 0.05. The weighted value flow occurrence scores using a threshold value of 0.01 were shown previously in Figure 49. The numeric scores for each value flow are listed in Appendix F.

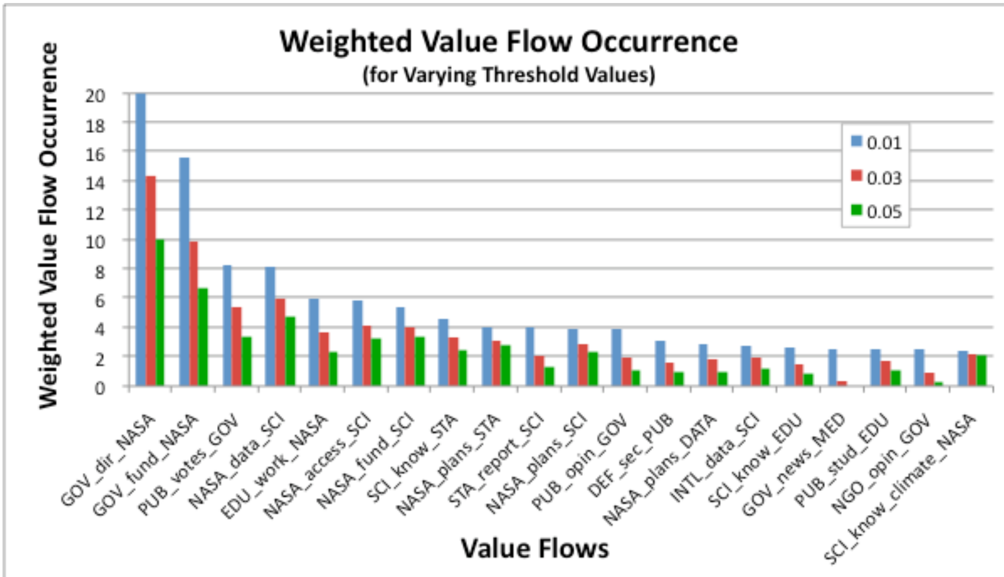


Figure 73. Most important value flows using different threshold values

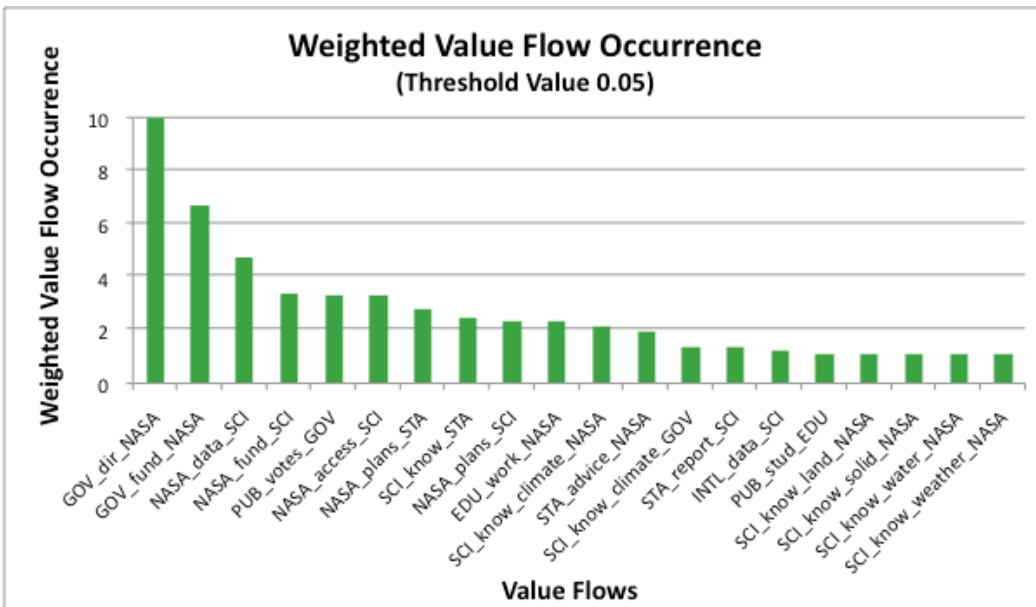


Figure 74. Top 20 value flows using threshold value of 0.05

Changing the threshold value has a moderate effect on the value flow rankings. Some of the value flows change position within the rankings but still remain within the top 20. These can be considered minor changes since the stakeholder analysis considers the top 20-30 value flows as a whole. The greatest changes that occurred using a threshold of 0.05, which includes value flows that were removed from or entered the top 20 list, are as follows:

- The following flows no longer appear in the top 20 list using a threshold of 0.05. The numbers in parenthesis indicate the original ranking using a threshold of 0.01 and the modified ranking using a threshold of 0.05 (0.01 → 0.05):
    - Opinions and support from Public to Government (12 → 22)
    - Security benefits from Defense to Public (13 → 24)
    - Future plans information from NASA/NOAA to Commercial Data Users (14 → 23)
    - Science knowledge from Scientists to Educators (16 → 26)
    - News and noteworthy information from Government to Media (17 → 104)
    - Opinions from NGOs to Government (19 → 72)

From this list, "opinions and support" from Public to Government and "science knowledge" from Scientists to Educators are included in the simplified stakeholder model shown in Figure 64. I might have overlooked these two flows if I had chosen a threshold value of 0.05, although the flow of "science knowledge" from Scientists to Educators would have been revealed in the list of top value loops anyway. The other four flows were not included in the simplified stakeholder model. The most notable changes in rank occurred with "news and noteworthy information" from Government to Media, and "opinions" from NGOs to Government.

- The following flows entered the top 20 list using a threshold of 0.05:
    - Science policy advice from S&T Advisory to NASA/NOAA
    - Science knowledge (climate) from Scientists to Government
    - Science knowledge (land use) from Scientists to NASA/NOAA
    - Science knowledge (solid Earth) from Scientists to NASA/NOAA
    - Science knowledge (water) from Scientists to NASA/NOAA
    - Science knowledge (weather) from Scientists to NASA/NOAA

All six of these value flows were already included in the simplified stakeholder model because they had been identified through the analysis of the top value loops. This highlights the importance of examining both the top value loops and the top value flows to ensure that all of the important value flows are captured. Notably, the value flow "climate-specific science knowledge" from Scientists to NASA/NOAA has roughly the same weighted occurrence score for each of the three threshold values.

NASA/NOAA Outputs and Inputs

This section investigates the effect of the threshold value on the most important NASA/NOAA outputs and inputs. Figure 75 below shows the weighted occurrence scores for NASA/NOAA outputs for the three threshold values. The weighted occurrence scores using a threshold value of 0.01 were shown previously in Figure 65. The numeric scores for each output are listed in Appendix F. Changing the threshold value has no effect on the relative rankings of the top seven outputs, and an insignificant effect on the ranking of the top 20 outputs. Using a threshold of 0.01, there are ten value flow outputs with significantly higher scores than the rest; the remaining outputs have relatively low scores with little differentiation among them. Using a threshold of 0.05, there are only five value flow outputs with significantly higher scores than the rest. This indicates that using the lower threshold score can help differentiate additional important value flow outputs.

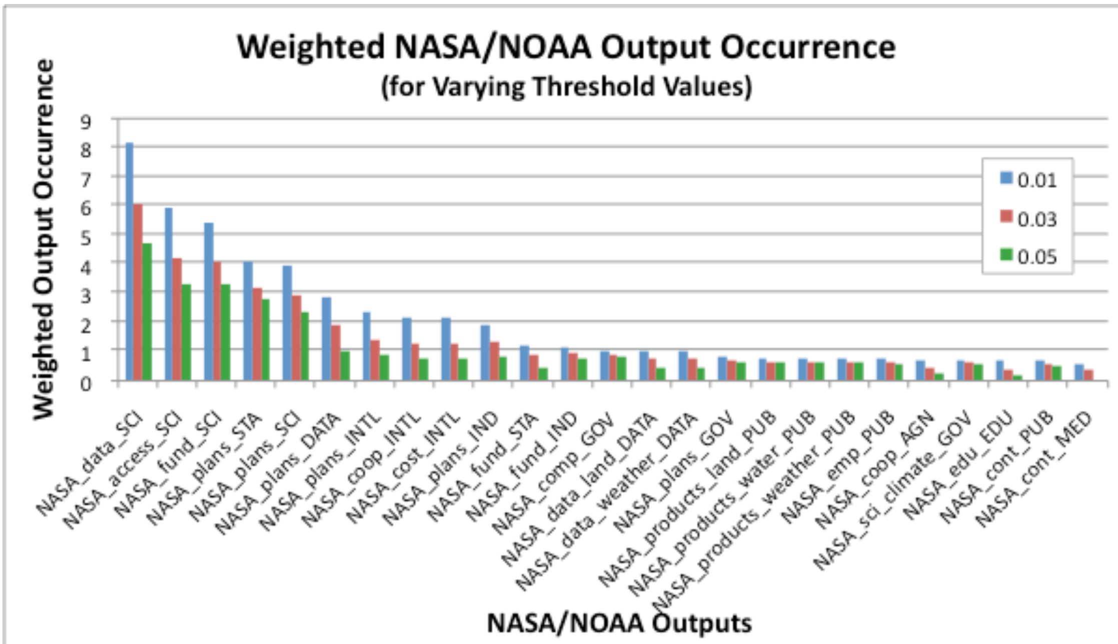


Figure 75. Most important NASA/NOAA outputs for varying threshold values

Figure 76 below shows the ranking of each input to NASA/NOAA for the three threshold values. Figure 77 shows the ranking of the inputs using a threshold value of 0.05. The weighted occurrence scores using a threshold value of 0.01 were shown previously in Figure 66. The numeric scores for each input are listed in Appendix F. The figures below indicate that the choice of threshold value has a more substantial impact on the relative rankings of NASA/NOAA's inputs compared to its outputs.

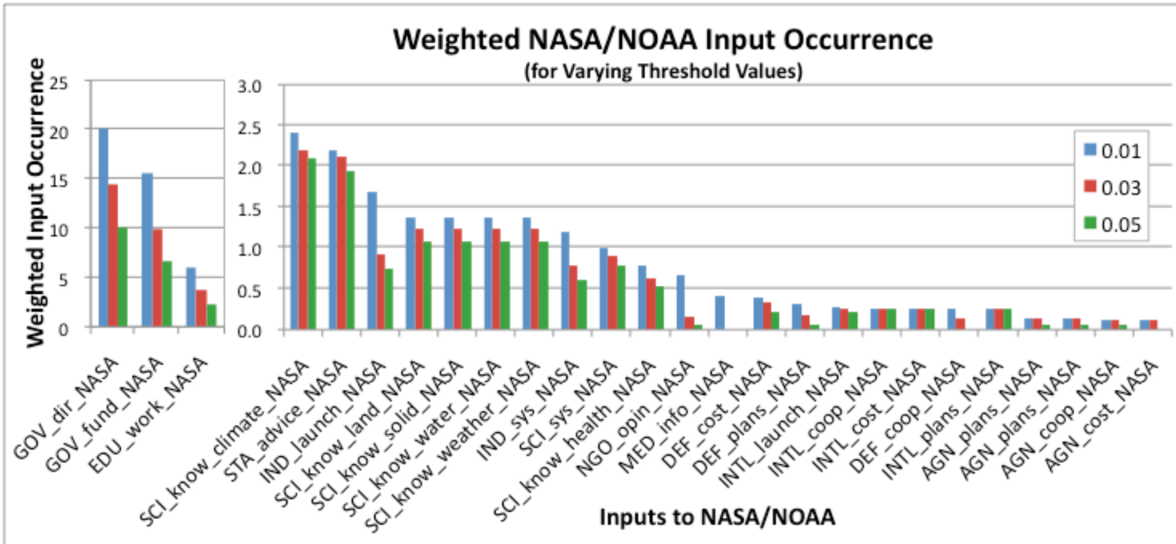


Figure 76. Most important NASA/NOAA inputs for varying threshold values

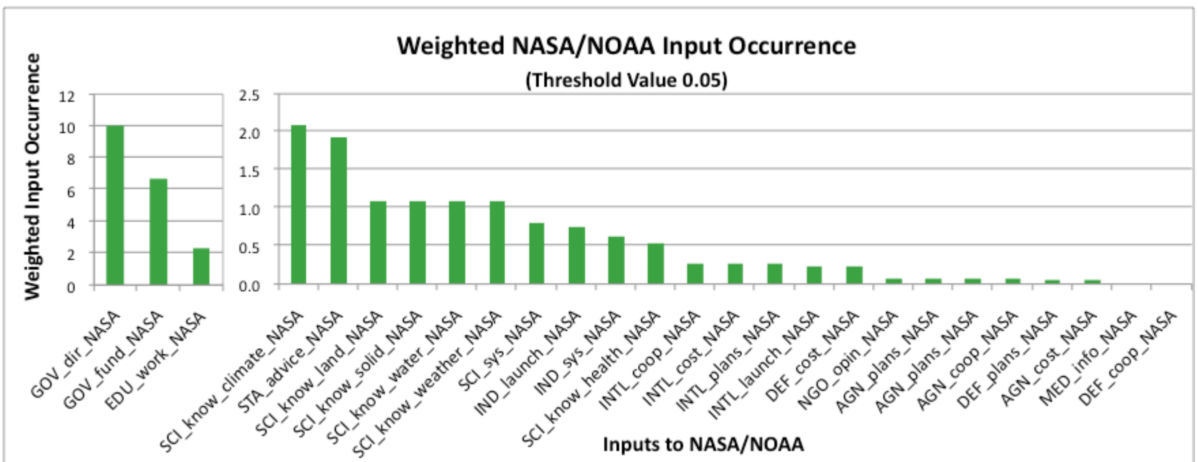


Figure 77. Most important NASA/NOAA inputs using 0.05 threshold value

The relative rankings of the following flows decreased substantially using a 0.05 threshold. The numbers in parenthesis indicate the original ranking using a threshold of 0.01 and the modified ranking using a threshold of 0.05 (0.01 → 0.05):

- Launch and space services from Commercial Industry to NASA/NOAA (6 → 11)
- Opinions from NGOs to NASA/NOAA (14 → 19)
- Informative content from Media to NASA/NOAA (15 → 25)
- Future plans information from Defense to NASA/NOAA (17 → 23)
- Program cooperation from Defense to NASA/NOAA (21 → 26)

Of these, the most important flow is launch and space services from Commercial Industry to NASA/NOAA, which still remains in the top half of the rankings list using a threshold of 0.05.

Because the relative rankings of each of these five value flows decrease using a threshold value of 0.05, this indicates that they appear more often in relatively low-scoring value loops. This means that NASA/NOAA's ability to affect these inputs through the allocation of its outputs may be limited.

Science Category Rankings

The final sensitivity study for the choice of threshold value was analyzing the effect on science category rankings. Figure 78 below shows the relative importance of the science categories for the three threshold values.

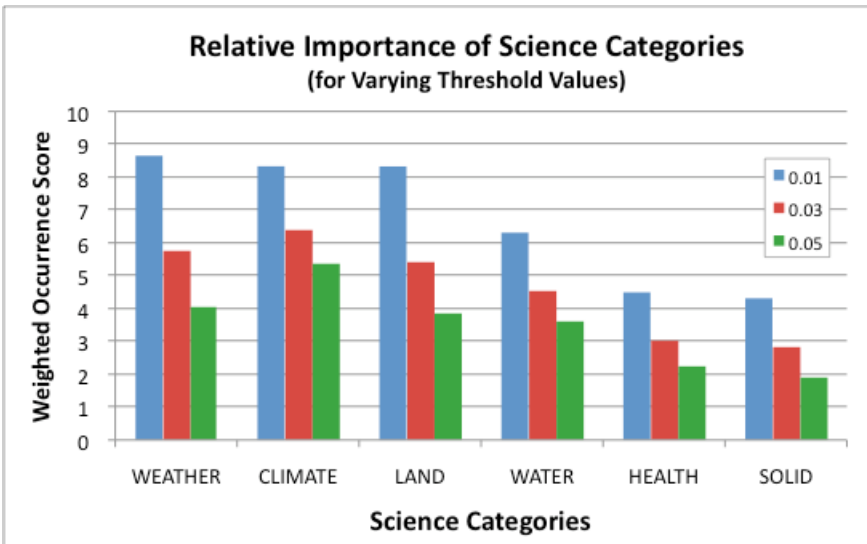


Figure 78. Relative importance of science categories for varying threshold values

The most significant change using a threshold of 0.05 is that climate becomes the most important science category, followed by weather and land use. This indicates that many of the climate-related value flows appear in shorter, high-scoring value loops, whereas many of the weather- and land-related value flows appear in longer, lower-scoring value loops. Because of this, the benefits produced by climate-related missions may be realized more easily or quickly than the benefits produced by weather or land use missions.

4.8.2 Sensitivity of Climate Science Category Ranking to Value Flow Scores

One of the key results of the model is the relative ranking of the importance of each science category. The previous section described the sensitivity of the science category rankings to the choice of value loop threshold. This section describes the sensitivity of the climate change science category ranking to the numeric scores assigned to individual value flows. I chose to test the climate change category because climate change is currently an issue of heightened national importance. Future work could investigate the sensitivity of the other science categories to the individual value flow scores.

Assigning numeric scores to each value flow is one of the critical steps in the stakeholder analysis, as described previously in Section 3.1. Recall that each value flow receives a "satisfaction/regret" score and a "source importance" score, and the combination of these scores yields a numeric value flow score. To test the sensitivity of the science category rankings to the scores of individual climate-specific value flows, I multiplied each climate-specific flow score by 1.7 and noted the change in the climate category ranking compared to the original case presented in Section 4.7. The factor of 1.7 corresponds to increasing the "satisfaction/regret" score by one level (e.g. from a score of "C" to "D" as shown previously in Table 4). Table 34 below lists all the climate-specific value flows in the model, the original value flow score, the increased value flow score, and the percent change in the climate category ranking compared to the rankings shown previously in Figure 68. Recall that the science category ranking was calculated using the weighted science category occurrence score shown in Figure 68. The table below is sorted in order of decreasing effect on the climate category ranking.

Table 34. Sensitivity of climate change science category ranking to individual value flow scores

From: Stakeholder	Value Flow	To: Stakeholder	Original Score	Increased Score	% Change in Climate Ranking
Scientists	**Science knowledge**	**Government**	**0.43**	**0.73**	**17.6%**
S&T Advisory	**Science policy advice**	**Government**	**0.43**	**0.73**	**14.8**
Scientists	**Science knowledge**	**NASA/NOAA**	**0.65**	**0.96***	**13.9**
NASA/NOAA	Science knowledge	Government	0.42	0.71	5.7
NASA/NOAA	Space-acquired data	Defense	0.54	0.92	3.0
Scientists	Science knowledge	Defense	0.24	0.41	2.1
NASA/NOAA	Program cooperation	Defense	0.17	0.29	1.8
NASA/NOAA	Earth observations-derived products & services	Public	0.11	0.19	1.8
NASA/NOAA	Space-acquired data	Com. Data Users	0.15	0.26	1.2
Scientists	Science knowledge	Com. Data Users	0.11	0.19	0.7
NASA/NOAA	Cost sharing	Defense	0.09	0.15	0.5
Com. Data Users	Earth observations-derived products & services	Public	0.14	0.24	0.8
Int'l Partners	Space-acquired data	Com. Data Users	0.08	0.14	0.0

*Note: the maximum allowable value flow score was 0.96

This analysis indicates that the climate category weighted occurrence score is highly sensitive to the following three value flow scores (the value flow scores are shown in parenthesis):

- Science knowledge from Scientists to the Government (0.43)
- Science policy advice from S&T Advisory Bodies to the Government (0.43)
- Science knowledge from Scientists to NASA/NOAA (0.65)

Using the higher score for just one of the three value flows listed above gives the climate category the highest ranking of the six categories. Figure 79 below shows the result of increasing the value flow score from 0.65 to 0.96 for climate-related science knowledge from Scientists to NASA/NOAA, which increases the climate category ranking by 13.9%.

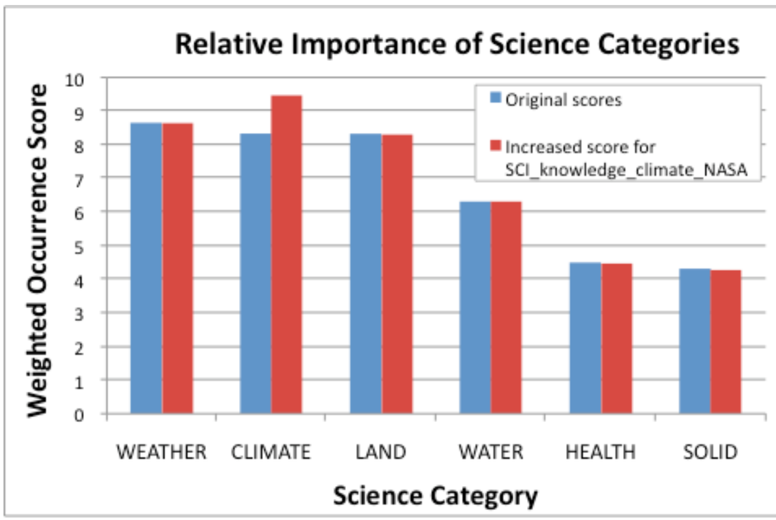


Figure 79. Sensitivity of science category rankings to value flow scores

Section 3.2 described the methods used to validate these three value flow scores. The scores for each of these three value flows was originally relatively high. A value flow score of 0.43 for the first two value flows listed above corresponds to a satisfaction/regret score of D—"Its presence is necessary, and I would regret its absence"—and a source importance score of 4—"Very important – it is strongly desirable that this source fulfills this need." The value flow score for science knowledge from Scientists to NASA/NOAA is 0.65, which roughly corresponds to the midpoint between a score of 0.43 and the maximum possible score of 0.96. This is the sixth-highest ranking value flow in the model; the highest-scoring value flow is science data from NASA/NOAA to Scientists with a score of 0.74.

Although the science category rankings are sensitive to these three value flow scores, the validation techniques described previously in Section 3.2 provide a measure of confidence in the final scores use for each of these flows.

4.8.3 Increasing the Importance of International Partners

The decadal survey recommends that NASA and NOAA seek cooperation with International Partners to help reduce mission costs by avoiding duplicative efforts with international space agencies. The lack of budgetary resources for NASA's Earth science program has become an urgent concern, and the NASA Advisory Council - Earth Science Subcommittee recently requested a study to analyze the cost of Earth science missions and identify opportunities to reduce mission costs (NAC Earth Science Subcommittee 2008). Because of these concerns, NASA and NOAA may place a greater importance on program cooperation and cost sharing with International Partners than my model currently reflects.

To investigate the effect of increasing the importance of International Partners, I increased the scores of the value flows from International Partners to NASA/NOAA, Scientists, and S&T Advisory bodies and noted the changes in stakeholder importance rankings, most important value flows, and NASA/NOAA outputs and inputs. I multiplied the score of these value flow outputs by 1.7, which corresponds to increasing the "satisfaction/regret" score by one level (e.g. from a score of "C" to "D"). The following sections describe the results of this analysis.

Table 35 below lists the value flows whose scores were increased for this analysis. The table is sorted in order of decreasing value flow score.

Table 35. Value flow outputs from International Partners used for sensitivity analysis

From:	Value Flow	To:	Original Score	Increased Score
Int'l Partners	Space-acquired data	Scientists	0.57	0.96*
Int'l Partners	Access to space systems	Scientists	0.38	0.65
Int'l Partners	Launch services	NASA/NOAA	0.34	0.58
Int'l Partners	Program cooperation	NASA/NOAA	0.34	0.58
Int'l Partners	Cost sharing	NASA/NOAA	0.34	0.58
Int'l Partners	Future plans information	NASA/NOAA	0.34	0.58
Int'l Partners	Future plans information	S&T Advisory	0.31	0.53

*Note: the maximum allowable value flow score was 0.96

Stakeholder Importance Rankings

Figure 80 below shows the stakeholder importance rankings using the increased value flow scores for International Partner outputs. The original rankings, shown previously in Figure 46, are shown below in blue, and the revised International Partners score is shown in red.

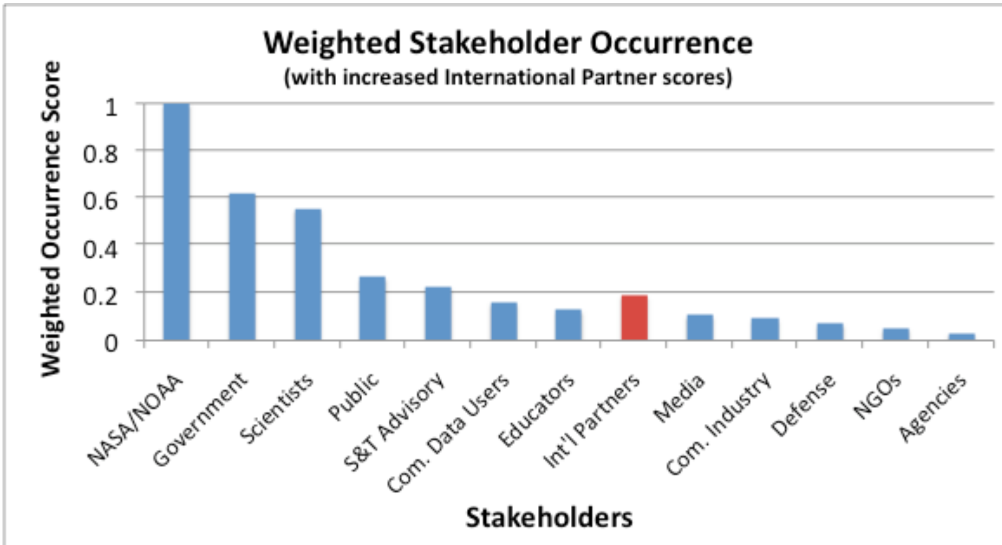


Figure 80. Stakeholder importance rankings with increased International Partner scores

Increasing the value flow scores increases the rank of the International Partners to sixth, from its original ranking of eighth. While International Partners do not enter the list of top five stakeholders, they become the most important stakeholder after S&T Advisory Bodies.

Most important value flows

Figure 81 below shows the original and increased scores of the original top 20 value flows. Figure 82 below shows the top 20 value flows using the increased International Partners value flow scores. The weighted value flow occurrence scores using a threshold value of 0.01 were shown previously in Figure 49. The numeric scores for each value flow are listed in Appendix F. Increasing the International Partners scores has a moderate effect on the value flow rankings. Some of the value flows change position within the rankings but still remain within the top 20 rankings. The value flow with the most significant increase in score is space-acquired data from International Partners to Scientists. As described earlier, I consider these minor changes since the analysis technique generally considers the top 20-30 value flows as a whole.

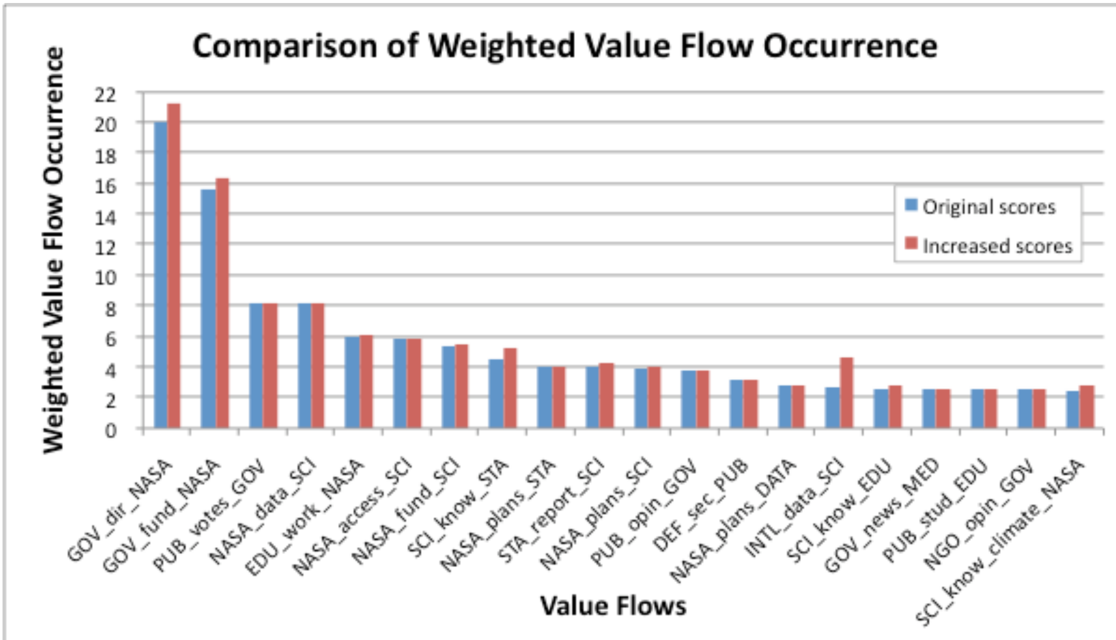


Figure 81. Most important value flows using two sets of International Partner scores

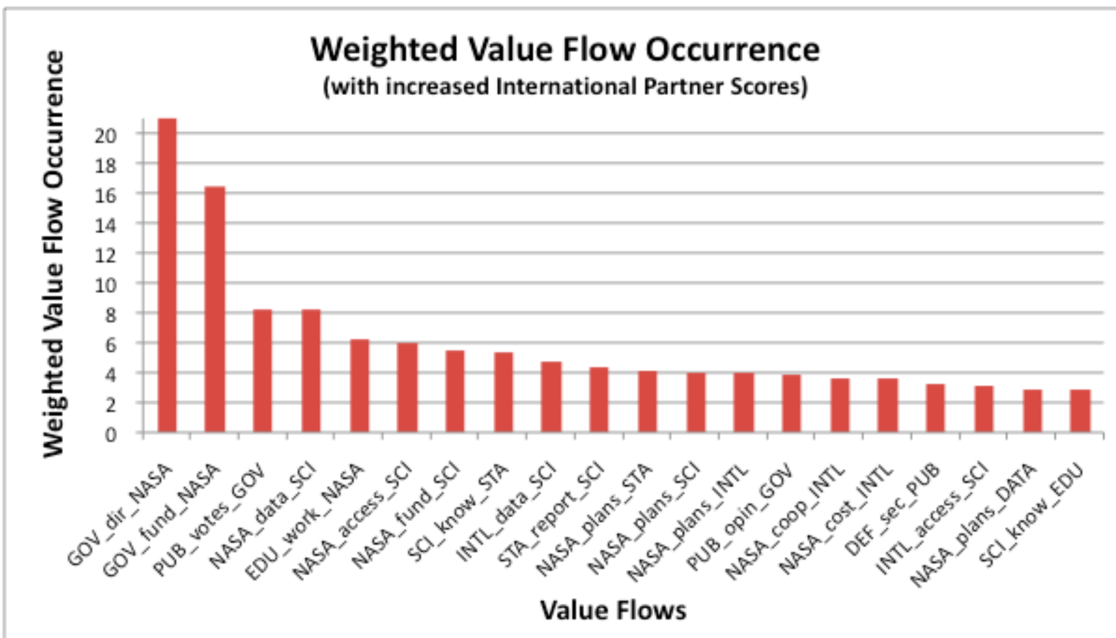


Figure 82. Most important value flows using increased International Partner scores

The greatest changes using the increased International Partners scores, which include value flows that were removed from or entered the top 20 list, are as follows. The numbers in parenthesis indicate the rankings using the original value flow scores and the modified rankings using the increased value flow scores for International Partners (original → modified):

- The following flows were removed from the top 20 list using increased International Partners scores:
    - News and noteworthy information from Government to Media (17 → 22)
    - Opinions from NGOs to Government (19 → 24)
    - Climate-specific science knowledge from Scientists to NASA (20 → 21)

The changes in rank for these three value flows are minor—each of them remains in the list of top 25 value flows. Of these three value flows, only climate-specific knowledge from Scientists to NASA appears in the simplified stakeholder model, and it would have been revealed in the list of top value loops anyway.

- The following flows entered the Top 20 list using increased International Partners scores:
    - Cost sharing from NASA/NOAA to International Partners (24 → 16)
    - Program cooperation from NASA/NOAA to International Partners (23 → 15)
    - Future plans information from NASA/NOAA to International Partners (21 → 13)

These flows, with the exception of future plans information, were already included in the simplified stakeholder model in Figure 63 because they were included in the original list of top 30 value flows.

NASA/NOAA Outputs and Inputs

Figure 83 below shows the most important outputs from NASA/NOAA using the increased International Partners scores. Changing the scores results in a significant increase in the scores for future plans information, program cooperation, and cost sharing from NASA/NOAA to International Partners, although each of the three value flows moves just one position higher in the overall ranking. The increase in the weighted occurrence scores occurs primarily because these three value flows form direct transaction value loops with the corresponding value flows from International Partners to NASA/NOAA.

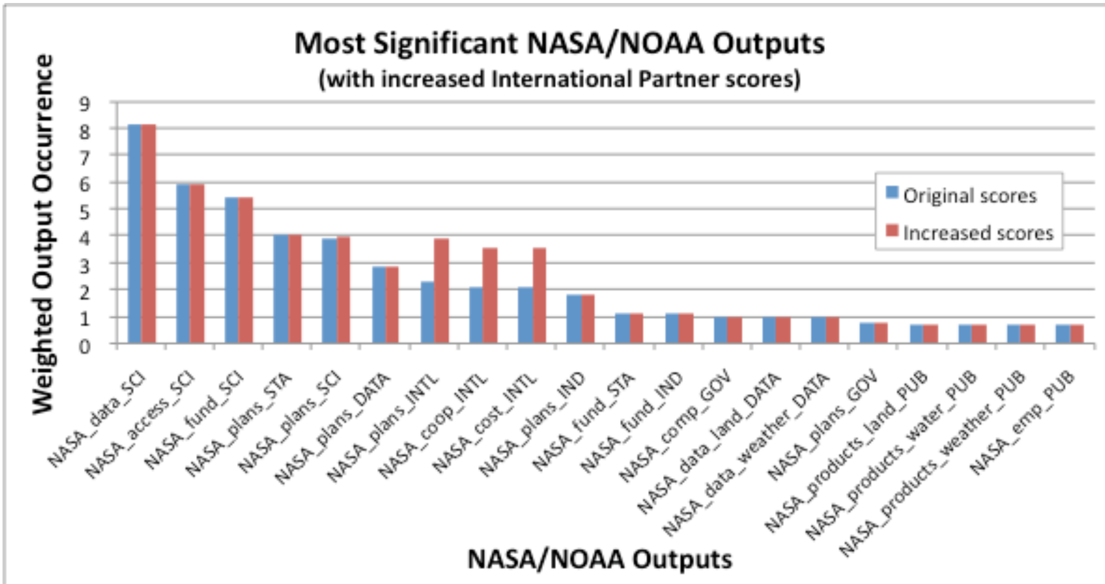


Figure 83. Most important NASA/NOAA outputs using increased International Partners scores

Figure 84 below shows the most important inputs from NASA/NOAA using the increased International Partners scores. Compared to the original diagram in Figure 66, the collaborative value flows with International Partners increase in importance and surpass the collaborative links with Defense. The rankings of the other inputs to NASA/NOAA remain largely unchanged.

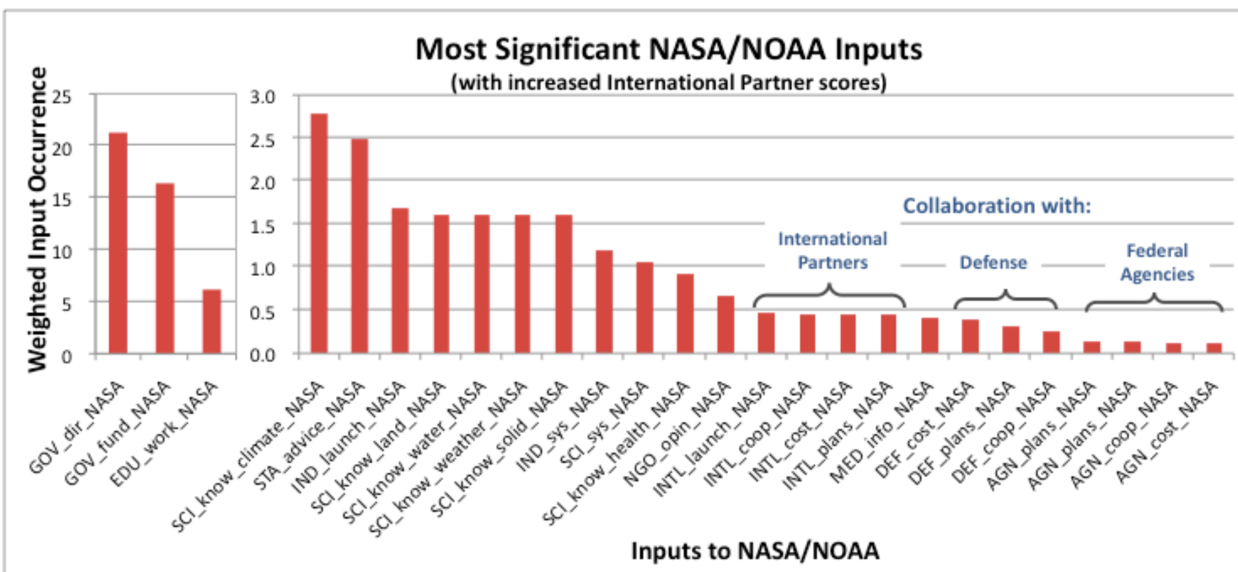


Figure 84. Most important NASA/NOAA inputs

Not surprisingly, increasing the value flow scores for the International Partners value flows results in International Partners becoming a more important stakeholder whose outputs provide greater value to the stakeholder network. The International Partners also gain priority over Defense with respect to collaborative efforts with NASA/NOAA, although this represents a relatively minor change in the overall rankings.

4.8.4 Modeling NOAA as an Individual Stakeholder

In the stakeholder value network mode, I aggregated NASA and NOAA into a single stakeholder. I chose to model NASA and NOAA this way for two reasons. First, their inputs and outputs are nearly identical, which would create redundancies in the model's results if they were to be considered separately. Second, in reality the operational boundaries between NASA and NOAA can be fuzzy at times. Some of the decadal survey missions blur the traditional distinctions between the two agencies.

To investigate how the results of the analysis would differ if I had treated NASA and NOAA as separate stakeholders, I created a duplicate model in which NOAA was the primary stakeholder instead of NASA/NOAA. To do this, I examined the list of NASA/NOAA outputs and deleted those outputs that did not seem relevant to NOAA. These primarily involved land-use and solid Earth value flows, as well as launch services value flows. Table 36 below lists the value flows that I removed for this part of the analysis. Due to the lack of detailed information about NOAA's stakeholder relationships, I did not change any other flows in the model.

Table 36. Value flows deleted for NOAA stakeholder model

From:	Value Flow	To:
NASA/NOAA	Cost sharing (land use missions)	Defense
NASA/NOAA	Cost sharing (solid Earth missions)	Defense
NASA/NOAA	Space-acquired data (land use)	Com. Data Users
NASA/NOAA	Space-acquired data (land use)	Defense
NASA/NOAA	Space-acquired data (solid Earth)	Com. Data Users
NASA/NOAA	Space-acquired data (solid Earth)	Defense
NASA/NOAA	Earth observations-derived goods & services (land use)	Public
NASA/NOAA	Earth observations-derived goods & services (solid Earth)	Public
NASA/NOAA	Launch services	Com. Data Users
NASA/NOAA	Launch services	Defense
NASA/NOAA	Launch services	Int'l Partners
NASA/NOAA	Science knowledge (solid Earth)	Government
NASA/NOAA	Science knowledge (land use)	Government
NASA/NOAA	Space technology	Com. Industry

For this analysis, I was interested only in how the science category rankings would change using NOAA as the primary stakeholder, which are shown below in Figure 85. The importance of land-use missions drops significantly to fourth place, and the importance of solid Earth missions drops as well. There is an insignificant decrease in the importance of water missions.

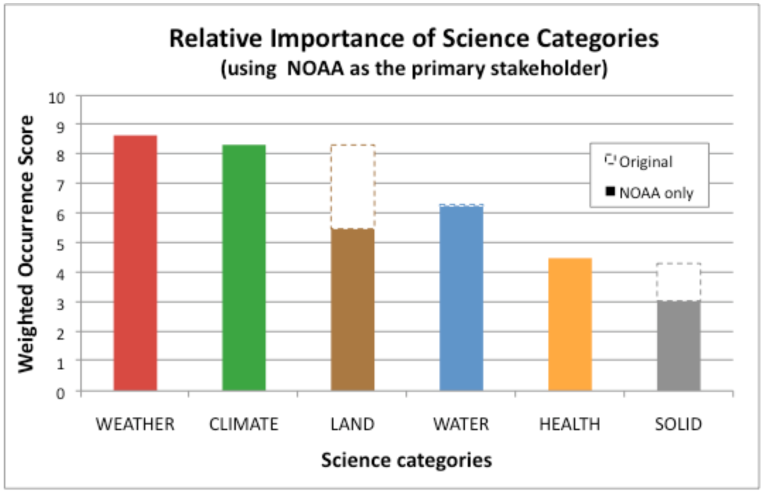


Figure 85. Change in science category rankings using NOAA as the primary stakeholder

The results from this analysis were not very enlightening. By decreasing the scores of the value flows related to land-use and solid Earth, the results indicate that land-use and solid Earth become less important to NOAA. To produce more insightful results, this analysis would require a more in-depth assessment of every output from NASA/NOAA to determine how the source importance scores for each value flow would differ between the original NASA/NOAA case and for the case considering NASA and NOAA separately.

4.8.5 Using a Modified Formula for Calculating Value Loops

This section describes the changes to the value loop results using a modified formula to calculate the score of each value loop. As mentioned previously in Section 3.3.1, the MIT System Architecture group is concurrently developing the mathematical theory underlying the value loop calculation method. The value loops in this thesis were calculated by multiplying the score of each value flow within a value loop to produce the value loop score: A*B*C for a value loop containing three value flows. The theoretical work suggests that this calculation method corresponds to a stakeholder network that maximizes the returns (i.e. net satisfaction or benefit) to the central stakeholder (e.g. NASA/NOAA) by minimizing the net benefit to the other stakeholders in the model. The theory suggests that a more general formula for calculating value loops is to multiply the score of each value flow within the value loop, using the square of the last value flow score: $A*B*C^2$ for a value loop containing three value flows. The final value flow is the input to the central stakeholder.

A comparison of the distribution of the value flow scores between the two methods is shown in Figure 85 below. By lowering the score of each value loop, the ABC^2 method decreases some of the useful variation among the value loop scores.

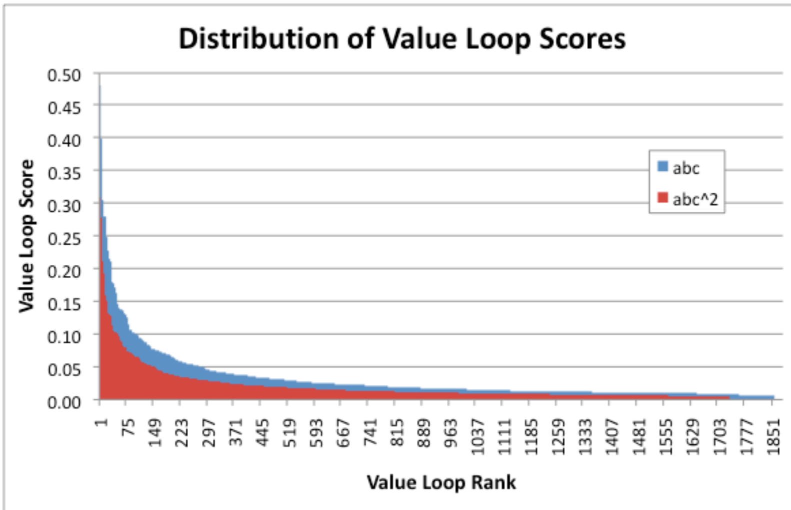


Figure 86. Comparison of the distribution of value loop scores between two value loop calculation methods

I compared the original results of the value loop analysis to the results obtained using the ABC^2 method. This includes the most important stakeholders, value flows, value loops, NASA/NOAA outputs, NASA/NOAA inputs, and science category rankings. The numeric scores accompanying each figure are listed in Appendix F.

Most Important Stakeholders

Figure 87 below shows the comparison of the most important stakeholders using the two value loop calculation methods. The figure indicates that there is no change in the relative rankings of each stakeholder between the two calculation methods.

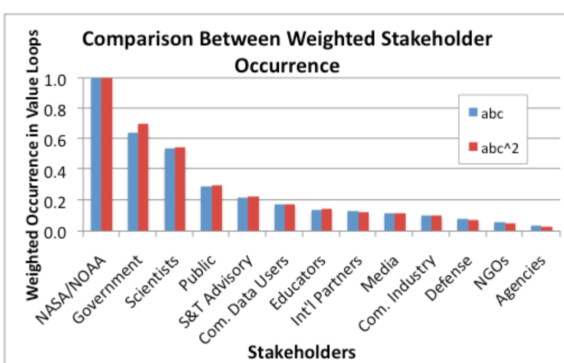


Figure 87. Comparison of most important stakeholders using two value loop calculation methods

Most Important Value Flows

The comparison between the most significant value flows for each calculation method is shown below in Figure 88. The changes to the value flow rankings using ABC^2 are insignificant. The list of top 20 value flows for each calculation method remains unchanged.

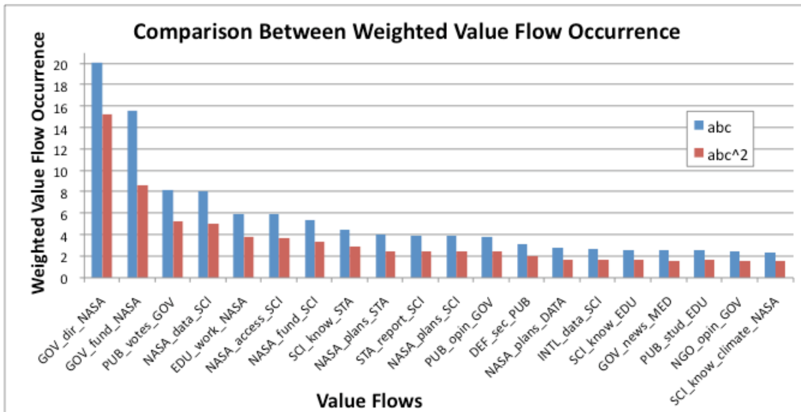


Figure 88. Comparison of most important value flows using two value loop calculation methods

Most Important Value Loops

To compare the changes to the value loop rankings, I considered the direct loops and indirect loops separately. Direct value loops involve NASA/NOAA and one other stakeholder; indirect value loops contain three or more stakeholders. I separated the direct and indirect value loops because I wanted to isolate any effects due to the fact that, using the multiplicative rule in the bounded range of [0, 0.96], direct value loops tend to have higher value scores than indirect value loops due to their shorter length. Figure 89 below shows the ranking of the top 15 direct value loops using the ABC^2 method. In the figure, the number in parenthesis represents the change in rank from the ABC method, with separate rankings used for the direct and indirect value loops.

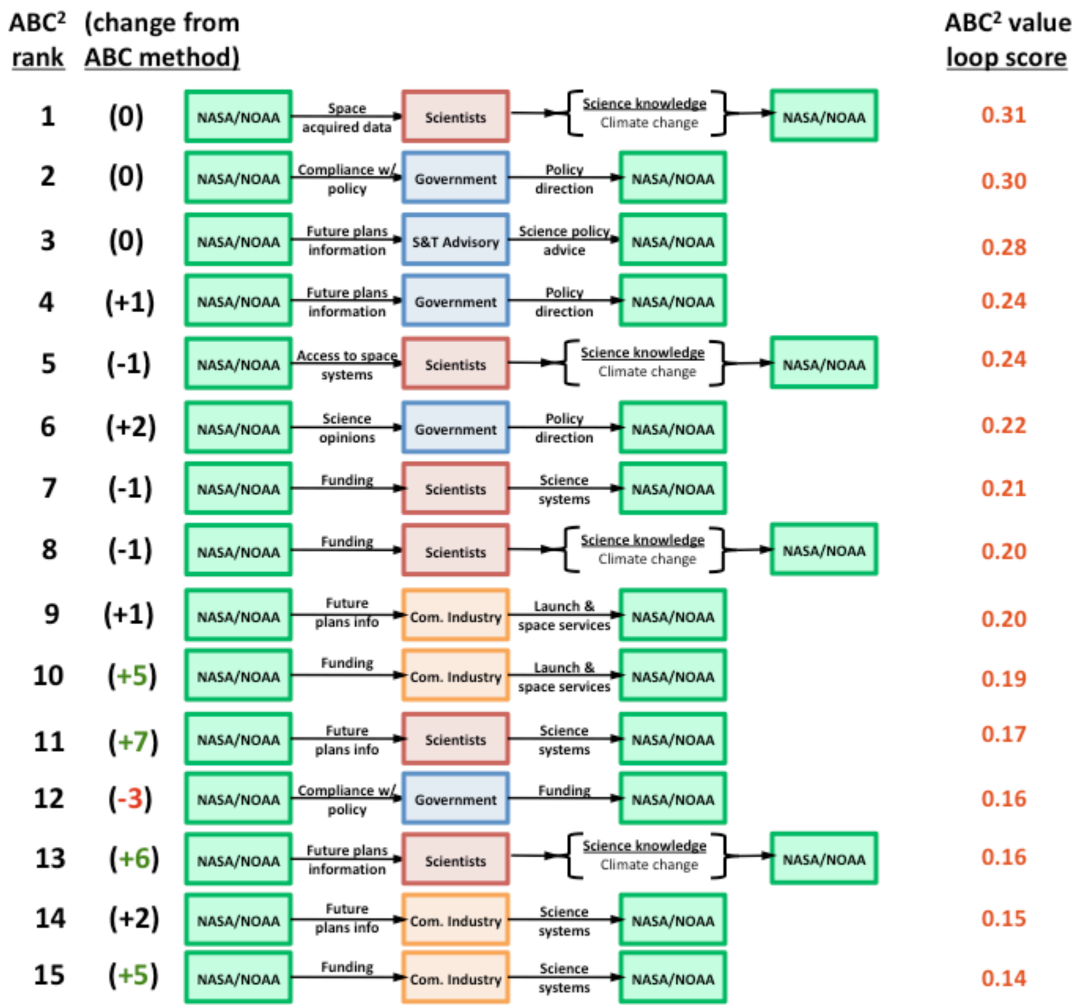


Figure 89. Top 15 direct value loops using ABC^2 method compared to ABC method

The most significant changes to the rankings occur towards the bottom of the list. The most notable changes involve the direct value loops containing Commercial Industry, which increased between one and five positions in the rankings. The value loops that decreased significantly and were removed from the top 15 list are shown in Figure 90 below.

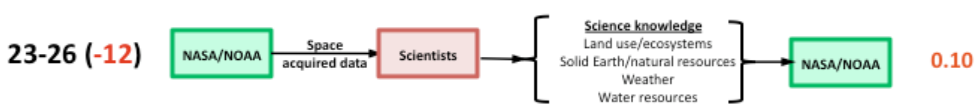


Figure 90. Direct value loops removed from list of top 15 direct loops using ABC^2 method

Figure 91 below shows the ranking of the top 15 indirect value loops using the ABC^2 method. In the figure, the number in parenthesis represents the change in rank from the ABC method, with separate rankings used for the direct and indirect value loops.

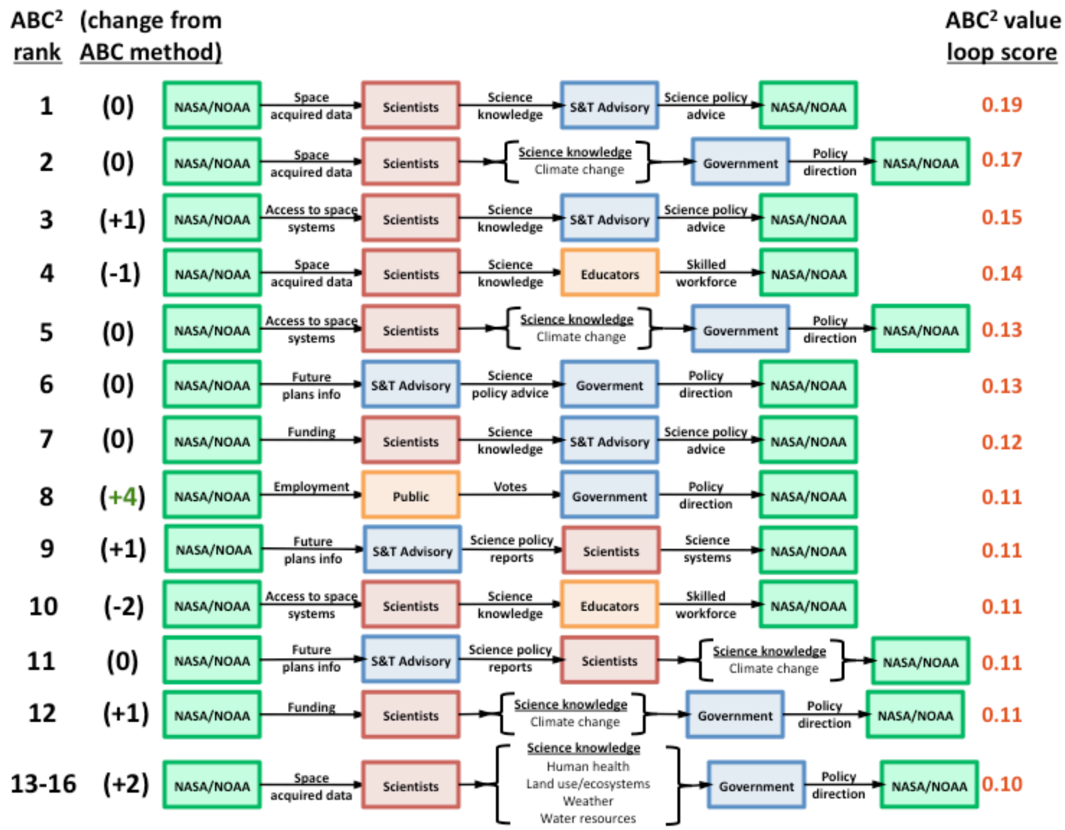


Figure 91. Top 15 indirect value loops using ABC² method compared to ABC method

In general the changes to the rankings of the indirect value loops are much less substantial than the rankings of the direct value loops The most significant change to the rankings in Figure 91 is the eighth-ranking value loop that includes employment to the Public, votes to the Government, and policy direction to NASA/NOAA. One value loop decreased significantly and was removed from the top 15 list, as shown in Figure 92 below. This was a surprising drop in the rankings, since climate-related science knowledge from Scientists to the Government is one of the most important outputs of the Earth Observations Program.

Figure 92. Indirect value loop removed from list of top 15 direct loops using ABC² method

To summarize these findings, the relative scores of the direct value flows vary more than the relative scores of the indirect value flows using the ABC² method compared to the ABC method. However, in most cases the changes in rankings are relatively minor. For this analysis, the most significant change using the ABC² method is that direct value loops containing Commercial Industry increased in relative importance.

Most Important NASA/NOAA Outputs

Figure 93 below shows the comparison of the most important NASA/NOAA outputs using the two value loop calculation methods. The figure indicates that there are no significant changes in the relative rankings of the NASA/NOAA outputs between the two calculation methods.

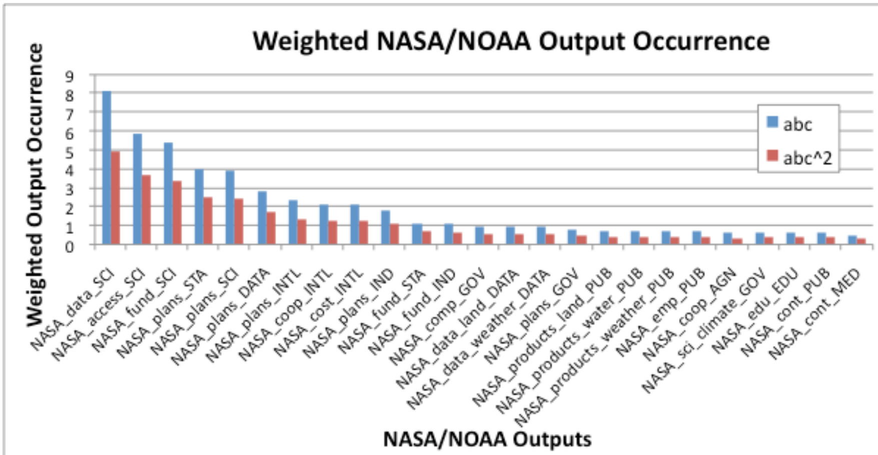


Figure 93. Comparison of most important NASA/NOAA outputs using two value loop calculation methods

Most Important NASA/NOAA Inputs

Figure 94 below shows the comparison of the most important NASA/NOAA inputs using the two value loop calculation methods.

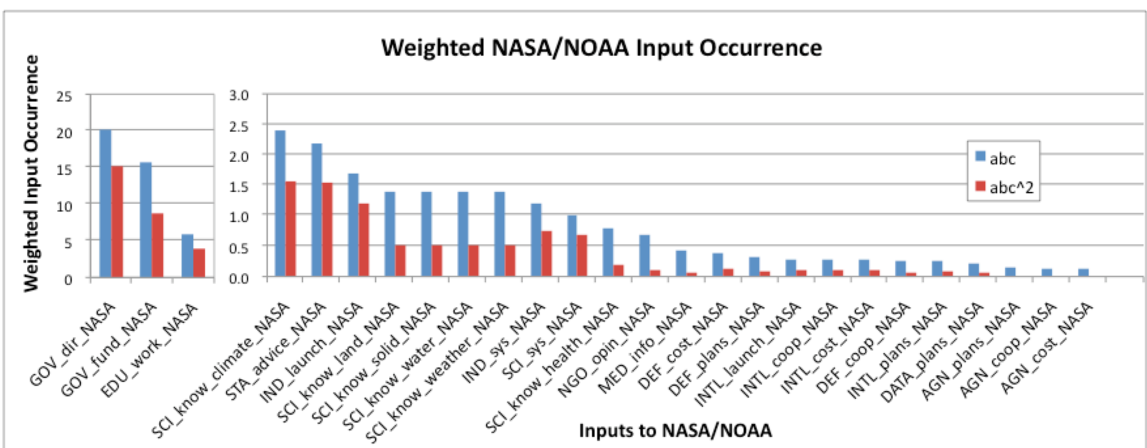


Figure 94. Comparison of most important NASA/NOAA inputs using two value loop calculation methods

The most significant change in the rankings occurs for the inputs of science systems from Commercial Industry and Scientists, which each increase four positions in the rankings using the ABC^2 method. Consequently, the inputs of climate knowledge related to land-use, solid Earth, water resources, and weather decreased by four positions in the rankings. The most substantial decrease in rankings involves the input of news and noteworthy information from the Media, which moved from 15th place to 23rd in the rankings.

Most Important Science Categories

Figure 95 below shows the comparison of the science category rankings using the two value loop calculation methods.

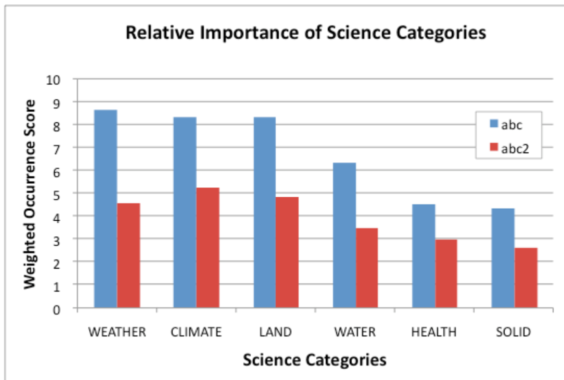


Figure 95. Comparison of science category rankings using two value loop calculation methods

The most significant change to the science category rankings is the decrease in the weather category from first place to third. Consequently, climate change and land-use increased to first and second in the rankings. Using the ABC^2 method, there is much less variation between the scores of all six categories than with the original ABC method.

Summary

In general, the differences between the results using the ABC and ABC^2 methods are relatively minor. In this case, there were no changes to the relative importance of each stakeholder, and insignificant changes to the most important value flows and most important outputs from NASA/NOAA. There were some notable changes to the list of top value flows and the most important inputs to NASA/NOAA, but these were relatively minor and would not change the simplified stakeholder map shown in Figure 64. The rankings of the science categories changed, but the climate, land-use, and weather categories still remained the top three categories. Future work could be done to investigate whether the similarities in the results are specific to the Earth Observations Program stakeholder network or more generally applicable to all stakeholder value networks.

4.9 Summary of Stakeholder Analysis Results

This chapter described the results from the quantitative portion of the stakeholder analysis. The OPN model yielded 1880 value loops that begin and terminate with NASA/NOAA. An analysis of these value loops indicated the most important stakeholders, value flows, and value loops within the network. I used this information to create a simplified stakeholder model that includes nine of the original 13 stakeholders and 28 of the original 190 value flows. This model has two tiers of stakeholders; the first tier includes the primary four stakeholders: NASA/NOAA, Scientists, the Public, and the Government. The second tier includes five other stakeholders that each have unique and important roles: S&T Advisory Bodies, International Partners, Commercial Data Users, Educators, and Commercial Industry.

An analysis of the outputs from NASA/NOAA provided an indication of how NASA/NOAA should prioritize its outputs in order to align them with the important value loops in the network. An analysis of the inputs to NASA/NOAA showed that collaboration with Defense, International Partners, and other Federal Agencies is inherently difficult due to the relatively low number of feedback loops produced by such collaborative efforts.

The value loop analysis also revealed that weather, climate change, and land-use missions provide roughly equivalent levels of value to the stakeholder network. Climate missions provide value primarily in the form of science knowledge delivered to NASA/NOAA and the Government. Weather and land-use missions provide value primarily in the form of Earth observations-derived products and services involving Commercial Data Users and the Public. Water resources missions rank forth on the list, and human health and solid Earth missions rank fifth and sixth.

After completing this analysis, I performed five sensitivity analyses to investigate the sensitivity of the results to various parameters and assumptions within the model. The first test investigated the choice of the threshold value used to eliminate low-scoring value loops. Increasing the threshold value from 0.01 to 0.03 or 0.05 increased the relative ranking of climate-related missions and reduced the apparent importance of launch and space services from Commercial Industry. The second test investigated the sensitivity of the science category rankings to the numeric scores assigned to each flow. This test revealed that three individual value flows have a significant effect on the science category rankings. The third test investigated the effect of increasing the importance of value flow outputs from International Partners. This resulted in increasing the relative importance of International Partners compared to the other stakeholders, and the importance of collaborative efforts with International Partners surpassed the importance of collaboration with Defense. The fourth test involved modeling NOAA as an individual stakeholder. The results from this test were uninformative, and more a more in-depth assessment would be required to produce more insightful results. Finally, the fifth test investigated the change results using a modified value loop calculation formula. In most cases, the changes were minor or insignificant. The biggest changes involved the importance of science systems from Commercial Industry and Scientists, and the relative rankings of the six science categories.

A more detailed discussion of the insights gained from the stakeholder analysis is provided next in Chapter 5, along with a list of recommendations based on the results from the model.

4.10 Future Work

This section describes possible areas of future work on topics specifically related to this stakeholder analysis, as well as broader areas related to the general methodology presented in this thesis.

4.10.1 Stakeholder Analysis for the Earth Observations Program

- **Develop a more in-depth analysis of some of the Level 3 stakeholder groups.** The Level 3 stakeholder map shown in Figure 14 shows a more detailed view inside some of the stakeholder groups used for this stakeholder analysis. For some of these stakeholders, such as the Government or Federal Agencies, it may be useful to conduct a more in-depth analysis of the value flows within the stakeholder sub-groups. For example, it would be useful to analyze the Federal Agencies in more detail to establish more specific opportunities for cost sharing and program collaboration with NASA/NOAA.
- **Consider including science-related value flows for the Public, Media, and NGOs.** As described in Section 2.4, certain science-related value flows such as “science knowledge” were modeled as six separate value flows corresponding to the categories of the six science-themed decadal survey panels. For this analysis, the value flows into the Public, Media, and NGOs were not separated into science-specific value flows. However, there may be compelling arguments for considering this for value flows such as “informative and entertaining content” from the Media to the Public. As climate change becomes an issue of greater national importance, media stories and NGOs concerned with this topic have become increasingly powerful in the national dialogue. Including science-specific value flows for the Public, Media, and NGOs may increase their relative importance within the stakeholder network.
- **Identify additional methods for validating value flow scores.** Section 3.2 described a variety of techniques used to validate the numeric scores assigned to each value flow.

Additional proxy literature and data sources could be identified for those value flows that were not validated in this analysis. Also, additional stakeholder representatives could be consulted to provide anecdotal verification of the relative value flow rankings for the remaining stakeholder groups.

- **Investigate the major value flows associated with water resources, solid Earth, and human health missions.** The analysis in Section 4.7 calculated the most important value flows created by missions from the top three science categories: climate, weather, and land-use. The charts in Figure 69, Figure 70, and Figure 71 provide visualizations of how each science category delivers value to the stakeholder network. A similar analysis with accompanying charts could be completed for water resources, solid Earth, and human health missions to understand the most important mechanisms by which they deliver value to the stakeholder network.

4.10.2 General Stakeholder Value Network Methodology

- **Investigate the timing or timeliness of value flows within a stakeholder model.** For certain value flows, timing is a critical issue to consider; for example, a project may need to obtain regulatory approval at the beginning of the project or at any point during the project. Timeliness might also be an important attribute to consider as a metric for assigning quantitative scores to value flows. For example, it may be critical for Scientists to obtain data regarding the arctic sea ice as soon as possible. Baron's diagram of market and non-market interactions shown in Figure 9 introduces the concept of timing by aligning the stakeholders and their interactions along a horizontal axis of time. A similar chart could be created for the value network methodology presented in this thesis. Also, the stakeholder scoring questionnaires presented in Section 3.1 could be modified to incorporate the attribute of timeliness.
- **Further develop the mathematical theory underlying the value loop calculation method.** Section 4.8.5 discussed one of the preliminary findings of the concurrent theoretical work by the MIT Systems Architecture group, which is to use the formula $A*B*C^2$ rather than $A*B*C$ to calculate the value flow scores. Further work on the theoretical foundation for the stakeholder value network analysis will provide a more sound justification for the value loop calculation methods and the overall methodology presented in this thesis.

4.11 Conclusions

The stakeholder analysis conducted within this thesis yielded a wealth of useful, insightful results that can be used by Earth Observations Program planners. Section 1.7 listed the five specific objectives of this thesis as follows:

- **To** develop a more complete understanding of the stakeholders of an Earth Observations Program **by** articulating the goals, objectives, and needs of every stakeholder **using** information contained in stakeholder policy or strategy documents, mission statements, websites, the decadal survey, government reports, legislation, and other official stakeholder documents.

- **To** understand the important interactions among all stakeholders **by** constructing a detailed stakeholder map showing the inputs and outputs of each stakeholder **using** information garnered from the articulation of stakeholder needs
- **To** identify the most important stakeholders, the highest value-producing interactions among stakeholders, and most important NASA & NOAA outputs **by** conducting a rigorous quantitative stakeholder analysis **using** the stakeholder value network analysis approach.
- **To** complement the recommendations of the decadal survey **by** providing more specific, targeted insights and recommendations **using** the results of the qualitative and quantitative stakeholder analyses presented in this thesis.
- **To** make the stakeholder analysis techniques presented n this thesis more broadly applicable as a business practice **by** generalizing the methodology for conducting the analysis **using** a set of templates for commonly encountered projects or systems with significant stakeholder concerns.

I achieved the objectives of this thesis by developing a qualitative and quantitative stakeholder model that yielded useful, insightful results and recommendations for the Earth observations program.

The stakeholder analysis articulated the objectives and needs of all the major stakeholders in the model, in contrast to the decadal survey, which focused mainly on scientific objectives. The objectives, needs, and inputs template allows for easy and direct traceability of stakeholder outputs and inputs to the satisfaction of specific stakeholder needs.

The complete stakeholder model captures all the major inputs and outputs, or value flows, between each stakeholder, while the simplified stakeholder model indicates only the most important stakeholders and value flows. This provides a succinct description of the role of each major stakeholder in the Earth Observations Program, their most important contributions to the program, and the specific inputs and outputs that contribute the most value to the stakeholder network.

The value loop analysis yielded numerous insights about the most important stakeholders, most important value flows and value loops within the system, and the most important outputs and inputs to NASA/NOAA. It also indicated the relative importance of each science category corresponding to the six science-themed decadal survey panels, which can be useful for prioritizing missions.

The insights and recommendations yielded from the stakeholder analysis, described next in Chapter 5, are largely consistent with those in the decadal survey. In some cases, the stakeholder analysis provided additional information that produced more specific or targeted insights and recommendations than those in the decadal survey. In other cases, the value loop analysis results differed with the decadal survey recommendations, and the analysis yielded some additional recommendations that were not included in the decadal survey.

Thus, the specific objectives and central hypothesis of this thesis are confirmed.

Central Thesis Question:

To establish a set of priorities for the Earth observations program, can a mathematically rigorous stakeholder analysis yield additional or more specific insights and recommendations than the group consensus process used by the Decadal Survey Committee? CONFIRMED

Chapter 5 describes the major insights yielded from the stakeholder value network analysis and presents a list of recommendations for the Earth Observations Program. This chapter is intended to function as a stand-alone executive summary for program planners interested in the results of the stakeholder analysis.

Chapter 6 presents a generalized description of the stakeholder analysis process described in this thesis. It is intended to function as a stand-alone document that can be used as a handbook for conducting a rigorous qualitative and quantitative stakeholder analysis as a general business practice.

5 Major Insights and Recommendations

This chapter presents a summary of insights and recommendations based on the results of the complete analysis of the stakeholder value network model. The models and analyses that support these results are described in detail in Chapters 2, 3, and 4 of this thesis. The specific objective of this chapter is as follows:

Objective of Stakeholder Analysis Results:

- **To** complement the recommendations of the decadal survey **by** providing independent verification of the decadal survey recommendations; and **by** providing more specific, targeted insights and recommendations **using** the results from the stakeholder value network analysis.

This chapter is organized into the following sections:

- **Section 5.1: Insights from Stakeholder Analysis.** This section describes the major insights gained from stakeholder value network analysis.
- **Section 5.2: Program Goals Derived from Stakeholder Analysis.** This section presents a list of program goals for the Earth Observations Program, derived from the analysis of the most important NASA/NOAA outputs and the most important value loops within the stakeholder network.
- **Section 5.3: Recommendations for the Earth Observations Program.** This section presents a set of specific recommendations for the Earth Observations Program, derived from the results of the stakeholder value network analysis. A comparison is made between these recommendations and those made by the decadal survey.

5.1 Insights from Stakeholder Analysis

5.1.1 Insights Related to the Stakeholder Model

This section describes the major insights related to the stakeholder model developed for this thesis. Each section includes a reference to the relevant thesis chapter.

- **The "stakeholder value network analysis" described in this thesis yields additional useful information that traditional stakeholder analysis techniques may not provide.** The value network method is superior because it captures transactions involving three or more stakeholders involved in value loops; whereas traditional methods consider only direct, bilateral transactions between the central stakeholder and the other stakeholders. For example, Freeman's method shown in Figure 96 below would not fully capture the importance of the Public as a stakeholder because there are no direct links flowing from the Public back to NASA. There are, however, numerous indirect links from the Public to NASA through other stakeholders in the stakeholder value network. (Chapter 2)

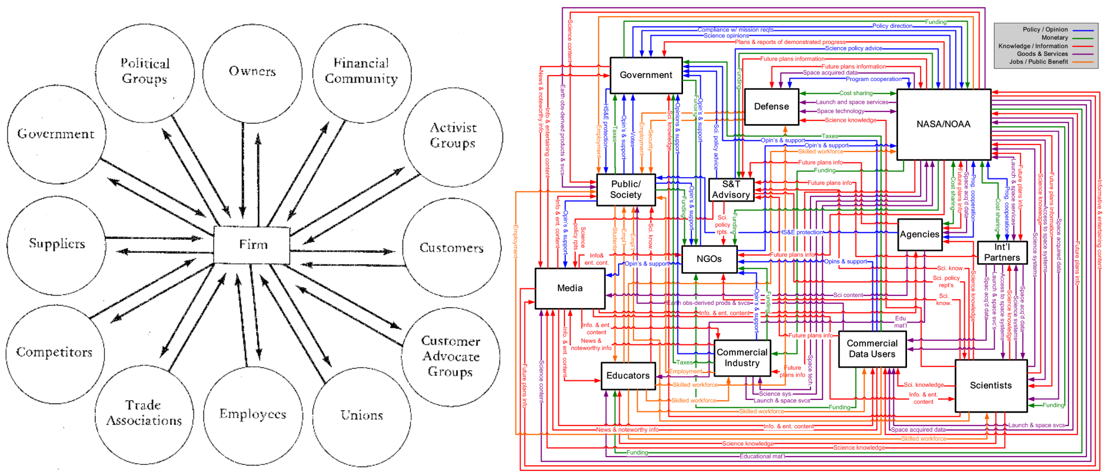


Figure 96. (Left) Traditional stakeholder map [Freeman]; (Right) Stakeholder value network map

- **The stakeholder map can be separated into four quadrants representing a high-level abstraction of the process by which the Earth Observations Program delivers value to its stakeholders.** These four quadrants represent policy makers and funding providers; data providers; data users; and public, beneficiaries, and advocates. This is referred to as the "Level 1" stakeholder map. (Chapter 2)

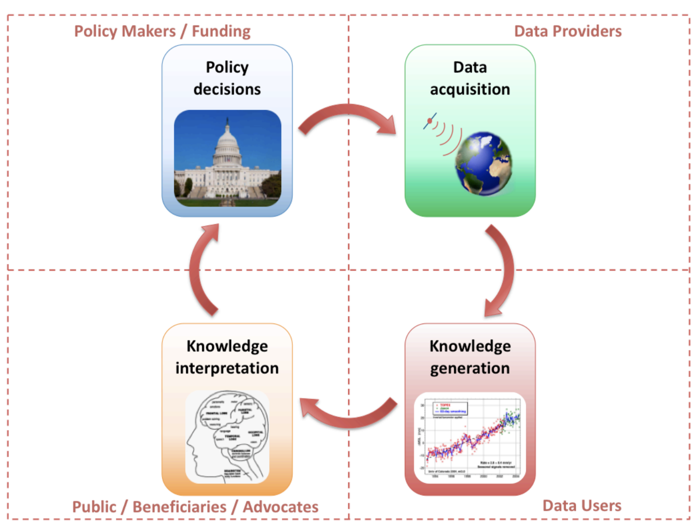


Figure 97. High-level map representing the four major categories of stakeholders for the Earth Observations Program

- **The 13 stakeholders in the model can be arranged within these four quadrants based on their roles within the Earth Observations Program. We identified 190 value flows and added them to the stakeholder map.** This map, called the "Level 2" map, forms the basis for the qualitative and quantitative stakeholder analyses. A more detailed "Level 3" map can be drawn to illustrate the hierarchy and aggregation within some of the stakeholder groups, but it contains too much detail to include in the final analysis. (Chapter 2)

Level 2 Map **190 Value Flows**

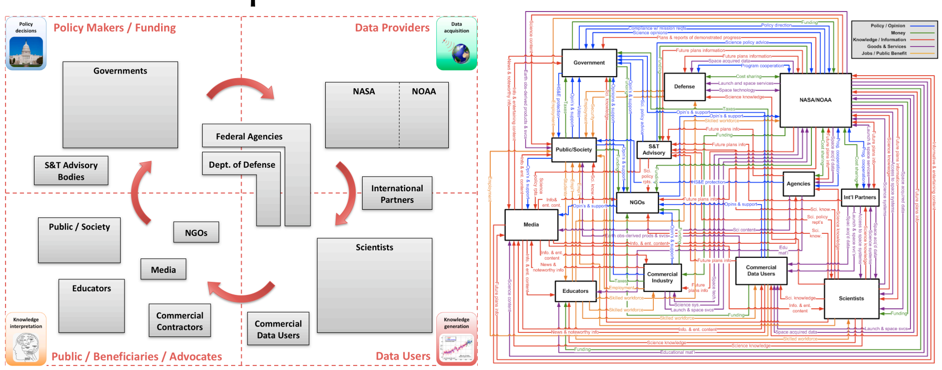


Figure 98. (Left) Stakeholder map with the 13 major stakeholders; (Right) Stakeholder value network showing 13 stakeholders and 190 value flows

- **A simplified model shows the most important stakeholders and value flows based on the value loop analysis. This includes four primary stakeholders, five secondary stakeholders, and 28 value flows.** The primary stakeholders are NASA/NOAA, Scientists, Government, and Public. The secondary stakeholders are S&T Advisory Bodies, International Partners, Commercial Industry, Commercial Data Users, and Educators. (Chapter 3)

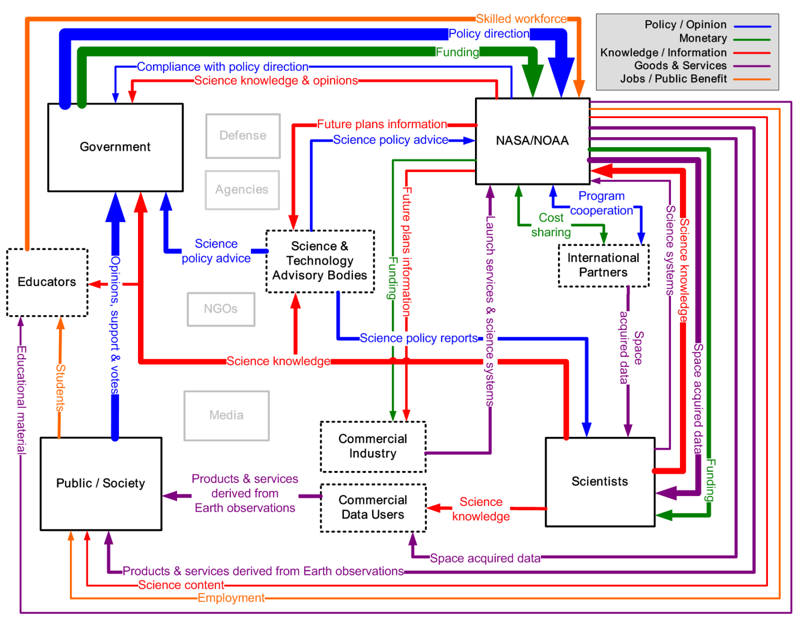
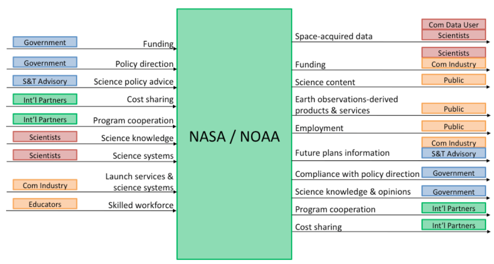


Figure 99. Simplified stakeholder map showing the most important stakeholders and value flows

- **Many of the numeric scores assigned to value flows can be validated using literature or data-gathering techniques.** For example, surveys of Congressmen or analyses of government records can be used to validate the relative rankings of information flows into the Government. Increasing the validity of the numeric value flow scores results in increased confidence in the model's results. (Chapter 3)

The following sections provide a brief description of the simplified roles of each stakeholder based on the analysis of their most important functions within the stakeholder network.

NASA/NOAA:

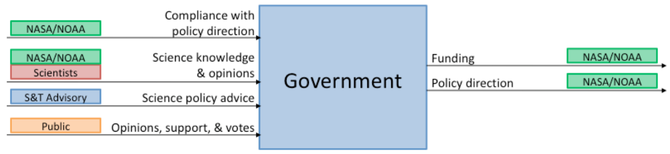


As the central stakeholder in the Earth Observations Program, NASA/NOAA has the greatest number of interactions with other stakeholders. It interacts directly with stakeholders from all four quadrants of the stakeholder map. The stakeholder analysis was performed from NASA/NOAA's perspective, so many of the important insights and recommendations involve NASA/NOAA.

Scientists

Scientists are the second primary stakeholder. Their major role is converting space-acquired data into science knowledge. Scientists receive inputs primarily from NASA/NOAA, International Partners, and S&T Advisory Bodies. The two most important outputs from Scientists are science systems to NASA/NOAA and science knowledge, which flows to stakeholders from all four quadrants on the stakeholder map.

Government

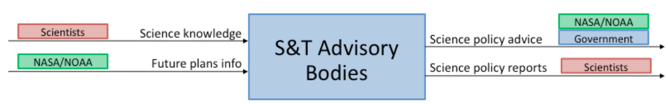


The Government is the third primary stakeholder. Its major role is using science knowledge, science policy advice, opinions, and support to establish policy direction and provide funding to NASA/NOAA. The Government receives inputs from stakeholders from all four quadrants on the stakeholder map. Its most important outputs flow to NASA/NOAA.

Public

The Public is the fourth primary stakeholder. Its major role is to use science knowledge and Earth observations-derived products and services to provide inspired students and to inform Public opinions and provide political support. The Public receives inputs from NASA/NOAA and Commercial Data Users. Its important outputs are to Educators and the Government.

S&T Advisory Bodies



S&T Advisory Bodies are the most important among the secondary stakeholders. Their role is to use science knowledge and NASA/NOAA's future plans information to provide science policy advice and reports to NASA/NOAA, the Government, and Scientists.

International Partners

International Partners play a simple but potentially high-value role as a provider of space-acquired data to Scientists. Their most important inputs and outputs are bilateral cost sharing and program cooperation with NASA/NOAA.

Commercial Data Users

Commercial Data users are the third secondary stakeholder. They use space-acquired data from NASA/NOAA and science knowledge from Scientists to provide Earth observations-derived products and services to the Public.

Educators

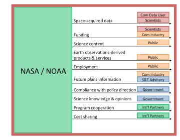
Educators are the fourth secondary stakeholder. They primarily use science knowledge from Scientists to transform inspired students into a skilled and motivated workforce for NASA/NOAA.

Commercial Industry

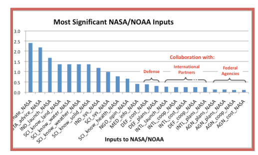
Commercial Industry is the fifth and final secondary stakeholder. It's most important role is to use funding and future plans information from NASA/NOAA to provide launch services and science systems to NASA/NOAA.

5.1.2 Insights Related to Value Loop Results

This section describes the major insights from the value loop analysis described in detail in Chapter 4.

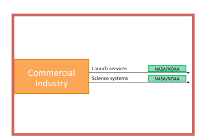


- **The value loop analysis indicates which outputs from NASA/NOAA have the greatest potential for creating value to the stakeholder network and returning value back to NASA/NOAA.** The analysis indicates that NASA/NOAA should prioritize its outputs in approximately the following order:
  1. Data and resources to Scientists
  2. Future plans information and funding to S&T Advisory Bodies
  3. Program cooperation and cost-sharing with International Partners
  4. Future plans information and funding to Commercial Industry
  5. Data and future plans information to Commercial Data Users
  6. Earth observations-derived products & services and employment to the Public



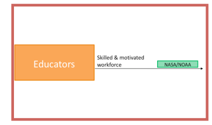
- **The value loop analysis indicates that it is inherently difficult for NASA/NOAA to achieve significant collaboration with Defense, International Partners, and other Federal Agencies.** The analysis provides an indication of NASA/NOAA's ability to affect each of its inputs by changing the level of its outputs. The lowest-scoring inputs were cost-sharing and collaborative efforts with Defense, International Partners, and Agencies—indicating an inherent difficult in the ability to increase the level of those inputs.

- **NASA/NOAA would reap greater benefits from collaboration with International Partners than it would with Defense or other Federal Agencies.** The value loop analysis indicates that International Partners are uniquely suited to provide and receive value from collaborative efforts with NASA/NOAA. NASA/NOAA and International Partners' objectives are closely aligned; whereas the objectives of Defense and Agencies differ more substantially from those of NASA/NOAA. Because of the lack of high-value feedback loops, collaboration with Defense and Agencies offers less incentive to NASA/NOAA.

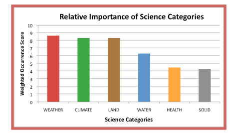


- **One of Commercial Industry's most important outputs is launch services to NASA/NOAA.** The potential retirement of the Delta II launch vehicle and the exorbitant cost of using larger launch vehicles are major issues currently under investigation by NASA. A commercially available medium-lift launch vehicle, at reasonable cost and high reliability, would generate significant value to NASA/NOAA and the entire stakeholder network.

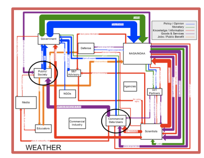
- **NASA/NOAA's third most "affectable" input is the flow of skilled workers from Educators, after policy direction and funding from the Government.** This ranks higher than science knowledge from Scientists, which is one of the primary benefits of the Earth Observations Program. This indicates that NASA/NOAA has a major role to play in using science knowledge to inspire students to pursue careers in science and engineering.



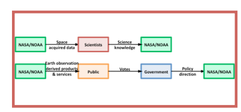
- **The value loop analysis produces an objective ranking of the relative importance of each decadal survey science category.** This ranking corresponds to the total potential value that each science category can contribute to the stakeholder network. These results can provide an objective, transparent metric that can be used as a starting point or the basis for prioritization of missions from each of the six science categories.



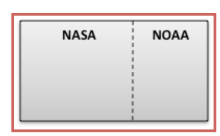
- **Weather and land-use missions provide roughly the same value as climate-related missions.** The value loop analysis indicates that weather, climate, and land-use missions provide the most value to the stakeholder network. Climate provides value primarily through the delivery of science knowledge to NASA/NOAA and the Government, while weather and land-use missions provide value primarily through the delivery of Earth observations-related products and services from Commercial Data Users to the Public. Because of this, Commercial Data Users have a potentially significant role to play in delivering value from weather and land-use missions.



- **Many climate-related value flows appear in shorter, high-scoring value loops; whereas many weather- and land-related value flows appear in longer, lower-scoring value loops.** Because of this, the benefits of climate-related missions may be realized more easily or quickly than the benefits from weather or land use missions.



- **The level of detail provided in this stakeholder model is not enough to adequately distinguish between NASA and NOAA.** NASA and NOAA were treated as a single stakeholder for this analysis. A more in-depth analysis of the operational boundaries between the two agencies would be required in order to determine how the results of the analysis would differ by considering NASA or NOAA individually.



5.2 Program Goals Derived from Stakeholder Analysis

The results from the value network analysis were used to derive high-level goals and requirements for the Earth observations program. The most important NASA/NOAA outputs and the highest-scoring value loops can be translated into specific program goals. Each program goal addresses a specific output from NASA/NOAA as well as the subsequent value flows created by the output, which represent the intent of the output. Figure 100 below shows the template for translating value loops into program requirements.

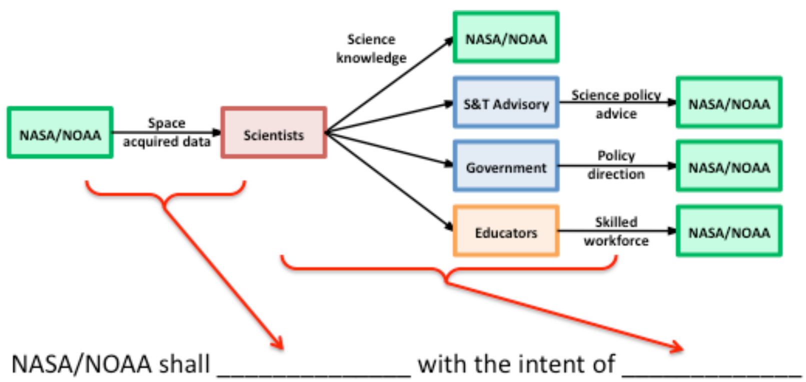


Figure 100. Template for translating value flows into program requirements

This template produces specific program goals that address the ways in which NASA/NOAA's outputs deliver the highest value to the stakeholder network, and ultimately the biggest returns back to NASA/NOAA. Using the top value loops shown previously in Section 4.3 and the important NASA/NOAA outputs determined in Section 4.5, the following is a list of program requirements that were derived from this value loop analysis. The program goals are prioritized based on the sum of value loop scores associated with each output, with the most important goals at the top of the list. The goal statements have also been separated into goals that influence *what* NASA/NOAA does and *how* NASA/NOAA does business:

"What" goals:

- NASA shall provide space-acquired data of interest to the Scientific Community, as well as funding and access to its space systems with the intent of:
  - Generating Earth science knowledge consistent with NASA's science program objectives
  - Fulfilling the recommendations of relevant Science & Technology Advisory Bodies
  - Providing the Government with policy-relevant science knowledge
  - Providing Educators with inspirational science content to promote student interest in science, technology, engineering, and mathematics

- NASA shall provide space-acquired Earth observation data to Commercial Data Users with the intent of:
    - Providing innovative products and services derived from Earth observations data to the Public

- NASA shall develop products and services derived from satellite Earth observations for the Public with the intent of:
    - Generating public support of NASA's Earth Observations Program
    - Inspiring students to pursue careers in science, technology, engineering, and mathematics
    - Generating political support for Earth Observations Programs

- NASA shall develop Earth science-related educational material for Educators with the intent of:
    - Inspiring students to pursue careers in science, technology, engineering, and mathematics
    - Creating a skilled and educated workforce for the future

"How" goals:

- NASA shall provide information regarding its future program plans and priorities to Science & Technology Advisory Bodies with the intent of:
    - Obtaining useful science policy advice
    - Influencing the science policy advice given to the Government
    - Providing direction for Scientists to produce sensors, other science systems, and Earth science knowledge

- NASA shall provide information about its future program plans to the Scientific community with the intent of:
    - Procuring sensors and other science systems
    - Generating Earth science knowledge consistent with NASA's science program objectives
    - Fulfilling the recommendations of relevant Science & Technology Advisory Bodies
    - Providing the Government with policy-relevant science knowledge

- NASA shall cooperate with International Partners, including providing future plans information and seeking cost-sharing arrangements for future missions with the intent of:
    - Providing additional or complementary sources of space-acquired data to Scientists
    - Reducing costs or eliminating the need for certain future missions

- NASA shall provide financial resources and information about its future program plans to Commercial Industry with the intent of:
  - Supporting the development of launch services for the Earth Observations Program
  - Supporting the development of science systems for the Earth observations program

- NASA shall comply with policy directives and specific program requirements from the Government with the intent of:
  - Guaranteeing future funding levels and priorities
  - Ensuring favorable policy direction in the future

- NASA shall provide stable and rewarding employment to its workforce with the intent of:
  - Generating political support for Earth science programs

- NASA shall periodically provide science knowledge, opinions, and information about its future program plans to the Government with the intent of:
  - Influencing future Earth science program objectives
  - Influencing future funding priorities and levels

For this analysis there are more "how" goals than "what" goals. The "what" goals listed above are fairly broad but suggest two things: First, NASA should prioritize the data it produces not only to be consistent with its own science priorities, but also to provide science knowledge needed by Government policy-makers. Second, in addition to Earth science data, NASA/NOAA should develop innovative products and services for public, educational, and commercial use. These requirements reinforce the theme of the decadal survey that both scientific inquiry and societal needs should drive mission requirements and the architecture of the entire program.

The "how" goals recommend things that NASA/NOAA should do to support the Earth Observations Program. These involve recommendations on where to invest funding and resources, which information should be shared with other stakeholders, and how to ensure that it continues to receive adequate resources and support from the Government in the future.

The following section presents a set of recommendations for the Earth Observations Program. The recommendations incorporate many of the ideas contained in the program requirements listed above, as well as insights from other aspects of the value network analysis.

5.3 Recommendations for the Earth Observations Program

This section presents a set of recommendations based on the results and insights of the stakeholder analysis presented in this thesis. The table below compares the recommendations from this analysis with a subset of the recommendations put forth by the decadal survey. There are three classes of recommendations presented here:

- Recommendations that are generally similar to those in the decadal survey (similar)
- Recommendations with minor changes to those in the decadal survey, including greater level of detail or specificity (minor change)
- Recommendations that differ substantially from those in decadal survey (substantial change)

The table below indicates the class of each recommendation. Recommendations from the decadal survey include the page number from the report in parentheses. Suggested changes to the decadal survey recommendations are emphasized in bold font.

Earth Science Decadal Survey	MIT Stakeholder Analysis
Achieving the vision of the Decadal Survey:	
The U.S. government, working in concert with the private sector, academe, the public, and its international partners, should renew its investment in Earth observing systems and restore its leadership in Earth science and applications. (p.1-3)	The U.S. government, working in concert with NASA, NOAA, the scientific community, the public, commercial sector, international partners, and educational institutions should renew its investment in Earth observing systems and restore its leadership in Earth science and applications. (similar)
A formal interagency planning and review process should be put into place that focuses on effectively implementing the committee recommendations and sustaining and building the knowledge and information systems for the next decade and beyond. (p.3-16)	A science & technology advisory body should periodically review the status of the Earth Observations Program and should continually **reassess key assumptions** from the decadal survey. The advisory body should **use sophisticated stakeholder analysis and system architecture modeling tools** to recommend changes to the program based on the updated progress and key assumptions. (substantial change)

Earth Science Decadal Survey	MIT Stakeholder Analysis
Consideration of societal benefits:	
Earth system observations should be accompanied by a complementary system of observations of human activities and their effects on Earth. (p.3-17) Socioeconomic factors should be considered in the planning and implementation of Earth observation missions and in developing the Earth Information System. (p.3-18)	The needs of the public should factor heavily into the prioritization and design of Earth observation mission. In addition to pure science benefits, missions should be selected based on their contribution to specific social, economic, and policy-related benefits. (similar)
Missions related to specific science categories:	
NASA should continue sustained measurements of precipitation and land cover by: • Launching GPM on or before 2012 • Securing a replacement to Landsat 7 data before 2012 The committee also recommends that NASA continue to seek cost-effective, innovative means for obtaining land cover change information. (p.2-11)	NASA & NOAA should prioritize missions that provide **weather**, climate change, and land-use measurements. These three categories of measurements have the potential to deliver the greatest value to the stakeholders. (minor change)
Management of agency roles and responsibilities:	
The Office of Science and Technology Policy, in collaboration with the relevant agencies, and in consultation with the scientific community, should develop and implement a plan for achieving and sustaining global Earth observations This plan should recognize the complexity of differing agency roles, responsibilities, and capabilities as well as the lessons from implementation of the Landsat, EOS, and NPOESS program. (p.3-5)	An independent **Science & Technology Advisory Body**, in collaboration with NASA & NOAA, **international partners**, relevant agencies, and the scientific community should develop and implement a plan for achieving and sustaining global Earth observations. The plan should precisely define the roles, responsibilities, and capabilities of the participating agencies. (minor change)

Earth Science Decadal Survey	MIT Stakeholder Analysis
Assimilation and distribution of measurements:	
In order to evolve the global observing system in a cost-effective way to meet broad scientific and societal objectives and to extract maximum useful information from multiple observations and/or sensors, teams of experts should be formed to focus on providing comprehensive data sets that combine measurements from multiple sensors. These teams should consider assimilation of data from all sources, including commercial providers and international partners. (p.3-9) As new Earth observation missions are developed, there must also be early attention to developing the requisite data processing and distribution system, and data archive. Distribution of data should be free or at low cost to users, and provided in an easily-accessible manner. (p.3-10)	In order to avoid duplicative efforts and to extract maximum use from Earth observation data from multiple sources, and independent authority should be formed to manage the integration of data from multiple sources. This authority should manage the assimilation and distribution of data from all sources, including NASA, NOAA, other agencies, international partners, and commercial data providers. (similar) Distribution of data should be free for scientific and academic purposes. To take advantage of the emerging commercial uses for Earth observation data, NASA & NOAA should consider **innovative approaches to partnerships with commercial data users, including mission cost-sharing, development of new commercial markets for data, and commercial licensing agreements for data access**. (substantial change)
Leveraging international efforts:	
Restructure or defer missions if international partners select missions which meet most of the measurement objectives of the recommended missions, then a) through dialogue establish data access agreements, and b) establish science teams to use the data in support of the science and societal objectives. Where appropriate, offer cost-effective missions that help extend the values of those missions. These actions should yield significant information in the identified areas at significantly less cost to the partners. (p.3-14)	NASA & NOAA should **create a permanent office to monitor the development and capabilities of international Earth observations missions** and to serve as a liaison to increase international cooperative efforts. NASA & NOAA should leverage the capabilities of international missions to reduce the number of required decadal survey missions. NASA & NOAA should also pursue cost- and data-sharing arrangements with international partners. (minor change)

Earth Science Decadal Survey	MIT Stakeholder Analysis
Educational outreach efforts:	
NASA, NOAA, and USGS should pursue innovative approaches to educate and train scientists and users of Earth observations and applications. A particularly important role is to assist educators in inspiring and training students in the use of Earth observations and the information derived from them. (p.3-18)	NASA & NOAA should pursue innovative approaches to inspiring students to pursue careers in Earth science and applications. NASA & NOAA should work closely with scientists and educators to develop educational material and train students in the use of Earth observations and the information derived from them. (similar)

Additional recommendations:

NASA & NOAA should prioritize cooperative efforts with International Partners over cooperation with the Department of Defense or other Federal Agencies. Investing resources to cooperate with International Partners provides the strongest feedback loops to deliver value to the entire stakeholder network and return value to NASA & NOAA. (substantial change)

NASA & NOAA should seek some cooperation with other Federal Agencies for missions related to human health & security and solid Earth hazards & natural resources. These missions return relatively less value to NASAA & NOAA than weather, climate change, and land-use missions. Partners for these missions might include USGS, Department of Energy, National Institutes of Health, Environmental Protection Agency, or Center for Disease Control. (minor change)

NASA should provide funding and other resources to support the development of low-cost, reliable medium-lift launch vehicles by commercial industry. The potential retirement of the Delta II launch vehicle and the excess cost of using larger launch vehicles are major issues currently facing NASA. A commercially available medium-lift launch vehicle would generate significant value to NASA/NOAA and the entire stakeholder network. (substantial change)

NASA & NOAA should investigate the use of marketing, branding or other means to inform recipients of knowledge and users of Earth observations-derived products and services that the information originated with NASA & NOAA Earth observation missions. In long value chains involving multiple stakeholders, it may be difficult or impossible to know that a particular value flow is part of a chain that originated with an output from NASA & NOAA. Keeping the public, beneficiaries, and advocacy groups more aware of NASA & NOAA's programs will help increase public support for favorable policy direction and funding for NASA & NOAA in the future. (substantial change)

6 Stakeholder Value Network Modeling Process

This chapter is intended to be a stand-alone process "handbook" for conducting a rigorous qualitative and quantitative stakeholder analysis using the techniques presented in this thesis. This handbook provides a step-by-step process for completing the stakeholder analysis. The process presented here is general and suitable for use in nearly any circumstance involving multiple interacting stakeholders.

This handbook will use the terms "enterprise" and "project" throughout the description of the stakeholder analysis process. Both of these terms are broadly defined. "Enterprise" refers to the central organization from whose perspective the stakeholder analysis is being conduced. The enterprise can be a company, a division or project within a company, a government agency, a group of individuals, or any other type of organization. "Project" refers to the activities of the enterprise that are the subject of the analysis. A project can be a specific project or program, or it can represent the everyday activities of the organization.

Throughout this handbook, examples are provided for a stakeholder analysis conducted for NASA's satellite Earth Observations Program. The referenced figures are attached at the end of the document. These help illustrate the ideas and concepts described in this handbook. The broad steps in the stakeholder value network analysis are shown below in Figure 101. The following sections describe each step in detail.

1. **Define the Enterprise and Project**
2. **Identify stakeholders**
3. **Identify stakeholder objectives and needs**
4. **Develop a stakeholder map**
5. **Visualize stakeholder value flows**
6. **Characterize the needs and value flows**
7. **Quantify the value flows**
8. **Calculate value loops**
9. **Analyze value loop results**
10. **Create simplified stakeholder map**
11. **Derive program requirements from value loop analysis**

Figure 101. The steps involved in the value network analysis process

6.1 Define the Enterprise and Project

The first task in the stakeholder value network process is to define the critical players in the stakeholder network—the Enterprise and the project or program for which the stakeholder analysis is being conducted. The following questions can guide this part of the discussion:

- Will the analysis consider the entire company (or agency), or just the specific business unit (or division)?
- What are the Enterprise boundaries?
- What is the scope of the project?
- What are the project boundaries?
- What is the context within which the enterprise and project exist?

As the first step in the process, the Enterprise and the project for which the stakeholder analysis is being conducted will be clearly defined before identifying the other relevant stakeholders.

6.2 Identify the Stakeholders

Identifying the stakeholders to include in the model is one of the most important parts of the process. Failure to include any key stakeholders could create unexpected difficulties should that stakeholder begin exerting influence later during the life cycle of the project.

Potential stakeholders are those who (1) have a direct or indirect affect on the enterprise's project or activities, **or** (2) receive direct or indirect benefits from the enterprise's project or activities, **or** (3) possess a significant, legitimate interest in the enterprise's project or activities.

The general types of stakeholders can include the following:

- "Stakeholders": Those who have a direct stake in the project
- Beneficiaries: Those who derive benefits from the project
- Users: The ultimate consumers or users of the project's outputs
- Agents: Those who act on behalf of other stakeholders in the model
- Institutions: Official bodies or organizations that directly impact the project
- Interests: Those with a significant, legitimate interest in the project's outputs, who may not be considered a direct stakeholder in the traditional sense

Table 37 below shows common stakeholder classes that are often included in stakeholder analyses. This list is not exhaustive, and not all those in the list may be necessary to include in any particular analysis.

Table 37. Stakeholder classes to consider for a stakeholder analysis

• Business Partners / Joint Venture
• Business units
• Competitors
• Contractors
• Corporation / Enterprise
• Economy / Commercial industry
• Educational institutions
• Employees
• Financial sector
• Government (national, regional, local)
• Interest groups
• International governments
• Investors
• Local community
• Markets
• Media
• Non-governmental organizations (NGOs)
• Policy-making / Advisory bodies
• Public / Society
• Public Agencies
• Regulators
• Suppliers
• Trade groups / Industry consortiums
• Unions
• Workforce

Often the preliminary list of stakeholders is too long to include in full detail throughout the entire stakeholder analysis. Once the initial stakeholders have been identified, they can be refined into a smaller, more manageable number of stakeholders. Reducing the number of stakeholders to no more than approximately 10 is desirable for two reasons – first, limiting the number of stakeholders helps keep the model conceptually manageable. Second, the stakeholder network model treats each stakeholder as a node, and the number of possible links in the system scales combinatorially with the number of nodes. Therefore, limiting the number of stakeholders also helps keep the model computationally manageable.

The challenge in this part of the process it to define the stakeholder groups so that the model is as simple as possible yet captures enough complexity to produce insightful results. Two classification schemes can be used to simplify the model: hierarchy and aggregation. Hierarchy involves combining stakeholders such that each level within the hierarchy has jurisdiction or control over lower levels. Hierarchy is often useful to use for Government stakeholders, which might include numerous branches of government or individual offices within each branch. Aggregation, described further in the next section, involves combining multiple stakeholders with similar roles or functions into a single stakeholder.

This step in the process will yield an initial list of no more than approximately 10 stakeholders whose objectives and needs will be rigorously articulated in the next step of the process.

6.3 Identify Stakeholder Objectives and Needs

Once the preliminary set of stakeholders have been identified, it is crucial to identify the major goals and objectives of each stakeholder. Performing a useful, informative stakeholder analysis requires developing an appreciation for the interests of each stakeholder as well as a deep understanding of how each stakeholder contributes to and derives value from the system.

To help with this, the template shown in Figure 102 can be used to succinctly articulate the role, objectives, and specific needs of each stakeholder. It also shows the inputs the stakeholder receives from other stakeholders. The template enables easy and direct traceability of stakeholder inputs to the satisfaction of specific needs and objectives. The template in Figure 102 has been populated with information for the Scientists stakeholder group in the NASA satellite Earth Observations Program.

Beginning with the top box in the template, define the role of each stakeholder within the context of the project. Below that, determine the stakeholder's objectives, which are goal statements that are often published on a stakeholder's website or can be found in policy and strategy documents, mission statements, or other official documents. Below that, list the stakeholder's specific needs, which are the resources required by the stakeholder in order to achieve its objectives. The specific needs can often be determined in the same manner as the objectives. Each stakeholder receives specific inputs from other stakeholders that fulfill its specific needs. List these inputs along the left side of the template; they will become "value flows" as described in the next section.

As mentioned in the previous section, after defining and articulating the role, objectives, specific needs, and inputs to each stakeholder, it may be necessary to revise the stakeholder map to reflect the more clearly defined stakeholder roles. Aggregation of multiple stakeholders into a single stakeholder can be used if two or more stakeholders have identical, or nearly identical, inputs and outputs in the model. This is similar to the concept of market segmentation—each of the stakeholders to be aggregated has approximately the same interests at the level of fidelity in the model.

After this step in the process, the list of stakeholders should be finalized such that each stakeholder has a unique set of inputs and outputs and fulfills a unique role within the stakeholder network.

6.4 Develop a Stakeholder Map

Once the stakeholders have been identified, it is useful to develop a baseline visual map showing each major stakeholder. Often the stakeholders can be arranged on the map such that areas of the map represent different general functions within the stakeholder network. Developing a coherent map can help the user better visualize and understand key stakeholder interactions. Figure 103 shows the 13 stakeholders for the NASA satellite Earth Observations Program.

Another useful task is to develop a higher-level "one-up" and a more detailed "one-down" version of the stakeholder map. Figure 104 shows the higher-level map for the NASA case. The one-up version of the map shows a general, high-level view of the context within which the enterprise and project operate. This may correspond to general functional groups to which the stakeholders belong. The one-up map is often useful to show to policy- or decision-makers to establish a broader context for the stakeholder analysis. The one-down version of the map shows a finer level of detail, including the hierarchy or aggregation within each stakeholder, to identify specific individuals or sub-groups that are involved in the transactions among the stakeholders. Figure 105 shows the more detailed stakeholder map for the NASA case. Although the analysis will not necessarily include all the detail in the one-down map, the information is useful to develop a greater appreciation for the finer details of the stakeholder network.

The development of the stakeholder map is a continuous process that will be revisited as the analysis progresses. The map may change based on new information about each stakeholder's role or objectives, or as decisions are made regarding the level of hierarchy or aggregation to consider for certain stakeholders, or as larger trends within the model become apparent.

6.5 Visualize Stakeholder Value Flows

Each stakeholder input identified in the Section 6.3 "Identify Stakeholder Objectives and Needs" becomes a "value flow" in the stakeholder model. A value flow flows out of one stakeholder and into another; it represents the delivery of value to the receiving stakeholder. Thus, each value flow satisfies a specific stakeholder need. To provide the most useful results, the model should contain value flows that are architecturally significant. This way, the results of the stakeholder analysis can be used to influence the architecture of the project and to derive project requirements.

Only stakeholder inputs, rather than stakeholder outputs, are considered when defining the value flows in the model. It is generally easier to identify the resources a stakeholder needs to fulfill its needs and objectives than it is to identify all the stakeholder's outputs to other stakeholders. Also, each stakeholder may produce outputs that are irrelevant or not useful to the other stakeholders, and these should not be included in the model. Alternatively, a stakeholder that was initially included in the model may not produce any inputs to the other stakeholders in the model. This would signify a superfluous stakeholder that should not be included in the model. This method of identifying stakeholder inputs helps ensure that the model is complete and consistent, such that every value flow in the model delivers positive value to at least one stakeholder. It also prevents cases where no stakeholder exists in the model to provide a critical input to another stakeholder.

Add the value flows to the stakeholder map by drawing arrows connecting the giving and receiving stakeholders. It is useful to use colors to distinguish different types of value flows. A good rule of thumb for the maximum number of value flows to include is 10 times the number of stakeholders in the model. Figure 106 shows the complete stakeholder value flow map for the NASA satellite Earth Observations Program, which contains 13 stakeholders and 190 value flows. The map includes five types of flows: policy-related, monetary, knowledge & information, goods & services, and public benefit flows.

Once the value flows have been added to the map, it becomes easier to visualize the connections among all the stakeholders in the model. The map indicates the inputs and outputs of each stakeholder and the degree of "connectedness" between stakeholders. It may be possible to identify cycles or patterns within the value flow diagram; for example, in the NASA case, value flows tend to travel counter-clockwise through the stakeholder map.

Another way to visualize the value flows is to separate them by category. This helps to simplify the diagrams by making the value flows more legible and comprehendible. It can also be useful to help identify any potential missing value flows during the creation of the model, since it is sometimes easier to think about how a single type of value flow, such as money, flows throughout the system. Figure 107 shows each of the five categories of value flows included in the complete NASA stakeholder model.

The process described above for articulating the stakeholder objectives, needs, and inputs and determining the value flows should involve several individuals, including those already familiar with this stakeholder analysis technique, those with expert knowledge and experience related to the project, and those somewhat unfamiliar with the project who may bring a fresh perspective to the process. The discussion should be open and inclusive to capture as many stakeholders and value flows as possible. The goal of the analysis is to generate a model that is as complete as possible.

At this point, the model should include the final set of stakeholders and value flows, which have been checked for the following:

- Similar roles: Stakeholders with similar inputs and outputs should be aggregated into a single stakeholder
- Hierarchy: An appropriate level of hierarchy should be established to include the important value flows without including too much detail
- Completeness: A complete model is one where each stakeholder has inputs from and outputs to other stakeholders in the model; there are no stakeholder needs that are satisfied by stakeholders not included in the model; and there are no "dangling outputs" from any stakeholders that do not act as an input to at least one other stakeholder in the model.

This completes the qualitative construction of the model. The model can now be quantified, beginning with the characterization of each value flow as described in the next section.

6.6 Characterize the Needs and Value Flows

Once all the value flows have been defined, characterize the key attributes of each need or value flow input. The following is a list of common need characteristics to consider:

- Intensity of the need
- Satisfaction level if need is fulfilled
- Regret level if need goes unfilled
- Awareness of need
- Urgency to fulfill need
- Timing of occurrence of needs

The following is a list of common value flow input characteristics to consider:

- Importance of a particular supplier in fulfilling a need
- Timing of inputs to fulfill a need
- Competition in fulfilling a need

Generally there should be two or three attributes that are most important to consider for the project. For example, in the NASA case, the following attributes were considered:

- Satisfaction level if need is fulfilled
- Regret level if need goes unfulfilled
- Importance of a particular source in fulfilling a need

Next, develop a scale to measure each attribute. A five-point scale seems to work best, since a three-point scale does not offer enough variation, and a four-point scale can be uncomfortable due to the lack of a "middle" value on the scale. In some cases, a single scale can incorporate two attributes, such as satisfaction & regret. Figure 108 shows the two scales used to measure the attributes of each value flow in the NASA satellite Earth Observations Program.

In practice, when assigning attribute scores to each value flow, it is better to assign all the satisfaction/regret scores for each need before assigning source importance scores to each value flow input. This method is preferred for two reasons: (1) assigning all the satisfaction/regret scores together helps keep the scorer's mind focused on one scoring rubric rather than alternating back and forth between the satisfaction/regret and source importance scales; and (2) if the satisfaction/regret and source importance scores are assigned simultaneously, we found that the scorer tends to couple the two responses together, as indicated Figure 109. Equally valid, however, are uncoupled scores, also indicated in Figure 109. Coupled responses produce less variation among the value flow scores, which removes some of the useful texture in the final results of the value network analysis.

Attribute scores should be obtained by asking several individuals with broad knowledge of the project to fill out a questionnaire containing descriptions of each need and value flow input, as well as the scoring rubrics. Once the scores are obtained, use an appropriate method such as the Delphi method for reconciling differences in the scores.

After a final set of scores has been determined, it is useful to validate the scores, or at least the relative ranking of each value flow, by interviewing individual experts representing each of the stakeholder groups. During a stakeholder interview, provide the individual with an overview of the stakeholder model, including the stakeholder maps and value flow maps. Create a diagram showing the *inputs* to that stakeholder ranked by their value flow scores. Ask the individual to evaluate the relative rankings of the inputs to provide an anecdotal validation of the flow scores. To avoid the need to explain the entire methodology to the interviewees, it may not be necessary tot ask the interviewee to validate the absolute numeric scores.

It may also be possible to validate the relative rankings of value flows using information contained in the relevant literature, or through proxy data-based techniques. For example, Kingdon conducted a survey in *Congressmen's Voting Decisions* (University of Michigan Press, 1989) asking 222 U.S. Congressmen to rank the importance of various sources in providing information that ultimately affects the Congressmen's voting decisions. The responses from this survey could be used to validate information-related value flows to Congress or the Government in a stakeholder model.

Once all the needs have been characterized, quantitative scores can be assigned to each value flow as described in the next section.

6.7 Quantify the Value Flows

After determining the attributes of each value flow, translate the attribute responses into numeric scores using an appropriate conversion. For many attributes, using a linear scale with a range of [0, 0.98] is appropriate. For other attributes, it may make sense to use a non-linear scale. For example, in the NASA case, we used a ratio, or log, scale for the satisfaction/regret attribute. This provided a greater differentiation between the "absolutely essential" needs (response E) and the less-essential "necessary" needs (response D) than a linear scale would provide. Using a [0, 0.98] range ensures that scores for each “value loop,” as discussed in the next section, remain bounded within the [0, 0.98] range. Figure 110 shows the conversions used to translate the value flow attributes into numeric scores in the NASA model.

To produce the value flow score, multiply the translated attribute scores together. Figure 111 shows a matrix for calculating the value flow scores using the attribute scores in the NASA stakeholder model. This numeric score is called the “value flow score.”

Once all the numeric value flow scores have been assigned, the construction of the quantitative model is complete. The analysis of the quantitative model begins with the calculation of value loops, described in the next section.

6.8 Calculate Value Loops

After finalizing each value flow score, the next step is to calculate all possible “value loops” within the stakeholder network. A value loop is defined as a chain of value flows that begins and ends with the Enterprise. Value loops can be used to understand the indirect transfer of benefit among three or more stakeholders. They can help illustrate which stakeholder needs are satisfied by strong feedback loops, and which needs are not well satisfied. Value loops also provide the means for developing an in-depth understanding of how value is created and delivered throughout the stakeholder network, which may not be immediately obvious or intuitive.

To calculate a value loop score, multiply the value flow scores of each value flow within the loop. Using a multiplicative rule with a [0, 0.98] range ensures that each value loop score will remain bounded within the [0, 0.96] range. Longer value loops are likely to have lower scores than shorter value loops, which is intuitive—delivering value through a chain of four or five stakeholders is often more difficult than delivering value through a chain of just two or three stakeholders. Figure 112 illustrates the calculation of a single value loop: Space acquired data from NASA/NOAA to Scientists; science knowledge from Scientists to Media; informative content from Media to Public; votes from Public to Government; and funding from Government back to NASA/NOAA. The value loop score is calculated as

$$0.74 \times 0.32 \times 0.33 \times 0.59 \times 0.53 = 0.024$$

To calculate all the possible value loops within a stakeholder model, a software simulation tool can be used. Object Process Network (OPN) is one tool that can be used for this. OPN is a domain-neutral, executable meta-language designed to represent, generate, and manipulate simulation models. As a model generation tool, OPN is particularly suitable for enumerating and analyzing large, complex system architectures or networks such as complex stakeholder models. In OPN, stakeholders are modeled as objects and value flows are modeled as processes. See http://opn.mit.edu for more details about creating and executing models using OPN.

After all the value loops have been calculated, it is often necessary to remove any illogical or inconsistent value flows that may have been created. An example of an illogical value loop is one where in reality, a specific value flow in the loop would not have an effect on the subsequent value flow. For example, the flow of science knowledge from Scientists to the Public would not have a direct effect on the flow of taxes from the Public to the Government. Therefore, any value loops that contained that sequence of value flows should be deleted.

Once all the unique, valid value loops have been identified, there are a number of analyses that can be performed to derive insights about the stakeholder value network, described in the following section.

6.9 Analyze Value Loop Results

The value loops yield tremendous insight into the value created by the project to the entire stakeholder network. Figure 113 shows an example of high-scoring value loops for the NASA satellite Earth Observations Program. There is perhaps a limitless number of ways to analyze the value loops to produce useful insights. The value loops can be used to identify important stakeholders, important value flows, important outputs from the Enterprise, important inputs to the enterprise, and other metrics of interest to the particular project.

The following list indicates some common value loop analyses and a description of how to conduct them:

- **Most important stakeholders:** To calculate the importance of each stakeholder, use the weighted sum of the stakeholder's occurrence in all value loops. Each time a stakeholder appears in a value loop, add the score for that loop to the stakeholder's total. Normalize the final stakeholder scores by Enterprise's score, which should equal the sum of all value flows in the model. The Enterprise's normalized score will equal 1.0 and the other stakeholders will fall within a range of [0,1]. Figure 114 shows the most important stakeholders for the NASA case.
- **Most important value flows:** Calculate the weighted occurrence of each flow within all the value loops. Each time a value flow appears in a value loop, add the score for that loop to the value flow's total. This will provide an indication of the strongest and most important

value flows in the model. Figure 115 shows the most important value flows for the NASA case.

- **Most important value loops:** Inspect the list of top-scoring value loops to understand the loops that provide the most value returned to the Enterprise. Many of the important value flows will appear in the top value loops, although there may be some differences between the two. Shorter value loops tend to score highest, so it is often useful to separate direct transactions (involving the Enterprise and one other stakeholder) and indirect transactions (involving more than two stakeholders). Figure 113 shows an example of some of the high-scoring value loops for the NASA case.
- **Highest scoring outputs of the Enterprise:** Calculate the weighted occurrence of each output within all the value loops. Each output's score corresponds to the sum of all value loops that begin with that output. The most significant outputs can be interpreted as the outputs that have the greatest potential for producing value to the stakeholder network. And since each value loop begins and ends with the Enterprise, this ranking also provide an indication of how the Enterprise should align its outputs to create the strongest feedback loops to its own inputs. Figure 116 shows the most important outputs for the NASA case.
- **Highest scoring inputs to the Enterprise:** Use the same weighted occurrence method to calculate the most significant inputs—each input's score represents the sum of all value loops that end with that input. The most significant inputs can be interpreted as the top "affectable" inputs to the Enterprise. If the Enterprise increased all its outputs by one unit, the weighted input occurrence is the amount each input to the Enterprise would increase. Therefore, the ranking of the inputs provides an indication of the Enterprise's ability to affect each input. Figure 117 shows the most important inputs for the NASA case.
- **Other metrics of interest:** Depending on the specific Enterprise and project, there may be other metrics of interest that can be determined through an analysis of the value loops.

During this step the value loops were analyzed to provide useful insights and information about the stakeholder value network. This information can be used to create a simplified stakeholder map and to derive high-level program requirements, as described in the next two sections.

6.10 Create a Simplified Stakeholder Map

The complete stakeholder map developed using this method is often highly complex and may contain 100 or more value flows. While a complete map demonstrates the complexity and completeness of the model, it often displays too much information, especially for project managers and policy-makers who are unfamiliar with this stakeholder modeling methodology. A diagram showing only the most important stakeholders and value flows provides a more comprehensible view of the stakeholder network and serves as a much more useful reference tool.

To produce a simplified stakeholder model, combine the information yielded from the analyses of the most important stakeholders, value flows, and value loops. Figure 118 shows the simplified stakeholder model for the NASA satellite Earth Observations Program. In the figure, the width of each value flow line is proportional to the weighted occurrence score of each flow. A good rule of thumb is to include approximately 7 +/- 2 stakeholders and 20-30 value flows. This is often a somewhat subjective process. Stakeholders and value flows that appear consistently across the three analyses should be included in the simplified model. Add additional stakeholders and value flows if they play a significant role in at least one of the three analyses. Certain stakeholders and value flows can be deleted if their presence is inconsistent and if they play only a minor role in the analyses.

The simplified stakeholder map is a concise way to represent the most important stakeholders, value flows, and value loops within the stakeholder network. It allows policy-makers and decision-makers to visualize how the Enterprise's outputs related to the project deliver value to the stakeholder network as well as return value to the Enterprise.

6.11 Derive Program Goals from the Value Loop Analysis

Finally, the results from the value loop analysis can be used to derive high-level goals and requirements for the program. Program goals can be derived from the highest-scoring value loops in the model. The program goal should address the output from the Enterprise as well as the subsequent value flows created by the output, which represent the intent of the Enterprise's output. Figure 113 shows an example of top-scoring value loops that begin with NASA's output of space-acquired data to Scientists. The template shown in Figure 119 can be used to structure the program goals. These value loops yield the following program goal:

- **NASA shall produce Earth science data of interest to the scientific community with the intent of:**
    - Fulfilling NASA's science program objectives
    - Fulfilling the recommendations of Science & Technology Advisory Bodies
    - Providing the Government with policy-relevant science knowledge
    - Providing Educators with inspirational science content to promote student interest in science, technology, engineering, and mathematics careers

Using this approach produces specific program goals that address the actual ways in which the Enterprise's outputs deliver the highest value to the stakeholder network and ultimately return value back to the Enterprise. Program goals should be prioritized based on the degree to which the corresponding output helps the Enterprise derive the inputs it needs. The goal statements can often be separated into goals that influence *what* the Enterprise does and *how* it does business.

The information from the qualitative stakeholder model and the value loop analysis can also be used to provide insights and suggest recommendations for the project. The following are common insights yielded from the value loop analysis:

- Identification of the most important stakeholders to the project
- Identification of the most important value flows within the stakeholder network
- Identification of the most important value loops produced by the project's outputs
- Identification of each stakeholder's most valuable contributions to the project
- Identification of potential "weak links" in the value loops
- Prioritization of the project's outputs

After developing the program goals, metrics should be identified for measuring the progress towards achieving the goals. Each metric should have a target value so that an unambiguous assessment of progress can be made. Finally, the list of program goals should satisfy the following criteria:

- **Representative:** A representative goal is one that ensures that value will be delivered to meet the stakeholders' needs. Metrics flow from goals and help ensure success of the project.
- **Complete**: The list of goals should be checked for completeness to ensure that all the relevant needs of the Enterprise and other stakeholders have been captured or rationally excluded.
- **Consistent:** The list of goals should be checked to ensure that none of the performance goals are internally contradictory.
- **Attainable:** All program goals should attainable with the project's allocated resources
- **Humanly solvable:** The goals of the program should be humanly solvable; that is, goals should be as clear and concise as possible. They should be written in solution-neutral form and stated using functional goals rather than suggesting particular solutions. Program goals should support all problem-solving strategies that may be needed, including: allowing for multiple users; allowing the shedding of mental workload by shifting strategies during problem solving; and accommodating of different problem-solving styles.

6.12 Conclusion

This handbook describes a sophisticated technique for performing a rigorous stakeholder analysis that transforms stakeholder needs into program goals and requirements. By creating a rigorous qualitative and quantitative stakeholder model, a value loop analysis can be conducted that yields useful insights and recommendations for the project. The methods presented in this handbook are sufficiently general to apply to nearly any Enterprise and any project involving numerous stakeholders. Using these techniques to derive program goals will help ensure a successful project that satisfies stakeholders' needs, delivers value to the entire stakeholder network, and returns maximum value to the Enterprise.

Figures:

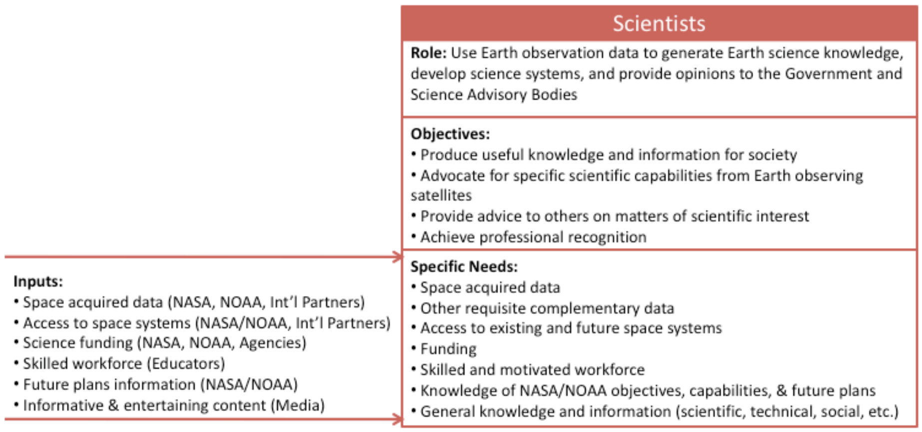


Figure 102. Template for articulating the role, specific objectives, needs, and value flow inputs of each stakeholder. The template enables easy and direct traceability of stakeholder inputs to the satisfaction of specific needs and objectives. This template has been populated with information for the Scientists stakeholder group in the NASA satellite Earth Observations Program.

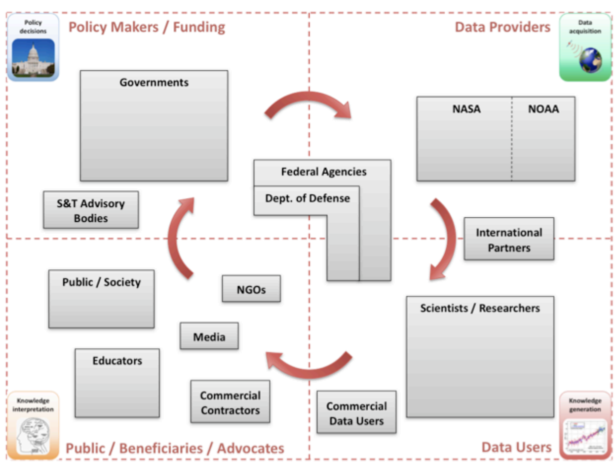


Figure 103. Baseline stakeholder map for NASA's satellite Earth observations program, showing the 13 stakeholders arranged according to their function in the network. The upper left quadrant contains policy makers and funding providers; the upper right quadrant contains data providers; the lower right quadrant contains data users; and the lower left quadrant contains the public, beneficiaries, and advocates.

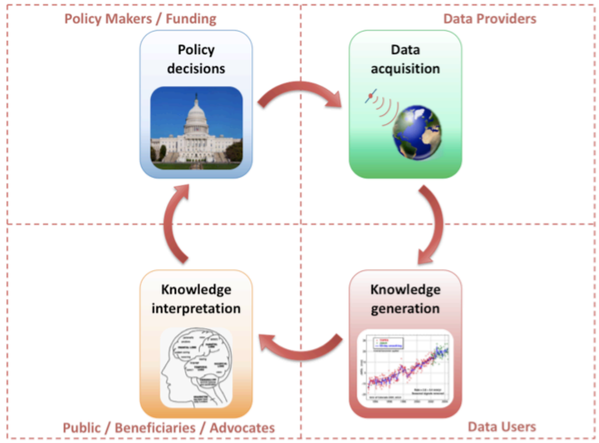


Figure 104. Higher-level, or "one-up," stakeholder map for NASA's satellite Earth observations program. This map shows the four main classes of stakeholders and the general clockwise flow of value through the network. Analyzing the stakeholder model at this level would capture too little information to provide useful results. However, the map illustrates the higher-level context within which the Earth Observations Program operates.

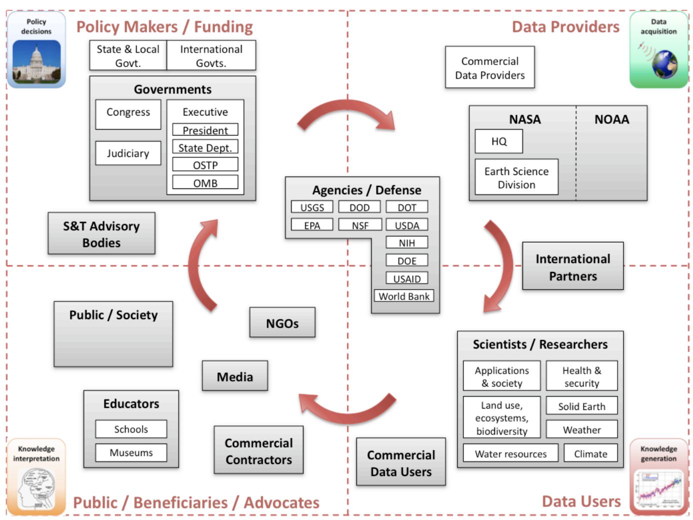


Figure 105. More detailed, or "one-down," map for NASA's satellite Earth observations program. This map illustrates the aggregation and hierarchy inside some of the stakeholders in Figure 103. This map helps provides a better understanding of the inner workings of the stakeholder network. Analyzing the stakeholder model at this level would result in too many value flows and too much detail.

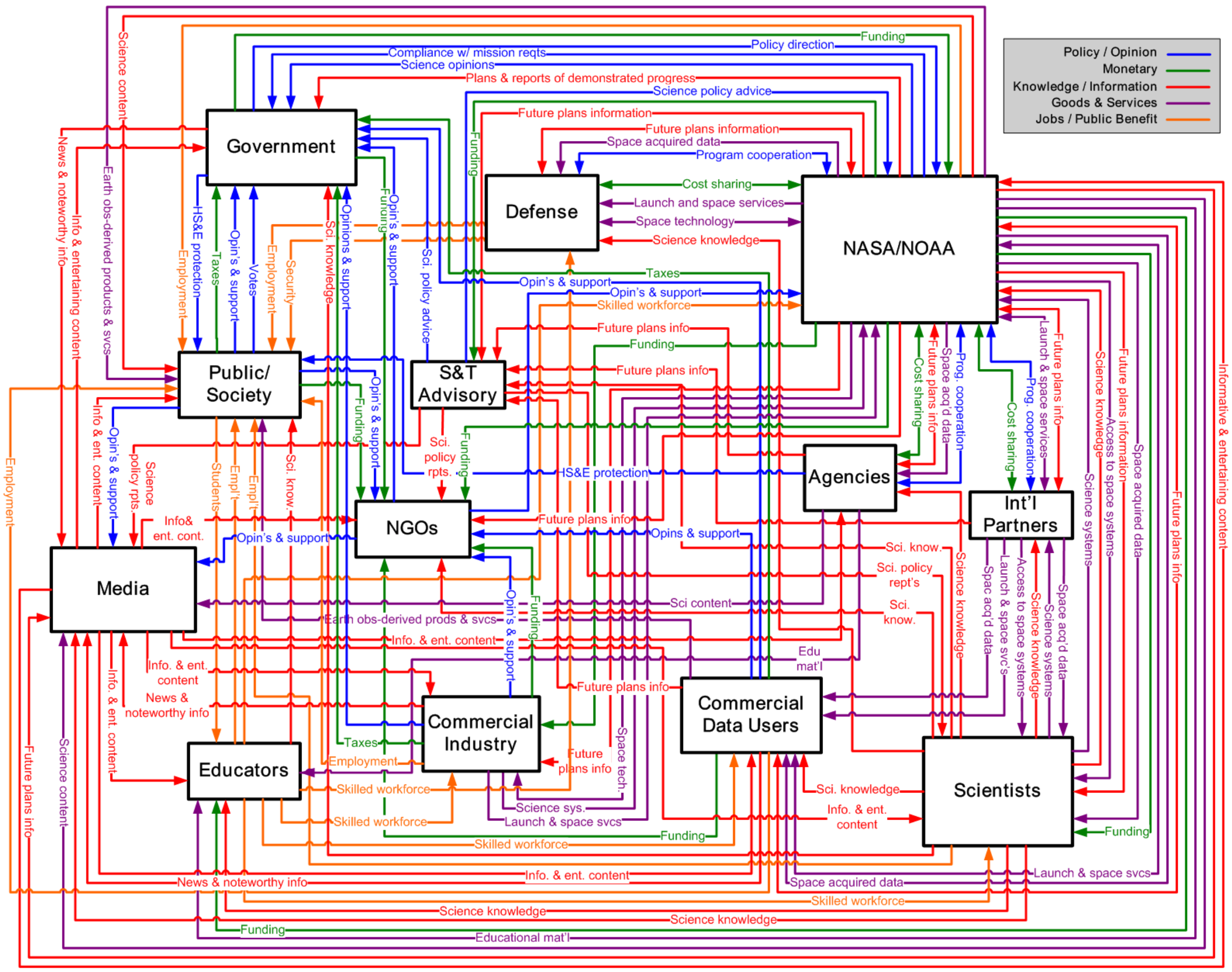


Figure 106. Complete stakeholder value flow map for the NASA Earth Observations Program, containing 13 stakeholders and 190 value flows. The value flows are grouped into five categories: policy/opinion, monetary, knowledge/information, goods & services, and public benefit flows.

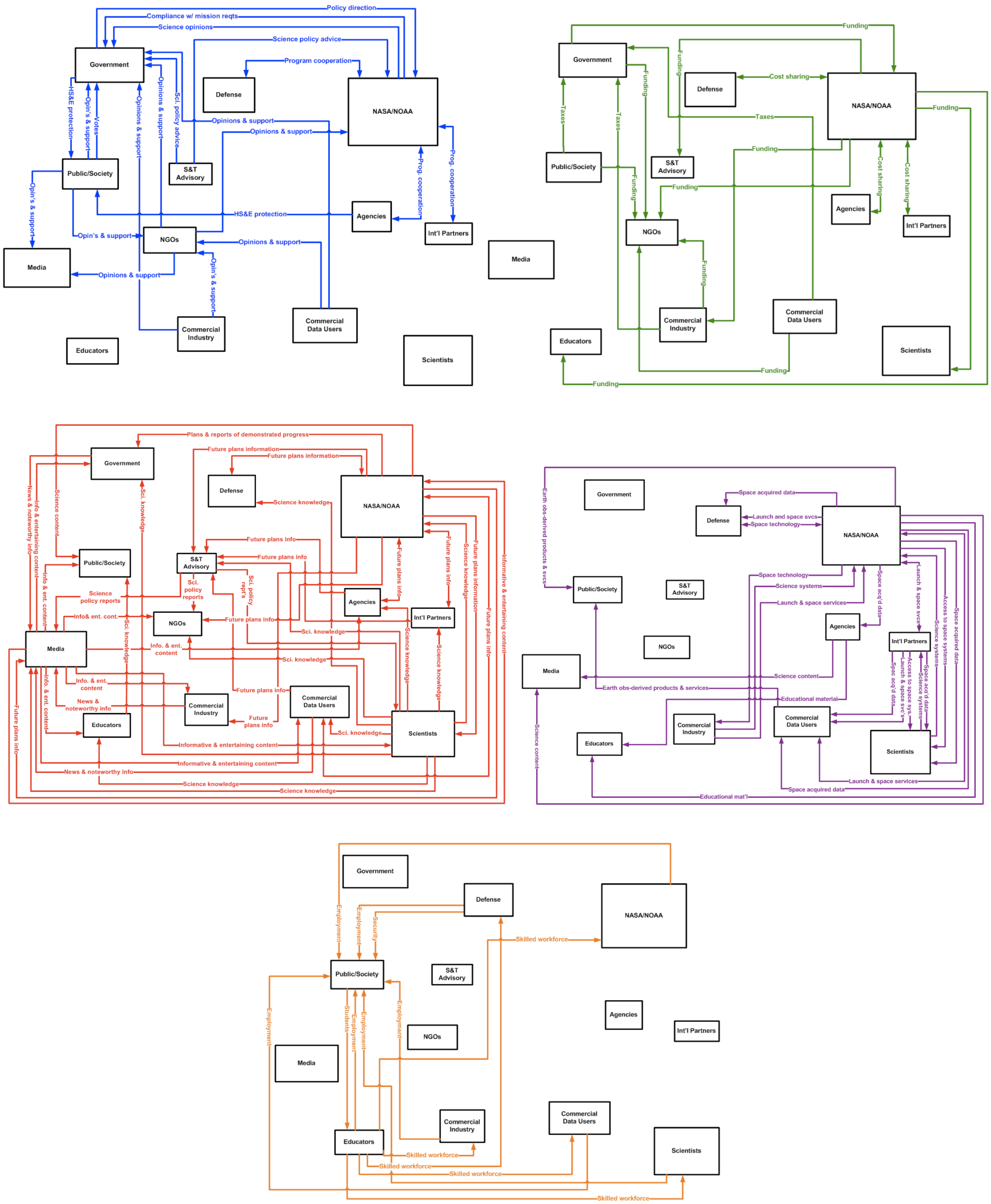


Figure 107. Five types of value flows:
(Top left) Policy & opinion; (Top right) Monetary; (Center left) Knowledge & information;
(Center right) Goods & services; (Bottom) Public benefits

Scales for Measuring Attributes of Value Flows

How would you characterize the presence/absence of fulfillment of this need?

A. I would be satisfied by its presence, but I would not regret its absence

B. I would be satisfied by its presence, and I would somewhat regret its absence

C. I would be satisfied by its presence, and I would regret its absence

D. Its presence is necessary, and I would regret its absence

E. Its presence is absolutely essential, and I would regret its absence

If this need were to be fulfilled, how important would this source be in fulfilling the need?

1. Not important – I do not need this source to fulfill this need
2. Somewhat important – It is acceptable that this source fulfills this need
3. Important – It is desirable that this source fulfills this need
4. Very important – It is strongly desirable that this source fulfills this need
5. Extremely important – It is indispensible that this source fulfills this need

Figure 108. Scales for measuring the attributes of each value flow. A five-point scale seems to work best for evaluating value flow attributes. Using an alphabetic scale for one attribute and a numeric scale for the other helps prevent the scorer from confusing the two attributes during the scoring process.

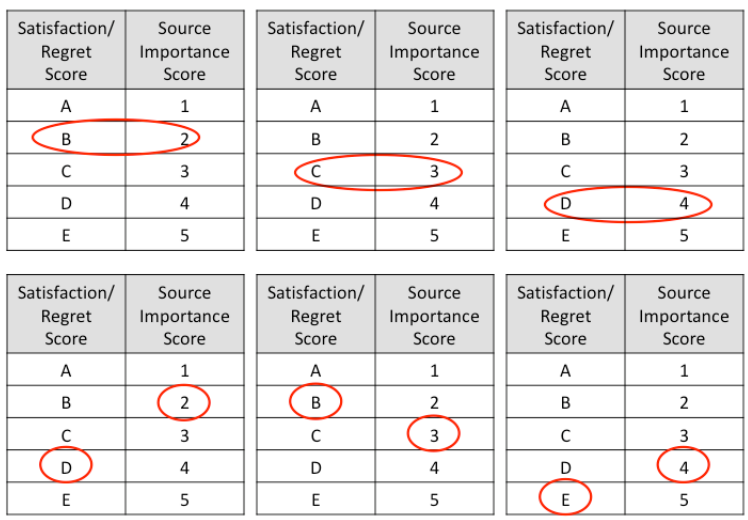


Figure 109. Coupled (top) and uncoupled (bottom) responses to value flow scoring questionnaires. If the satisfaction/regret and source importance scores are assigned simultaneously, the scorer tends to couple the two responses together, as indicated in the top figure. Equally valid, however, are uncoupled scores, indicated in the bottom figure. Coupled responses produce less variation among the value flow scores, which removes some of the useful texture in the final results of the value network analysis.

Satisfaction/Regret score translation		Source importance score translation	
A	0.11	1	0.11
B	0.19	2	0.33
C	0.33	3	0.55
D	0.57	4	0.78
E	0.98	5	0.98

Figure 110. Conversions for translating attribute responses into numeric scores for the NASA Earth Observations Program value flows. The satisfaction/regret scores use a ratio, or log, scale to increase the relative importance of "absolutely essential" needs (choice E) over less-critical needs (choice D or lower). The source importance scores are based on a linear scale.

		Satisfaction/Regret Score				
		A = 0.11	*B = 0.19*	*C = 0.33*	*D = 0.57*	*E = 0.98*
Source Importance Score	*1 = 0.11*	0.01	0.02	0.04	0.06	0.11
	2 = 0.33	0.04	0.06	0.11	0.19	0.32
	3 = 0.55	0.06	0.10	0.18	0.31	0.54
	4 = 0.78	0.09	0.15	0.26	0.44	0.76
	5 = 0.98	0.11	0.19	0.32	0.56	0.96

Figure 111. Matrix for calculating value flow scores based on attribute scores. The value flow scores are obtained by multiplying the two attribute scores together.

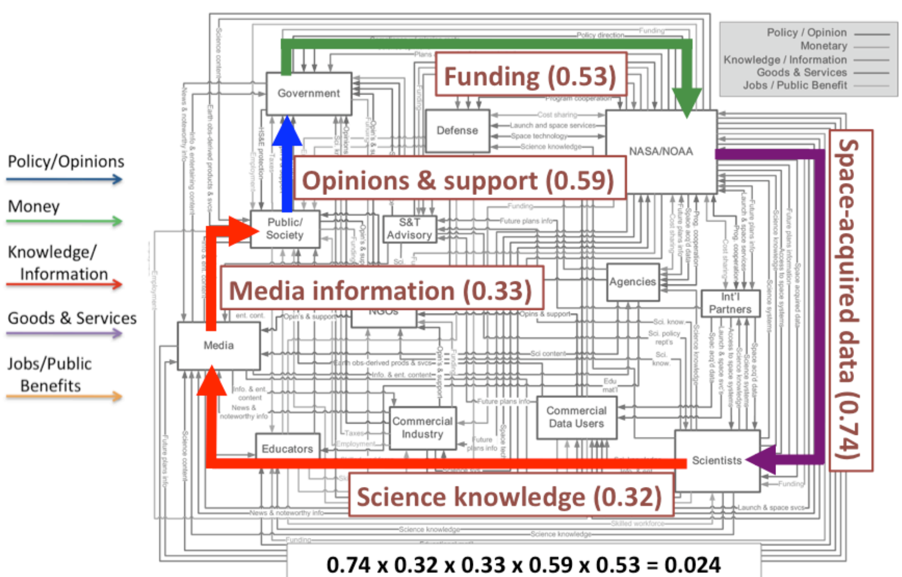


Figure 112. Calculating value loop scores by multiplying the scores of the individual flows comprising each value loop. This example shows a value loop containing five value flows.

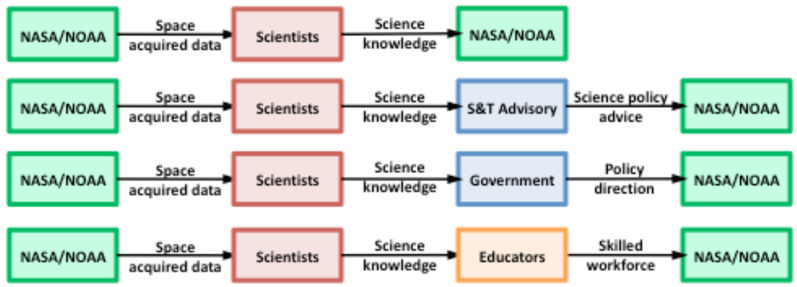


Figure 113. Example of high-scoring value loops for NASA satellite Earth Observations Program

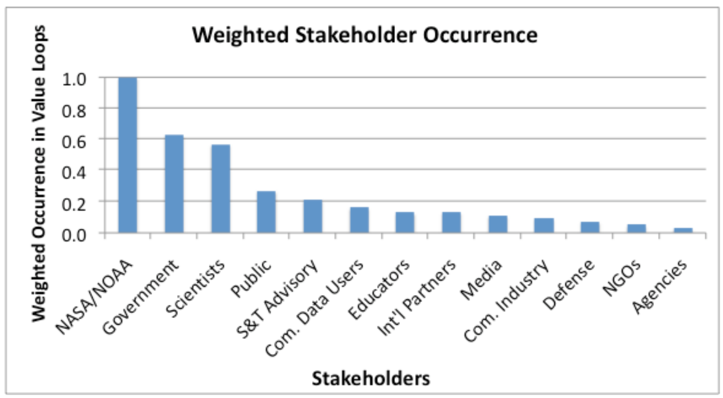


Figure 114. Weighted stakeholder occurrence, showing the most important stakeholders for the NASA Earth Observations Program. The weighted occurrence score is calculated as the sum of all value loops containing the stakeholder, normalized by the sum of all value loops in the model.

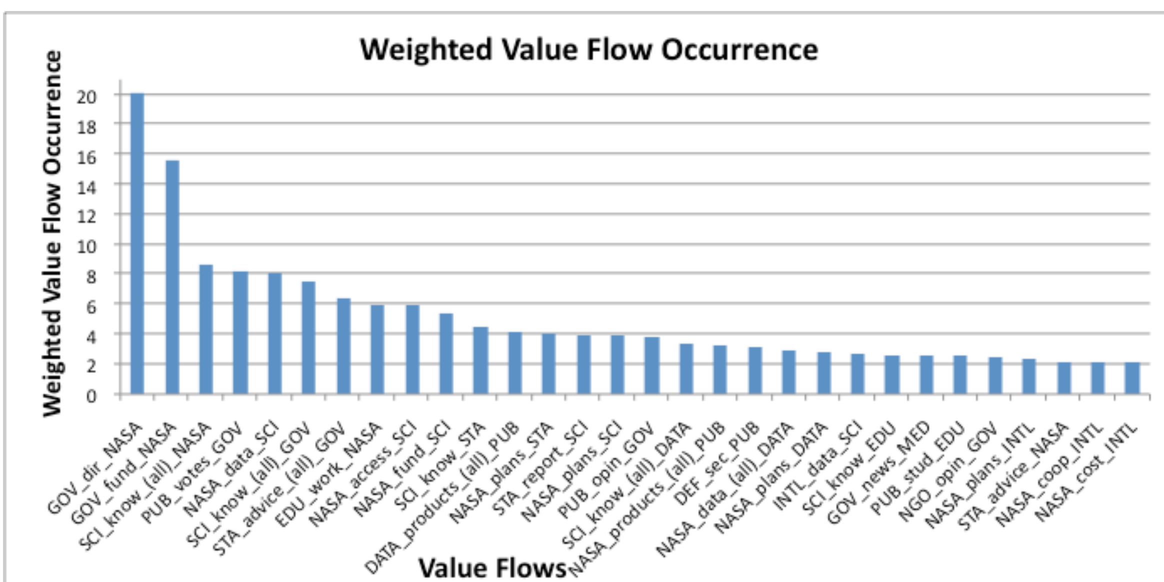


Figure 115. Weighted value flow occurrence, showing the most important value flows in the stakeholder network. The weighted occurrence score is calculated as the sum of all value loops containing the particular value flow.

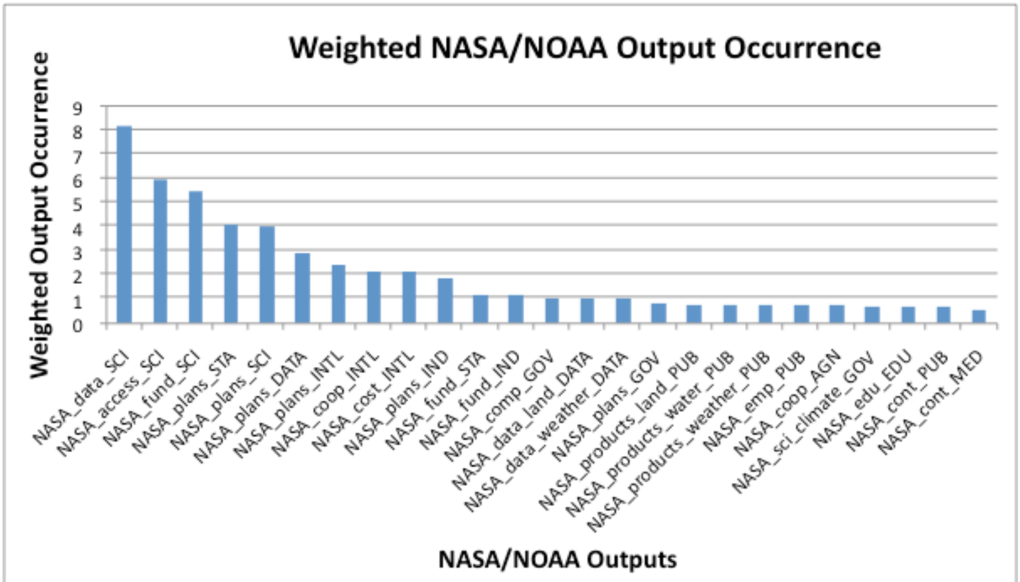


Figure 116. Weighted output occurrence, showing the most important outputs from the Enterprise. The weighted output occurrence is calculated as the sum of all value loops beginning with the particular output of the Enterprise.

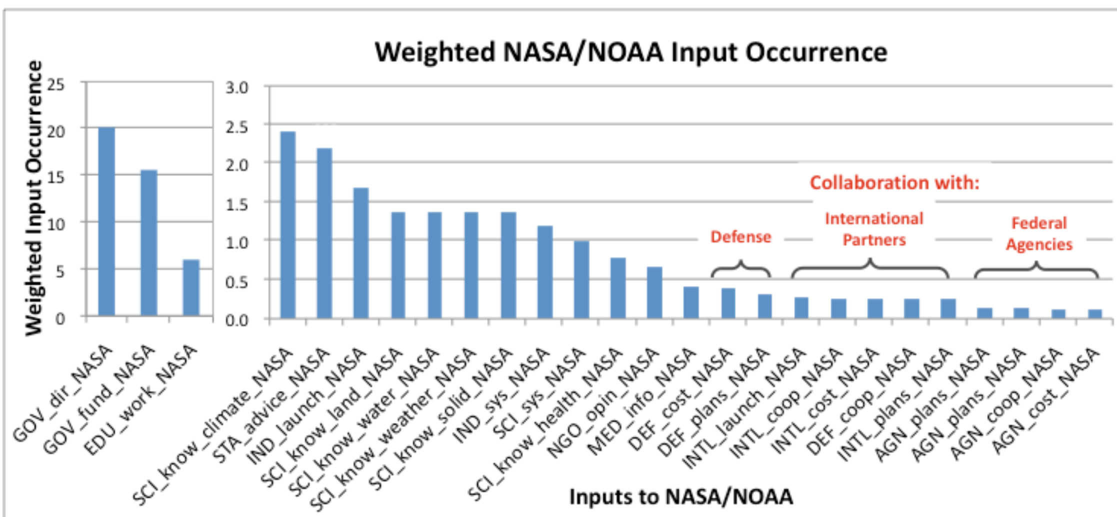


Figure 117. Weighted input occurrence, showing the most "affectable" inputs to the Enterprise. The weighted input occurrence is calculated as the sum of all value loops ending with the particular input to the Enterprise.

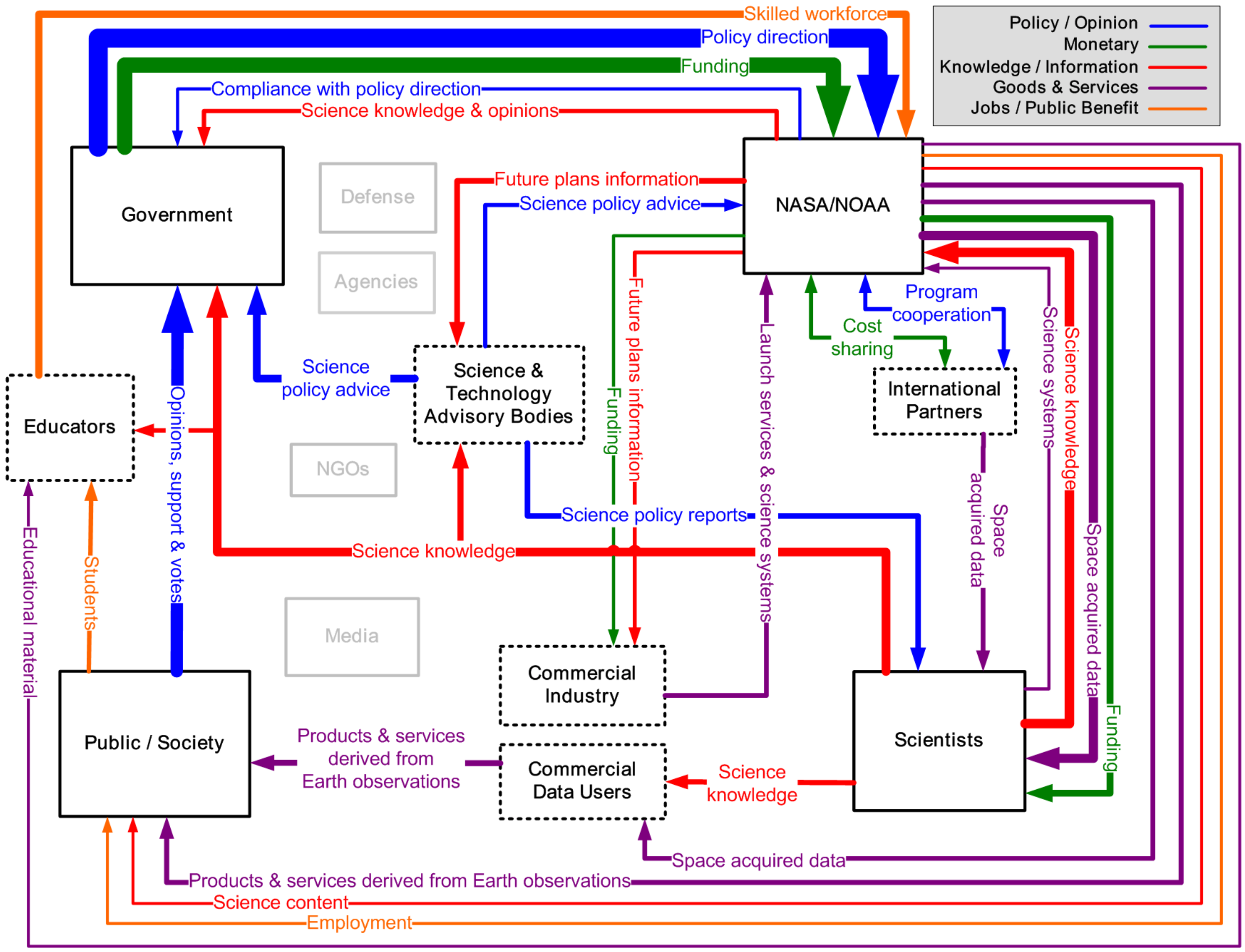


Figure 118. Simplified stakeholder value flow map for the NASA Earth Observations Program. This stakeholder map includes 13 stakeholders and the 30 most important value flows. The stakeholders have been grouped into four first-tier stakeholders (solid boxes), five second-tier stakeholders (dashed boxes), and four third-tier stakeholders (grey boxes). The thickness of the value flows is proportional to the weighted occurrence of the value flow in the value loops.

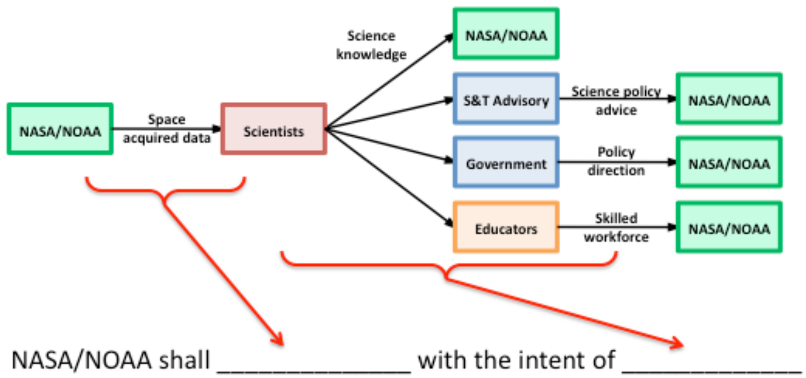


Figure 119. Template for translating value loops into high-level program requirements. Program goals can be derived from the highest-scoring value loops in the model as well as the most important outputs from the Enterprise. The program goal for this set of value loops is as follows:

> **Goal: NASA shall provide space-acquired data of interest to the Scientific Community, as well as funding and access to its space systems with the intent of:**
>
> - **Generating Earth science knowledge consistent with NASA's science program objectives**
> - **Fulfilling the recommendations of relevant Science & Technology Advisory Bodies**
> - **Providing the Government with policy-relevant science knowledge**
> - **Providing Educators with inspirational science content to promote student interest in science, technology, engineering, and mathematics**

7 Appendix A – Stakeholder Characterization Templates

The following diagrams show the stakeholder characterization templates for each of the Level 2 stakeholders in the model.

NASA/NOAA

Role: Responsible for program organization, management, data acquisition, and providers of products and services derived from space-based Earth observations. Does not include NASA/NOAA scientists.

NASA Objectives:
- Expand human knowledge of Earth
- Preserve role of U.S. as leader in space science & application
- Make available to military & non-military agencies information & discoveries of value and significance
- Cooperate with other nations & agencies to make most effective use of scientific & engineering resources by avoiding unnecessary duplication of effort/facilities
- Seek & encourage the fullest commercial use of space
- Stimulate private innovation in basic/applied research & technology for NASA related activities
- Study Earth from space to advance scientific understanding and meet societal needs
- Implement priorities defined by NRC reports
- Transfer results from Earth Science for use in decision support, policy making
- Understand how and why the global Earth system is changing, and predict how it will change in the future
- Understand the consequences for human civilization

NOAA Objectives:
- Protect, restore, and manage coastal and ocean resource
- Serve society's needs for weather and water information
- Support commerce with information for safe, efficient, environmentally sound transportation
- Monitor/observe land, sea, atmosphere, & space to create observational and data collection network to track Earth's changing systems
- Understand and describe how natural systems work together through investigation and interpretation of information
- Engage, advise, and inform individuals, partners, communities, and industries to facilitate information flow, assure coordination and cooperation, and provide assistance in the use, evaluation, and application of information
- Describe & understand the state of the climate system through integrated observations, analysis, and data stewardship
- Develop/sustain a world-class workforce
- Provide information & tools to support decision-makers in improving management of risks to the US economy in sectors sensitive to weather
- Transfer NOAA & non-NOAA research activities from research to operational status

Inputs:
- Cost sharing (Defense, Agencies, Int'l Partners)
- Funding (Government)
- Future plans information (Defense, Agencies, Int'l Partners, Com. Data Users)
- Informative & entertaining content (Media)
- Launch & space services (Com. Industry, Int'l Partners)
- Opinions & support (NGOs)
- Policy direction (Government)
- Program cooperation (Defense, Agencies, Int'l Partners)
- Science knowledge (Scientists)
- Science policy advice (S&T Advisory)
- Science systems (Scientists, Com. Industry)
- Skilled workforce (Educators)

Specific Needs:
- Policy direction
- Resources to implement its objectives (budgetary, human, technical)
- Program coordination/management cooperation
- Launch services
- Access to international space systems
- Access to facilities/mechanisms for distributing knowledge & information to others
- Expert input on scientific & technical issues
- Knowledge of agency/commercial/int'l partner needs, capabilities, & objectives
- General knowledge and information (scientific, technical, social, etc)

International Partners

Role: Non-U.S. national space agencies that collaborate with NASA/NOAA and fulfill the same role as NASA/NOAA in their respective nations.

Objectives:

ESA:

- Provide and promote exploitation of space science & applications, research, technology
- Promote an industrial policy that improves worldwide competitiveness of European industry and helps develop industrial markets
- Provide Earth satellite tools for meteorology, environmental & climate monitoring, earth resource management & other applications
- Foster the use of Earth Observation based geo-information services within new market sectors

JAXA:

- Build a secure & prosperous society by establishing a system for global env. Issues
- Develop aerospace as Japan's next key industry
- Turn Japan into world's leading science center through experiences of space observation
- Recognize international cooperation as essential while avoiding too much unilateral dependence on other countries

Inputs:

- Cost sharing (NASA/NOAA)
- Future plans information (NASA/NOAA)
- Launch and space services (NASA/NOAA)
- Program cooperation (NASA/NOAA)
- Science knowledge (Scientists)
- Science systems (Scientists)

Specific Needs:

- Resources (budgetary)
- Program coordination/management cooperation
- Launch services
- Space-acquired data to support objectives
- Access to U.S. space systems
- Knowledge of U.S. agency needs, capabilities, & objectives

Scientists

Role: Use Earth observation data to generate Earth science knowledge, develop science systems, and provide opinions to the Government and Science & Technology Advisory Bodies

Objectives:

- Produce useful knowledge and information for society
- Advocate for specific scientific capabilities from Earth observing satellites
- Provide advice to others on matters of scientific interest
- Achieve professional recognition

Inputs:

- Space acquired data (NASA/NOAA, Int'l Partners)
- Access to space systems (NASA/NOAA, Int'l Partners)
- Science funding (NASA/NOAA, Agencies)
- Skilled workforce (Educators)
- Future plans information (NASA/NOAA)
- Informative & entertaining content (Media)

Specific Needs:

- Space acquired data
- Other requisite complementary data
- Access to existing and future space systems
- Funding
- Skilled and motivated workforce
- Knowledge of NASA/NOAA objectives, capabilities, & future plans
- General knowledge and information (scientific, technical, social, etc.)

Commercial Data Users

Role: Use space-acquired Earth observations data and derived knowledge to develop innovative products and services

Objectives:

- Use Earth observation data for commercial purposes
- Create innovative ways of using Earth observation data

Inputs:

- Skilled workforce (Educators)
- Informative & entertaining content (Media)
- Future plans information (NASA/NOAA)
- Space acquired data (NASA/NOAA, Int'l Partners)
- Science knowledge (Scientists)

Specific Needs:

- Resources (human, technical)
- Space-acquired data to support objectives
- Science and technical knowledge
- Knowledge of agency plans & objectives
- General knowledge and information (scientific, technical, social, etc.)

Commercial Industry

Role: Interact directly or indirectly with NASA/NOAA and rely on funding, commercial contracts, launch and space services, and space technology from NASA/NOAA. Provide science systems (e.g. satellites and sensors) and launch & space services to NASA/NOAA.

Objectives:
- Provide high-quality jobs in the aerospace industry
- Benefit from NASA's technology investments with spin-off technology, indirect jobs & business

Inputs:
- Skilled workforce (Educators)
- Funding (NASA/NOAA)
- Informative & entertaining content (Media)
- Future plans information (NASA/NOAA)
- Launch & space services (NASA/NOAA, Int'l Partners)
- Space technology (NASA/NOAA)

Specific Needs:
- Resources (budgetary, human, technical)
- Launch services
- Expert knowledge on scientific & technical issues
- Knowledge of agency plans & objectives
- General knowledge and information (scientific, technical, social, etc.)

Public

Role: The general U.S. population and society as a whole.

Objectives:
- Form a more perfect union
- Insure domestic tranquility
- Provide for the common defense
- Promote general welfare
- Secure the blessings of liberty to ourselves and our posterity

Inputs:
- Earth observations-derived products & services (NASA/NOAA, Com. Data Users)
- Employment (Com. Data Users, Com. Industry, Defense, NASA/NOAA, Scientists)
- Health, safety, & environment protection (Agencies, Government)
- Informative & entertaining content (Media)
- Science content (NASA/NOAA)
- Science knowledge (Educators)
- Security benefits (Defense)

Specific Needs:
- Jobs
- National pride and inspiration
- Knowledge & prediction of Earth System processes (weather, solar activity, earthquakes, volcanoes, etc.)
- Sustainable management/stewardship of natural Earth and resources
- National security
- Good governance
- General knowledge and information (scientific, technical, social, etc.)

Educators

Role: Teach students, produce skilled citizens, build enthusiasm and motivation for learning

Objectives:
- Provide academic mastery and life skills to all students
- Develop and implement challenging programs that will provide relevant choices to prepare our students for college, the community, and the workplace

Inputs:
- Educational material (NASA/NOAA, Agencies)
- Informative & entertaining content (Media)
- Inspired students (Public)
- Science knowledge (Scientists)
- Funding (NASA/NOAA)

Specific Needs:
- Financial resources
- Inspired students
- Science & engineering educational content
- Science & engineering knowledge
- General knowledge and information (scientific, technical, social, etc.)

Media

Role: Distribute news, knowledge, information, entertainment to Public

Objectives:
- Enhance society by creating, collecting and distributing high-quality news, information and entertainment

Inputs:
- Future plans information (NASA/NOAA)
- News & noteworthy information (Com. Data Users, Com. Industry, Government)
- Opinions & support (Public, NGOs)
- Science content (NASA/NOAA, Agencies)
- Science knowledge (Scientists)
- Science policy reports (S&T Advisory)

Specific Needs:
- Mission and event content
- General news & content information
- Knowledge of agency plans & objectives
- Access to key events
- Science knowledge
- Expert/public opinions on all topics

NGOs

Role: Advocacy and industry trade groups that promote the importance of Earth science and observations on behalf of scientists, industry, and the public.

Objectives:
MAPPS: develop strength and unity on matters affecting the interests of its member firms engaged in surveying, photogrammetry, satellite and airborne remote sensing, aerial photography, hydrography, aerial and satellite image processing, GPS and GIS data collection and conversion services.
IGES: develop and implement activities and programs for students, teachers, and the broad Earth and space science education community; promote the importance and benefits of Earth observations
- Advocate on behalf of scientists, public, industry, etc. the need for Earth Science observation data and related products
- Advocate for specific policy decisions

Inputs:
- Funding (Com. Data Users, Com. Industry, Government, NASA/NOAA, Public)
- Future plans information (NASA/NOAA)
- Informative & entertaining content (Media)
- Opinions & support (Com. Data Users, Com. Industry, Public)
- Science knowledge (Scientists)
- Science policy reports (S&T Advisory)

Specific Needs:
- Resources to implement its objectives (budgetary, human)
- Mission and event content
- Science knowledge
- Knowledge of agency/commercial/Int'l partner plans & objectives
- Expert/public opinions on all topics
- General news & content information
- Access to policy makers

Government

Role: Provide policy direction and funding to the Earth Observations Program

Objectives:
- Evaluation of activities with respect to NASA objectives
- Appropriate funds to government agencies/programs
- Provide oversight of government agencies/programs
- Protect U.S. people through good legislation
- Promote programs that will provide jobs to U.S. citizens
- Get re-elected or sustain/increase political support
- Command the military forces

Inputs:
- Compliance with policy direction (NASA/NOAA)
- Informative & entertaining content (Media)
- Opinions & support (Com. Data User, Com. Industry, NGOs, Public)
- Plans and reports of progress (NASA/NOAA)
- Political support – votes (Public)
- Science knowledge (Scientists)
- Science opinions (NASA/NOAA)
- Science policy advice (S&T Advisory)
- Taxes (Public, Com. Data Users, Com. Industry)

Specific Needs:
- Resources to implement objectives (budgetary)
- Descriptions of NASA's previous year activities/accomplishments
- Progress reports from all agencies
- Content and data from government-funded programs
- Data and analysis to use as basis for policy decisions
- Expert scientific, technical, and policy advice
- Policy support & favorable public opinion
- General knowledge & information (scientific, technical, social, etc.)
- Political support (votes)

Department of Defense

Role: Provide funding, program coordination/cooperation; provide security to the U.S. Public

Objectives:
- Ensure safety and security of U.S. people
- Ensure safety and security of U.S. troops around the world
- Support all phases of military operations with worldwide meteorological, space environmental and oceanographic analysis and prediction services

Specific Needs:
- Earth observation data to support objectives
- Resources (budgetary, human, technical)
- Launch services
- Program coordination/management cooperation
- General knowledge and information (scientific, technical, social, etc)

Inputs:
- Cost sharing (NASA/NOAA)
- Future plans information (NASA/NOAA)
- Launch & space services (NASA/NOAA)
- Program cooperation (NASA/NOAA)
- Science knowledge (Scientists)
- Skilled workforce (Educators)
- Space acquired data (NASA/NOAA)
- Science systems (Com. Industry)

Federal Agencies

Role: Partial mission funding, program coordination, data users. Agencies and other organizations involved in public health, safety, environmental protection, scientific research, land use, transportation, energy, and agriculture

Objectives:

USGS:
- Protect the nation's natural, cultural, and heritage resources
- Manage resources to promote responsible use and sustain a dynamic economy
- Safeguard lives, property and assets, advance scientific knowledge, and improve the quality of life for communities we serve
- Manage the Department to be highly skilled, accountable, modern, functionally integrated, citizen-centered and result-oriented
- Improve knowledge & understanding of Earth's past/present climate & environment, forces bringing about changes in Earth's climate, and sensitivity/ adaptability of natural and managed ecosystems to climate change

EPA:
- Investigate adaptation options to improve society's ability to effectively respond to the risks/opportunities of global change
- Support/foster projects that link producers and users of knowledge
- Examine potential consequences of global change on air quality in the U.S.
- Investigate possible impacts of global climate and land-use change on water quality using a watershed approach
- Protect human health and safeguard the natural environment
- Develop integrated health evaluation frameworks that consider the effects of multiple stresses, their interactions, and human adaptive responses.

Specific Needs:
- Resources to implement its objectives (budgetary, human, technical)
- Space-acquired data to support objectives
- Expert input on scientific & technical issues
- Launch services
- Program coordination/management cooperation
- Knowledge of agency needs, capabilities, & objectives
- General knowledge and information (scientific, technical, social, etc.)

Inputs:
- Cost sharing (NASA/NOAA)
- Future plans information (NASA/NOAA)
- Informative & entertaining content (Media)
- Program cooperation (NASA/NOAA)
- Science knowledge (Scientists)
- Space acquired data (NASA/NOAA)

Science & Technology Advisory Bodies

Role: Provide science policy advice through decadal study / related reports

Objectives:
- Provide science, technology and health policy advice to the federal government

Specific Needs:
- Authority to conduct independent reports
- Funding/resources (budgetary, human)
- Expert input on scientific & technical issues
- Expert input on commercial issues
- Scientific and technical knowledge
- Knowledge of agency/commercial/Int'l partner plans & objectives
- General knowledge and information (scientific, technical, social, etc.)

Inputs:
- Funding (NASA/NOAA)
- Future plans information (Agencies, Com. Industry, Com. Data Users, Int'l Partners, NASA/NOAA)
- Science knowledge (Scientists)

8 Appendix B – Definitions of Each Value Flow Type

This section presents the definitions of all the value flows included in the model.

Value Flow Type	Abbreviation	Definition
Access to space systems	access	This represents the ability of stakeholders to access NASA or International Partner Earth observation space systems (e.g. schedule experiments, acquire data, control operations, etc.) *Ex: A scientist requests a data collection time slot on one of NASA's Earth-observing satellites*
Compliance with policy direction	comp	NASA and NOAA must comply with the policy direction given to them by the Government, as well as legislative requirements affecting certain science missions. Ex: The NPOESS climate sensor program must comply with certain legislative requirements
Cost sharing	cost	The sharing of mission costs by two stakeholders. *Ex: NASA, NOAA, and DOD share the total cost of NPOESS.*
Earth observation-derived products & services	products	This represents products and services offered by NASA/NOAA and commercial companies that require or are derived from Earth observation data. Includes weather forecasts, mapping products, coastal monitoring, fisheries management, etc. *Ex1: NOAA's CoastWatch service provides near real-time access to satellite data monitoring coastal winds, weather, and climate data; Ex2: Google maps and related satellite imagery products*
Educational material	edu	Educational content specifically designed to be used by teachers (K-12 and also university level) or for public displays such as in museums. Considered a goods & services flow.
Employment	emp	The extent to which an Earth-observation campaign provides high-quality employment to NASA, scientists, and the commercial sector. *Ex: NASA employs engineers at GSFC, and a commercial company wins a contract to build the control system for a new satellite*
Funding	fund	Money provided to one stakeholder from another - can represent an annual budget, one-time project funding, or periodic payments. *Ex1: The government gives money to the U.N. Food & Agriculture Org; Ex2: Government, Agency (NSF, EPA), commercial (Weather Channel to Boston Museum of Science), NGO (Mass Tech. Collaborative) grants given to science museums; Ex3: NASA provides funding & support to the Institute of Global Environmental Strategies; Ex4: NASA provides commercial funding contracts*
Future plans information; Plans & reports of demonstrated progress	plans	Information regarding the organization's plans for future scientific research. Useful for planning collaboration between two stakeholders. *Ex: NASA informs DOD of its future plans for weather and climate satellites to foster collaboration and to avoid unnecessary redundancy in satellite capabilities*

Value Flow Type	Abbreviation	Definition
Health, safety, & environmental protection	hse	Laws, agency regulations and programs that are designed to protect public health, safety, and the environment. *Ex: Congress passes vehicle fuel efficiency laws; Ex2: EPA establishes limits on carbon dioxide emissions from power plants.*
Informative & entertaining content	info	Includes all media coverage of NASA and relevant Earth-science related news and information, especially regarding climate change.
Inspired students	stud	Students are provided to Educators by the Public, to the extent that they are inspired to pursue careers in science & technical fields.
Launch & space services	launch	Use of NASA or International Partner infrastructure (ex: TDRSS) or launch services (ex: Delta II) by security or international partners for Earth-observation purposes
News & noteworthy info	news	Information that stakeholders provide to the Media. This includes press releases, announcements, and other noteworthy information.
Opinions & support	opin, concerns	Persuasive views, opinions, and expressions of support that are made on aspects relating to NASA and Earth, environmental, and social issues. *Ex: Lobbying of Congress by satellite manufacturers or commercial satellite data providers.*
Policy direction	dir	1) Executive direction on the priorities of NASA, including types of missions as well as the characterization of those missions. 2) Congressional feedback on plans and progress reports, including directives that carry possible funding or programmatic implications. Ex: The President may change NASA's priorities to place a larger emphasis on Earth science
Program cooperation	coop	Cooperation between NASA and other stakeholders regarding mission requirements, capabilities, operations, and future plans information. This may also include the sharing of data, but does not necessarily imply cost sharing. *Ex: NASA may cooperate with ESA to launch a mission and provide international scientists with data.*
Science content	cont / content	This includes published reports, internet, video, and audio content that is made available for direct consumption by stakeholders. This does not include technical data. This content is more media-friendly than pure "science knowledge." *Ex: NASA's "Ozone Hole Watch" website that provides a daily image of the ozone hole above Antarctica.*
Science knowledge	know	Knowledge gained from Earth observations and related scientific research, as processed and created by scientists from science data. *Ex1: NASA and Agencies receive science reports from Scientists about the thickness and movements of polar ice sheets; Ex2: Scientists testify to Congress about the dangers of climate change; Ex3: The media reports on a new scientific paper about climate change; Ex4: Educators compile science knowledge into science textbooks*

Value Flow Type	Abbreviation	Definition
Science opinions	sci	Science-based information given to the government by NASA that includes scientific knowledge as well as science policy recommendations. *Ex: A NASA climate scientist testifies before Congress to explain the current state of knowledge about global warming and to make recommendations on how to direct future science funding.*
Science policy advice	advice	Recommendations given to the government and NASA/NOAA regarding science research, science funding, and future science priorities. *Ex: The NRC produces a decadal survey to recommend how the government should invest in Earth science research.*
Science policy reports	report	Reports containing science policy opinions and recommendations specifically released to the media. *Ex: The NRC writes a press release announcing major results from the Earth science decadal survey.*
Science systems	sys	Hardware and software systems developed for Earth observation science. *Ex1: Software developed by scientists for fusing multiple raw data sets together; Ex2: A satellite control system developed by a commercial contractor*
Security	sec	The protection from harm or public threats; a feeling of security. This is recognized in the model as another mechanism by which an Earth observation campaign contributes to quality of life.
Skilled workforce	work	The result of training students in a specific discipline. Educators are the source of skilled workers. The assumption made is that each stakeholder has a stock of human capital, and workers are not transferred between stakeholders. *Ex: MIT trains scientists and engineers who go on to work at NASA*
Space technology	tech	Technology relevant to future space-based Earth observation applications. Includes technology shared between government organizations as well as commercial spin-offs. *Ex1: NASA may use technology developed by the DOD as the basis for its next generation sensor. Ex2: A startup company uses technology originally developed by NASA to start a business providing Earth satellite imagery*
Space-acquired data	data	Data obtained from space-based Earth observation measurements. *Ex1: NASA provides ocean wind speed, ice sheet thickness, land temperature data to scientists. Ex2: Scientists obtain land survey data from commercial providers*
Taxes	tax	Personal and corporate taxes paid to the government.
Votes	votes	The need for government officials to capture votes to win (or remain in) public office.

9 Appendix C – Value Flow Scoring Questionnaires

This section shows the value flow scoring questionnaires that were used to solicit numeric scores for each value flow from individuals having a broad knowledge of the decadal survey. Note that some of the value flows here differ from the final set of value flows in Appendix D. This reflects changes to the model that were made after the value flow questionnaires were initially completed.

INSTRUCTIONS:

The intent of this survey is to develop insight into the needs of stakeholders and how they are fulfilled. We have identified a number of stakeholders that interact with each other. We have also identified a number of needs that each particular stakeholder may have. This survey seeks to characterize the nature of the needs of each stakeholder, as well as their preferred source of fulfillment.

The following pages of the survey contain a series of questions regarding the needs of each stakeholder, divided into sections by stakeholder. **In answering the questions, try to think of yourself as a representative from that particular stakeholder group.** For each identified need, there are two questions. The column labeled "needs characterization" asks you to characterize both the "satisfaction" of fulfillment, as well as the "regret" you feel when the need goes unfulfilled. In the column labeled "Importance of specific source" you are asked to evaluate how much benefit or utility you derive from having a particular source fulfill that need. In some instances there is more than one source capable of fulfilling a need, and you will be asked to provide feedback on several competing sources. At the end of the survey, you will be asked if there are any important needs missing from the survey.

Although your feelings on a particular need or source may be described by more than one answer, please select the one that BEST describes how you feel. You may wish to print out the Question box below to refer to while you complete the survey. A representative visualization of stakeholder interactions and definitions of the pertinent stakeholders are also included on for reference.

Thank you for taking the time to complete the survey!

Satisfaction / Regret

How would you characterize the presence or absence of fulfillment of this need?

A. I would be satisfied by its presence, but I would not regret its absence
B. I would be satisfied by its presence, and I would somewhat regret its absence
C. I would be satisfied by its presence, and I would regret its absence
D. Its presence is necessary, and I would regret its absence
E. Its presence is absolutely essential, and I would regret its absence

Source Importance Questionnaire

If this need were to be fulfilled, how important would this source be in fulfilling the need?

1. Not important – I do not need this source to fulfill this need
2. Somewhat important – It is acceptable that this source fulfills this need
3. Important – It is desirable that this source fulfills this need
4. Very important – It is strongly desirable that this source fulfills this need
5. Extremely important – It is indispensible that this source fulfills this need

To:	Value Flow	Need Characterization (A B C D E)
Agencies	Cost sharing	
	Future plans information	
	Informative & entertaining content	
	Program cooperation	
	Science knowledge	
	Space acquired data	

Commercial	Funding	
	Future plans information	
	Informative & entertaining content	
	Launch & space services	
	Science knowledge	
	Skilled workforce	
	Space acquired data	
	Space technology	

Defense	Cost sharing	
	Future plans information	
	Launch and space services	
	Program cooperation	
	Science knowledge	
	Skilled workforce	
	Space acquired data	
	Space technology	

To:	Value Flow	Need Characterization (A B C D E)
Educators	Educational material	
	Informative & entertaining content	
	Inspired students	
	Science knowledge	

Government	Compliance with mission requirements	
	Informative & entertaining content	
	Opinions & support	
	Plans and reports of demonstrated progress	
	Political support (votes)	
	Science knowledge	
	Science opinions	
	Science policy advice	
	Taxes	

International Partners	Cost sharing	
	Future plans information	
	Launch and space services	
	Program cooperation	
	Science knowledge	
	Science systems	

Media	Future plans information	
	News & noteworthy info	
	Opinions & support	
	Science content	
	Science knowledge	
	Science policy reports	
NASA/NOAA	Cost sharing	
	Funding	
	Future plans information	
	Informative & entertaining media content	
	Launch and space services	
	Opinions & support	
	Plans and reports of demonstrated progress	
	Policy direction	
	Program cooperation	
	Science knowledge	
	Science policy advice	
	Science systems	
	Skilled workforce	
	Space technology	

To:	Value Flow	Need Characterization (A B C D E)
NGOs	Funding	
	Future plans information	
	Informative & entertaining media content	
	Opinions & support	
	Science knowledge	
	Science policy reports	
Public	Earth & environmental products & services	
	Earth observations-derived products & services	
	Employment	
	HS&E protection	
	Informative & entertaining media content	
	Science content	
	Science knowledge	
	Security benefits	
S&T Advisory Bodies	Funding	
	Future plans information	
	Science knowledge	
Scientists	Access to space systems	
	Funding	
	Future plans information	
	Informative & entertaining media content	
	Skilled workforce	
	Space acquired data	

To:	Value Flow	From:	Source Importance (1 2 3 4 5)
Agencies	Cost sharing	NASA/NOAA	
	Future plans information	NASA/NOAA	
	Informative & entertaining content	Media	
	Program cooperation	NASA/NOAA	
	Science knowledge	Scientists	
	Space acquired data	NASA/NOAA	

Commercial	Funding	NASA/NOAA	
	Future plans information	NASA/NOAA	
	Informative & entertaining media content	Media	
	Launch services	Int'l Partners	
	Science knowledge	Scientists	
	Skilled workforce	Educators	
	Space acquired data	Int'l Partners	
		NASA/NOAA	
	Space technology	NASA/NOAA	

Defense	Cost sharing	NASA/NOAA	
	Future plans information	NASA/NOAA	
	Launch and space services	NASA/NOAA	
	Program cooperation	NASA/NOAA	
	Science knowledge	Scientists	
	Skilled workforce	Educators	
	Space acquired data	NASA/NOAA	
	Space technology	NASA/NOAA	

Educators	Educational material	Agencies	
		NASA/NOAA	
	Informative & entertaining media content	Media	
	Inspired students	People	
	Science knowledge	Scientists	

Media	Future plans information	NASA/NOAA	
	News & noteworthy info	Commercial	
		Government	
	Opinions & support	NGOs	
		People	
	Science content	Agencies	
		NASA/NOAA	
	Science knowledge	Scientists	
	Science policy reports	S&T Advisory	

To:	Value Flow	From:	Source Importance (1 2 3 4 5)
Government	Compliance with mission requirements	NASA/NOAA	
	Informative & entertaining media content	Media	
	Opinions & support	Commercial	
		NGOs	
		People	
	Plans and reports of demonstrated progress	NASA/NOAA	
	Political support (votes)	People	
	Science knowledge	Scientists	
	Science opinions	NASA/NOAA	
	Science policy advice	S&T Advisory	
	Taxes	Commercial	
		People	

Int'l Partners	Cost sharing	NASA/NOAA	
	Future plans information	NASA/NOAA	
	Launch and space services	NASA/NOAA	
	Program cooperation	NASA/NOAA	
	Science knowledge	Scientists	
	Science systems	Scientists	

NASA/NOAA	Cost sharing	Agencies	
		Defense	
		Int'l Partners	
	Funding	Government	
	Future plans information	Agencies	
		Defense	
		Int'l Partners	
	Informative & entertaining content	Media	
	Launch and space services	Int'l Partners	
		Commercial	
	Opinions & support	NGOs	
	Plans and reports of demonstrated progress	Commercial	
	Policy direction	Government	
	Program cooperation	Agencies	
		Defense	
		Int'l Partners	
	Science knowledge	Scientists	
	Science policy advice	S&T Advisory	
	Science systems	Commercial	
		Scientists	
	Skilled workforce	Educators	
	Space technology	Defense	

To:	Value Flow	From:	Source Importance (1 2 3 4 5)
NGOs	Funding	Commercial	
		Government	
		NASA/NOAA	
		People	
	Future plans information	NASA/NOAA	
	Informative & entertaining media content	Media	
	Opinions & support	Commercial	
		People	
	Science knowledge	Scientists	
	Science policy reports	S&T Advisory	
Public	Earth & environmental products & services	NASA/NOAA	
	Earth observations-derived products & services	Commercial	
		NASA/NOAA	
	Employment	Commercial	
		Defense	
		NASA/NOAA	
		Scientists	
	HS&E protection	Agencies	
		Government	
	Informative & entertaining media content	Media	
	Science content	NASA/NOAA	
	Science knowledge	Public Ed. Inst.	
	Security benefits	Defense	
S&T Advisory	Funding	NASA/NOAA	
	Future plans information	Agencies	
		Commercial	
		Int'l Partners	
		NASA/NOAA	
	Science knowledge	Scientists	
Scientists	Access to space systems	Int'l Partners	
		NASA/NOAA	
	Funding	NASA/NOAA	
	Future plans information	NASA/NOAA	
	Informative & entertaining media content	Media	
	Skilled workforce	Educators	
	Space acquired data	Commercial	
		Int'l Partners	
		NASA/NOAA	

10 Appendix D – Value Flow Scores

This section shows the combined scores and final scores for each value flow in the model.

To:	From:	Value Flow	Model Abberviation	Combined Score	Final Score
Agencies	NASA/NOAA	Cost sharing	NASA_cost_AGN	0.15	0.15
Agencies	NASA/NOAA	Future plans information	NASA_plans_AGN	0.17	0.17
Agencies	Media	Informative & entertaining content	MED_info_AGN	0.07	0.07
Agencies	NASA/NOAA	Program cooperation	NASA_coop_AGN	0.25	0.25
Agencies	Scientists	Science knowledge	SCI_know_AGN	0.37	0.37
Agencies	NASA/NOAA	Space acquired data	NASA_data_AGN	0.32	0.32
Com. Data User	Educators	Skilled workforce	EDU_work_DATA	0.63	0.63
Com. Data User	Media	Informative & entertaining content	MED_info_DATA	0.18	0.18
Com. Data User	NASA/NOAA	Future plans information	NASA_plans_DATA	0.41	0.41
Com. Data User	NASA/NOAA	Space acquired data		0.43	-
		(health)	NASA_data_health_DATA	0.15	0.15
		(land use)	NASA_data_land_DATA	0.43	0.43
		(solid Earth)	NASA_data_solid_DATA	0.25	0.25
		(climate change)	NASA_data_climate_DATA	0.15	0.15
		(weather)	NASA_data_weather_DATA	0.43	0.43
		(water)	NASA_data_water_DATA	0.15	0.15
Com. Data User	Int'l Partenrs	Space acquired data		0.24	-
		(health)	INTL_data_health_DATA	0.08	0.08
		(land use)	INTL_data_land_DATA	0.24	0.24
		(solid Earth)	INTL_data_solid_DATA	0.14	0.14
		(climate change)	INTL_data_climate_DATA	0.08	0.08
		(weather)	INTL_data_weather_DATA	0.24	0.24
		(water)	INTL_data_water_DATA	0.08	0.08
Com. Data User	Scientist	Science knowledge		0.33	-
		(health)	SCI_know_health_DATA	0.11	0.11
		(land use)	SCI_know_land_DATA	0.33	0.33
		(solid Earth)	SCI_know_solid_DATA	0.19	0.19
		(climate change)	SCI_know_climate_DATA	0.11	0.11
		(weather)	SCI_know_weather_DATA	0.33	0.33
		(water)	SCI_know_water_DATA	0.11	0.11
Com. Industry	Educators	Skilled workforce	EDU_work_IND	0.63	0.63
Com. Industry	NASA/NOAA	Funding	NASA_fund_IND	0.25	0.39
Com. Industry	Media	Informative & entertaining content	MED_info_IND	0.16	0.16

To:	From:	Value Flow	Model Abberviation	Combined Score	Final Score
Com. Industry	NASA/NOAA	Future plans information	NASA_plans_IND	0.41	0.41
Com. Industry	NASA/NOAA	Launch & space services	NASA_launch_IND	0.06	0.06
Com. Industry	Int'l Partners	Launch & space services	INTL_launch_IND	0.25	0.25
Com. Industry	NASA/NOAA	Space technology	NASA_tech_IND	0.20	0.20
Defense	NASA/NOAA	Cost sharing		0.09	-
		(health)	NASA_cost_health_DEF	0.03	0.03
		(land use)	NASA_cost_land_DEF	0.06	0.06
		(solid Earth)	NASA_cost_solid_DEF	0.03	0.03
		(climate change)	NASA_cost_climate_DEF	0.09	0.09
		(weather)	NASA_cost_weather_DEF	0.09	0.09
		(water)	NASA_cost_water_DEF	0.09	0.09
Defense	NASA/NOAA	Future plans information	NASA_plans_DEF	0.22	0.22
Defense	NASA/NOAA	Launch & space services	NASA_launch_DEF	0.49	0.49
Defense	NASA/NOAA	Program cooperation		0.17	-
		(health)	NASA_coop_health_DEF	0.06	0.06
		(land use)	NASA_coop_land_DEF	0.10	0.10
		(solid Earth)	NASA_coop_solid_DEF	0.06	0.06
		(climate change)	NASA_coop_climate_DEF	0.17	0.17
		(weather)	NASA_coop_weather_DEF	0.17	0.17
		(water)	NASA_coop_water_DEF	0.17	0.17
Defense	Scientists	Science knowledge		0.24	-
		(health)	SCI_know_health_DEF	0.08	0.08
		(land use)	SCI_know_land_DEF	0.14	0.14
		(solid Earth)	SCI_know_solid_DEF	0.08	0.08
		(climate change)	SCI_know_climate_DEF	0.24	0.24
		(weather)	SCI_know_weather_DEF	0.24	0.24
		(water)	SCI_know_water_DEF	0.24	0.24
Defense	Educators	Skilled workforce	EDU_work_DEF	0.60	0.60
Defense	NASA/NOAA	Space acquired data		0.54	
		(health)	NASA_data_health_DEF	0.19	0.19
		(land use)	NASA_data_land_DEF	0.32	0.32
		(solid Earth)	NASA_data_solid_DEF	0.19	0.19
		(climate change)	NASA_data_climate_DEF	0.54	0.54
		(weather)	NASA_data_weather_DEF	0.54	0.54
		(water)	NASA_data_water_DEF	0.54	0.54
Defense	Com Industry	Science systems	IND_sys_DEF	0.38	0.54
Educators	Agencies	Educational material	AGN_edu_EDU	0.25	0.25
Educators	NASA/NOAA	Educational material	NASA_edu_EDU	0.26	0.26
Educators	Media	Informative & entertaining content	MED_info_EDU	0.31	0.31

To:	From:	Value Flow	Model Abberviation	Combined Score	Final Score
Educators	Public	Inspired students	PUB_stud_EDU	0.65	0.65
Educators	Scientists	Science knowledge	SCI_know_EDU	0.48	0.48
Educators	NASA/NOAA	Funding	NASA_fund_EDU	0.12	0.12
Government	NASA/NOAA	Compliance with policy	NASA_comp_GOV	0.57	0.57
Government	Media	Informative & entertaining content	MED_info_GOV	0.24	0.24
Government	Com Data User	Opinions & support	DATA_opin_GOV	0.29	0.29
Government	Com. Industry	Opinions & support	IND_opin_GOV	0.26	0.26
Government	NGOs	Opinions & support	NGO_opin_GOV	0.30	0.30
Government	Public	Opinions & support	PUB_opin_GOV	0.34	0.34
Government	NASA/NOAA	Plans and reports of progress	NASA_plans_GOV	0.47	0.47
Government	Public	Votes	PUB_votes_GOV	0.59	0.59
Government	Scientists	Science knowledge		0.43	-
		(health)	SCI_know_health_GOV	0.26	0.43
		(land use)	SCI_know_land_GOV	0.26	0.43
		(solid Earth)	SCI_know_solid_GOV	0.15	0.26
		(climate change)	SCI_know_climate_GOV	0.43	0.43
		(weather)	SCI_know_weather_GOV	0.26	0.26
		(water)	SCI_know_water_GOV	0.26	0.26
Government	NASA/NOAA	Science opinions		0.42	-
		(health)	NASA_sci_health_GOV	0.25	0.25
		(land use)	NASA_sci_land_GOV	0.25	0.25
		(solid Earth)	NASA_sci_solid_GOV	0.14	0.14
		(climate change)	NASA_sci_climate_GOV	0.42	0.42
		(weather)	NASA_sci_weather_GOV	0.25	0.25
		(water)	NASA_sci_water_GOV	0.25	0.25
Government	S&T Advisory	Science policy advice		0.43	-
		(health)	STA_advice_health_GOV	0.25	0.25
		(land use)	STA_advice_land_GOV	0.25	0.25
		(solid Earth)	STA_advice_solid_GOV	0.15	0.15
		(climate change)	STA_advice_climate_GOV	0.43	0.43
		(weather)	STA_advice_weather_GOV	0.25	0.25
		(water)	STA_advice_water_GOV	0.25	0.25
Government	Com. Data Users	Taxes	DATA_tax_GOV	0.31	0.31
Government	Com. Industry	Taxes	IND_tax_GOV	0.31	0.31
Government	Public	Taxes	PUB_tax_GOV	0.42	0.42
Int'l Partners	NASA/NOAA	Cost sharing	NASA_cost_INTL	0.25	0.25
Int'l Partners	NASA/NOAA	Future plans information	NASA_plans_INTL	0.27	0.27
Int'l Partners	NASA/NOAA	Launch & space services	NASA_launch_INTL	0.28	0.28
Int'l Partners	NASA/NOAA	Program cooperation	NASA_coop_INTL	0.25	0.25
Int'l Partners	Scientists	Science knowledge	SCI_know_INTL	0.57	0.57

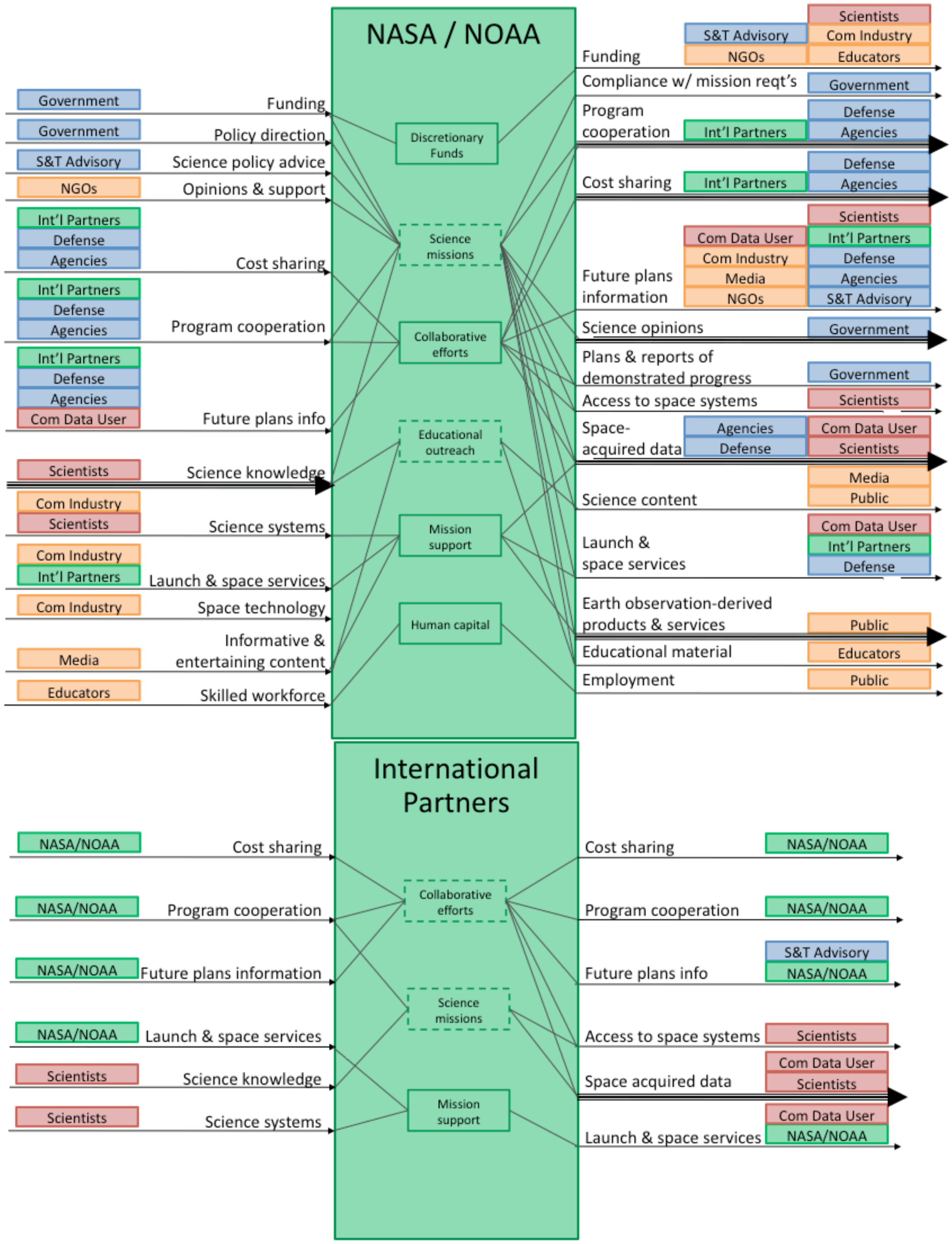
To:	From:	Value Flow	Model Abberviation	Combined Score	Final Score
Int'l Partners	Scientists	Science systems	SCI_sys_INTL	0.44	0.44
Media	NASA/NOAA	Future plans information	NASA_plans_MED	0.11	0.11
Media	Com. Data User	News & noteworthy information	DATA_news_MED	0.48	0.48
Media	Com. Industry	News & noteworthy information	IND_news_MED	0.48	0.48
Media	Government	News & noteworthy information	GOV_news_MED	0.48	0.48
Media	NGOs	Opinions & support	NGO_news_MED	0.15	0.15
Media	Public	Opinions & support	PUB_concerns_MED	0.22	0.22
Media	Agencies	Science content	AGN_content_MED	0.19	0.19
Media	NASA/NOAA	Science content	NASA_content_MED	0.28	0.28
Media	Scientists	Science knowledge	SCI_know_MED	0.32	0.32
Media	S&T Advisory	Science policy reports	STA_report_MED	0.17	0.17
NASA/NOAA	Agencies	Cost sharing	AGN_cost_NASA	0.19	0.19
NASA/NOAA	Defense	Cost sharing	DEF_cost_NASA	0.30	0.30
NASA/NOAA	Int'l Partners	Cost sharing	INTL_cost_NASA	0.34	0.34
NASA/NOAA	Government	Funding	GOV_fund_NASA	0.53	0.53
NASA/NOAA	Agencies	Future plans information	AGN_plans_NASA	0.23	0.23
NASA/NOAA	Defense	Future plans information	DEF_plans_NASA	0.24	0.24
NASA/NOAA	Int'l Partners	Future plans information	INTL_plans_NASA	0.33	0.33
NASA/NOAA	Media	Informative & entertaining content	MED_info_NASA	0.09	0.09
NASA/NOAA	Int'l Partners	Launch & space services	INTL_launch_NASA	0.34	0.34
NASA/NOAA	Com. Industry	Launch & space services	IND_launch_NASA	0.69	0.69
NASA/NOAA	NGOs	Opinions & support	NGO_opin_NASA	0.13	0.13
NASA/NOAA	Com. Data User	Future plans information	DATA_plans_NASA	0.28	0.28
NASA/NOAA	Government	Policy direction	GOV_dir_NASA	0.72	0.72
NASA/NOAA	Agencies	Program cooperation	AGN_coop_NASA	0.22	0.22
NASA/NOAA	Defense	Program cooperation	DEF_coop_NASA	0.20	0.20
NASA/NOAA	Int'l Partners	Program cooperation	INTL_coop_NASA	0.25	0.34
NASA/NOAA	Scientists	Science knowledge		0.65	-
		(health)	SCI_know_health_NASA	0.22	0.38
		(land use)	SCI_know_land_NASA	0.38	0.38
		(solid Earth)	SCI_know_solid_NASA	0.38	0.48
		(climate change)	SCI_know_climate_NASA	0.65	0.65
		(weather)	SCI_know_weather_NASA	0.38	0.48
		(water)	SCI_know_water_NASA	0.38	0.48

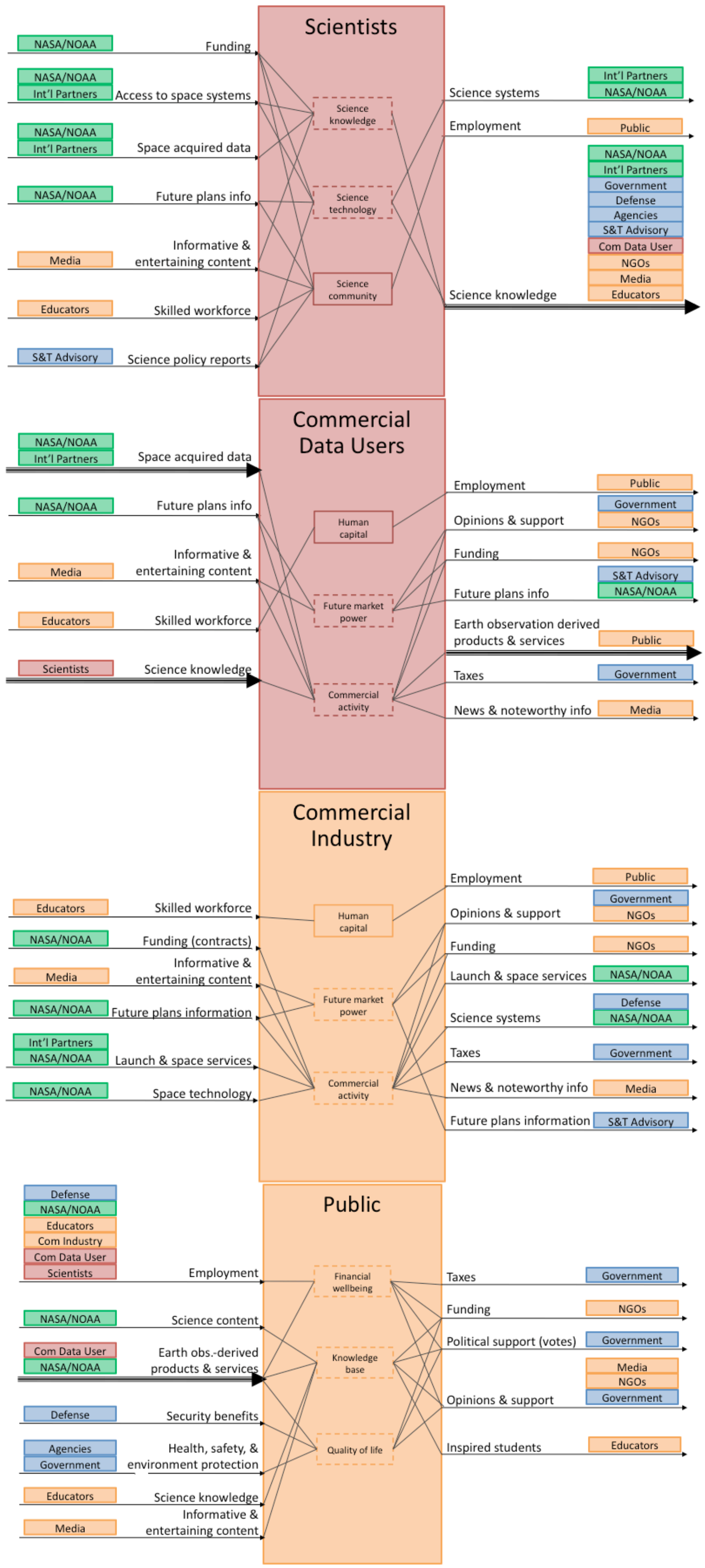
To:	From:	Value Flow	Model Abberviation	Combined Score	Final Score
NASA/NOAA	S&T Advisory	Science policy advice	STA_advice_NASA	0.70	0.70
NASA/NOAA	Com. Industry	Science systems	IND_sys_NASA	0.61	0.61
NASA/NOAA	Scientists	Science systems	SCI_sys_NASA	0.67	0.67
NASA/NOAA	Educators	Skilled workforce	EDU_work_NASA	0.63	0.63
NGOs	Com. Data User	Funding	DATA_fund_NGO	0.18	0.18
NGOs	Com. Industry	Funding	IND_fund_NGO	0.18	0.18
NGOs	Government	Funding	GOV_fund_NGO	0.15	0.15
NGOs	NASA/NOAA	Funding	NASA_fund_NGO	0.14	0.14
NGOs	Public	Funding	PUB_fund_NGO	0.20	0.20
NGOs	NASA/NOAA	Future plans information	NASA_plans_NGO	0.48	0.48
NGOs	Media	Informative & entertaining content	MED_info_NGO	0.21	0.21
NGOs	Com. Data User	Opinions & support	DATA_opin_NGO	0.34	0.34
NGOs	Com. Industry	Opinions & support	IND_opin_NGO	0.32	0.32
NGOs	Public	Opinions & support	PUB_opin_NGO	0.47	0.47
NGOs	Scientists	Science knowledge	SCI_know_NGO	0.35	0.35
NGOs	S&T Advisory	Science policy reports	STA_report_NGO	0.36	0.36
Public	Com. Data User	Earth observations-derived products & services		0.32	-
		(health)	DATA_products_health_PUB	0.25	0.25
		(land use)	DATA_products_land_PUB	0.42	0.42
		(solid Earth)	DATA_products_solid_PUB	0.25	0.25
		(climate change)	DATA_products_climate_PUB	0.14	0.14
		(weather)	DATA_products_weather_PUB	0.42	0.42
		(water)	DATA_products_water_PUB	0.42	0.42
Public	NASA/NOAA	Earth observations-derived products & services		0.42	--
		(health)	NASA_products_health_PUB	0.19	0.19
		(land use)	NASA_products_land_PUB	0.32	0.32
		(solid Earth)	NASA_products_solid_PUB	0.19	0.19
		(climate change)	NASA_products_climate_PUB	0.11	0.11
		(weather)	NASA_products_weather_PUB	0.32	0.32
		(water)	NASA_products_water_PUB	0.32	0.32
Public	Com. Data User	Employment	DATA_emp_PUB	0.32	0.32
Public	Com. Industry	Employment	IND_emp_PUB	0.54	0.54
Public	Defense	Employment	DEF_emp_PUB	0.44	0.44
Public	NASA/NOAA	Employment	NASA_emp_PUB	0.37	0.37
Public	Scientists	Employment	SCI_emp_PUB	0.46	0.46
Public	Agencies	HS&E protection	AGN_hse_PUB	0.29	0.29
Public	Government	HS&E protection	GOV_hse_PUB	0.34	0.34
Public	Media	Informative & entertaining content	MED_info_PUB	0.33	0.33

To:	From:	Value Flow	Model Abberviation	Combined Score	Final Score
Public	NASA/NOAA	Science content	NASA_cont_PUB	0.31	0.31
Public	Educators	Science knowledge	EDU_know_PUB	0.29	0.29
Public	Defense	Security benefits	DEF_sec_PUB	0.49	0.43
S&T Advisory	NASA/NOAA	Funding	NASA_fund_STA	0.21	0.21
S&T Advisory	Agencies	Future plans information	AGN_plans_STA	0.36	0.36
S&T Advisory	Com. Data User	Future plans information	DATA_plans_STA	0.36	0.33
S&T Advisory	Com. Industry	Future plans information	IND_plans_STA	0.36	0.36
S&T Advisory	Int'l Partners	Future plans information	INTL_plans_STA	0.31	0.31
S&T Advisory	NASA/NOAA	Future plans information	NASA_plans_STA	0.57	0.57
S&T Advisory	Scientists	Science knowledge	SCI_know_STA	0.53	0.53
Scientists	Int'l Partners	Access to space systems	INTL_access_SCI	0.38	0.38
Scientists	NASA/NOAA	Access to space systems	NASA_access_SCI	0.57	0.57
Scientists	NASA/NOAA	Funding	NASA_fund_SCI	0.47	0.47
Scientists	NASA/NOAA	Future plans information	NASA_plans_SCI	0.37	0.37
Scientists	Media	Informative & entertaining content	MED_info_SCI	0.10	0.10
Scientists	Educators	Skilled workforce	EDU_work_SCI	0.62	0.62
Scientists	Int'l Partners	Space acquired data	INTL_data_SCI	0.57	0.57
Scientists	NASA/NOAA	Space acquired data	NASA_data_SCI	0.74	0.74
Scientists	S&T Advisory	Science policy reports	STA_report_SCI	0.44	0.44

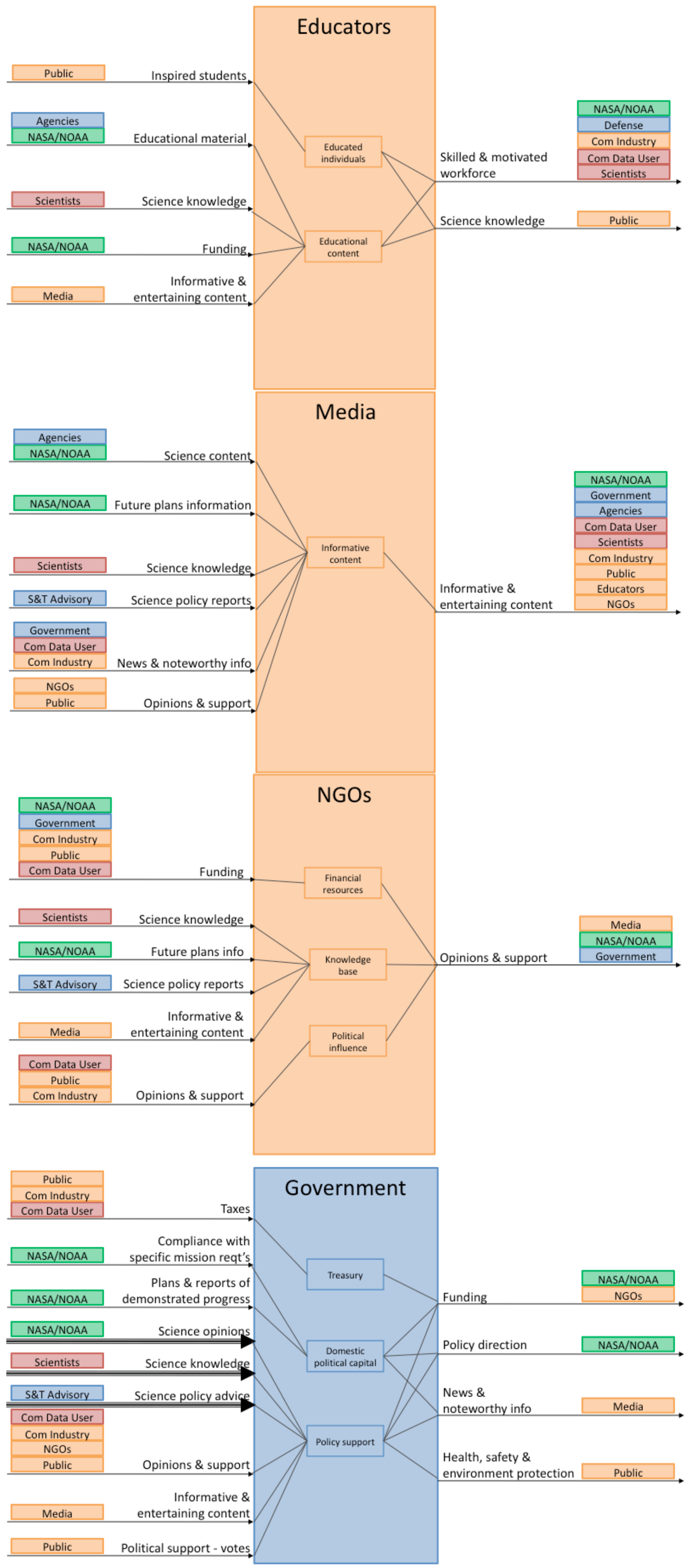
11 Appendix E – Internal Assets for Each Stakeholder

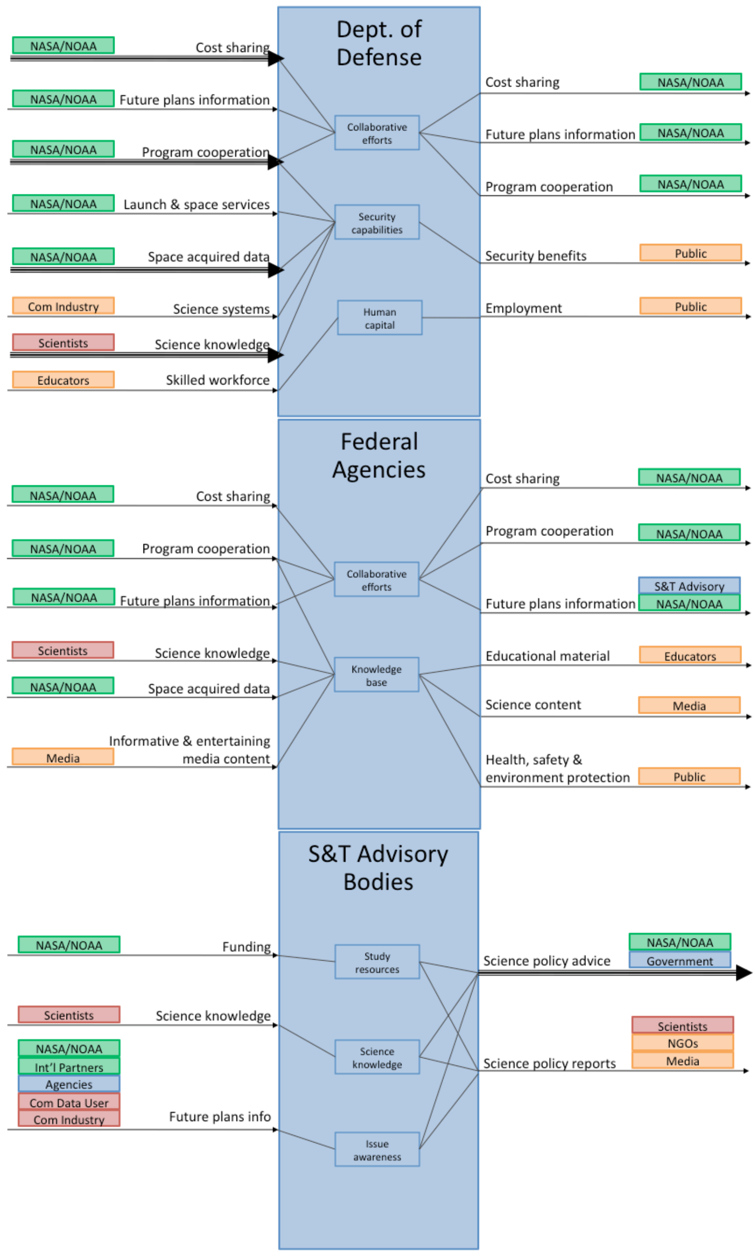
The following diagrams show the internal assets that were used to connect each stakeholder's inputs and outputs. The dashed lines indicate internal assets that resulted in duplicate value loops.





Scientists
NASA/NOAA
Funding
NASA/NOAA
Int'l Partners
Access to space systems
NASA/NOAA
Int'l Partners
Space acquired data
NASA/NOAA
Future plans info
Media
Informative & entertaining content
Educators
Skilled workforce
S&T Advisory
Science policy reports
Science knowledge
Science technology
Science community
Science systems
Int'l Partners
NASA/NOAA
Employment
Public
Science knowledge
NASA/NOAA
Int'l Partners
Government
Defense
Agencies
S&T Advisory
Com Data User
NGOs
Media
Educators
Commercial Data Users
NASA/NOAA
Int'l Partners
Space acquired data
NASA/NOAA
Future plans info
Media
Informative & entertaining content
Educators
Skilled workforce
Scientists
Science knowledge
Human capital
Future market power
Commercial activity
Employment
Public
Opinions & support
Government
NGOs
Funding
NGOs
Future plans info
S&T Advisory
NASA/NOAA
Earth observation derived products & services
Public
Taxes
Government
News & noteworthy info
Media
Commercial Industry
Educators
Skilled workforce
NASA/NOAA
Funding (contracts)
Media
Informative & entertaining content
NASA/NOAA
Future plans information
Int'l Partners
NASA/NOAA
Launch & space services
NASA/NOAA
Space technology
Human capital
Future market power
Commercial activity
Employment
Public
Opinions & support
Government
NGOs
Funding
NGOs
Launch & space services
NASA/NOAA
Science systems
Defense
NASA/NOAA
Taxes
Government
News & noteworthy info
Media
Future plans information
S&T Advisory
Public
Defense
NASA/NOAA
Educators
Com Industry
Com Data User
Scientists
Employment
NASA/NOAA
Science content
Com Data User
NASA/NOAA
Earth obs.-derived products & services
Defense
Security benefits
Agencies
Government
Health, safety, & environment protection
Educators
Science knowledge
Media
Informative & entertaining content
Financial wellbeing
Knowledge base
Quality of life
Taxes
Government
Funding
NGOs
Political support (votes)
Government
Media
NGOs
Government
Opinions & support
Inspired students
Educators


Educators
Public
Inspired students
Agencies
NASA/NOAA
Educational material
Scientists
Science knowledge
NASA/NOAA
Funding
Media
Informative & entertaining content
Educated individuals
Educational content
Skilled & motivated workforce
NASA/NOAA
Defense
Com Industry
Com Data User
Scientists
Science knowledge
Public
Media
Agencies
NASA/NOAA
Science content
NASA/NOAA
Future plans information
Scientists
Science knowledge
S&T Advisory
Science policy reports
Government
Com Data User
Com Industry
News & noteworthy info
NGOs
Public
Opinions & support
Informative content
Informative & entertaining content
NASA/NOAA
Government
Agencies
Com Data User
Scientists
Com Industry
Public
Educators
NGOs
NGOs
NASA/NOAA
Government
Com Industry
Public
Com Data User
Funding
Scientists
Science knowledge
NASA/NOAA
Future plans info
S&T Advisory
Science policy reports
Media
Informative & entertaining content
Com Data User
Public
Com Industry
Opinions & support
Financial resources
Knowledge base
Political influence
Opinions & support
Media
NASA/NOAA
Government
Government
Public
Com Industry
Com Data User
Taxes
NASA/NOAA
Compliance with specific mission reqt's
NASA/NOAA
Plans & reports of demonstrated progress
NASA/NOAA
Science opinions
Scientists
Science knowledge
S&T Advisory
Science policy advice
Com Data User
Com Industry
NGOs
Public
Opinions & support
Media
Informative & entertaining content
Public
Political support - votes
Treasury
Domestic political capital
Policy support
Funding
NASA/NOAA
NGOs
Policy direction
NASA/NOAA
News & noteworthy info
Media
Health, safety & environment protection
Public


Dept. of Defense
NASA/NOAA
Cost sharing
NASA/NOAA
Future plans information
NASA/NOAA
Program cooperation
NASA/NOAA
Launch & space services
NASA/NOAA
Space acquired data
Com Industry
Science systems
Scientists
Science knowledge
Educators
Skilled workforce
Collaborative efforts
Security capabilities
Human capital
Cost sharing
NASA/NOAA
Future plans information
NASA/NOAA
Program cooperation
NASA/NOAA
Security benefits
Public
Employment
Public
Federal Agencies
NASA/NOAA
Cost sharing
NASA/NOAA
Program cooperation
NASA/NOAA
Future plans information
Scientists
Science knowledge
NASA/NOAA
Space acquired data
Media
Informative & entertaining media content
Collaborative efforts
Knowledge base
Cost sharing
NASA/NOAA
Program cooperation
NASA/NOAA
Future plans information
S&T Advisory
NASA/NOAA
Educational material
Educators
Science content
Media
Health, safety & environment protection
Public
S&T Advisory Bodies
NASA/NOAA
Funding
Scientists
Science knowledge
NASA/NOAA
Int'l Partners
Agencies
Com Data User
Com Industry
Future plans info
Study resources
Science knowledge
Issue awareness
Science policy advice
NASA/NOAA
Government
Science policy reports
Scientists
NGOs
Media

12 Appendix F – Numeric Scores Accompanying Graphs

This section provides the numerical data that corresponds to most of the charts presented in Chapter 4.

Figure 46: Weighted stakeholder occurrence scores
Figure 47: Normalized weighted stakeholder occurrence scores
Figure 48: Stakeholder importance using Freeman's stakeholder modeling technique

	Figure 46	Figure 47	Figure 48
Stakeholders	Weighted Occurrence Score	Norm. Weighted Occurrence Score	Freeman's Wtd. Occurrence Score
Agencies	0.03	0.019	0
Com. Data Users	0.16	0.021	0.01
Com. Industry	0.09	0.024	0.10
Defense	0.07	0.024	0
Educators	0.13	0.023	0.02
Government	0.63	0.029	0.24
Int'l Partners	0.13	0.025	0.07
Media	0.11	0.016	0
NASA/NOAA	1.0	0.034	1.0
NGOs	0.05	0.019	0
Public	0.27	0.025	0
S&T Advisory	0.21	0.026	0.04
Scientists	0.57	0.034	0.52

Figure 49: Top 30 most significant value flows

	Value Flow	Wtd. Occurrence Score		Value Flow	Wtd. Occurrence Score
1	GOV_dir_NASA	20.10	16	PUB_opin_GOV	3.87
2	GOV_fund_NASA	15.65	17	SCI_know_(all)_DATA	3.37
3	SCI_know_(all)_NASA	8.70	18	NASA_products_(all)_PUB	3.24
4	PUB_votes_GOV	8.22	19	DEF_sec_PUB	3.16
5	NASA_data_SCI	8.15	20	NASA_data_(all)_DATA	2.95
6	SCI_know_(all)_GOV	7.59	21	NASA_plans_DATA	2.87
7	STA_advice_(all)_GOV	6.47	22	INTL_data_SCI	2.76
8	EDU_work_NASA	5.95	23	SCI_know_EDU	2.62
9	NASA_access_SCI	5.43	24	GOV_news_MED	2.57
10	NASA_fund_SCI	5.43	25	PUB_stud_EDU	2.56
11	SCI_know_STA	4.55	26	NGO_opin_GOV	2.53
12	DATA_products_(all)_PUB	4.17	27	NASA_plans_INTL	2.36
13	NASA_plans_STA	4.03	28	STA_advice_NASA	2.19
14	STA_report_SCI	4.00	29	NASA_coop_INTL	2.13
15	NASA_plans_SCI	3.96	30	NASA_cost_INTL	2.13

Figure 65: Most significant NASA/NOAA outputs

	Value Flow	Wtd. Occurrence Score		Value Flow	Wtd. Occurrence Score
1	NASA_data_SCI	8.15	14	NASA_data_land_DATA	0.99
2	NASA_access_SCI	5.92	15	NASA_data_weather_DATA	0.99
3	NASA_fund_SCI	5.43	16	NASA_plans_GOV	0.79
4	NASA_plans_STA	4.03	17	NASA_products_land_PUB	0.75
5	NASA_plans_SCI	3.96	18	NASA_products_water_PUB	0.75
6	NASA_plans_DATA	2.87	19	NASA_products_weather_PUB	0.75
7	NASA_plans_INTL	2.36	20	NASA_emp_PUB	0.73
8	NASA_coop_INTL	2.13	21	NASA_coop_AGN	0.69
9	NASA_cost_INTL	2.13	22	NASA_sci_climate_GOV	0.67
10	NASA_plans_IND	1.85	23	NASA_edu_EDU	0.63
11	NASA_fund_STA	1.15	24	NASA_cont_PUB	0.63
12	NASA_fund_IND	1.11	25	NASA_cont_MED	0.54
13	NASA_comp_GOV	1.01			

Figure 66: Most significant NASA/NOAA inputs

	Value Flow	Wtd. Occurrence Score		Value Flow	Wtd. Occurrence Score
1	GOV_dir_NASA	20.10	14	NGO_opin_NASA	0.67
2	GOV_fund_NASA	15.65	15	MED_info_NASA	0.41
3	EDU_work_NASA	5.95	16	DEF_cost_NASA	0.38
4	SCI_know_climate_NASA	2.41	17	DEF_plans_NASA	0.31
5	STA_advice_NASA	2.19	18	INTL_launch_NASA	0.27
6	IND_launch_NASA	1.68	19	INTL_coop_NASA	0.26
7	SCI_know_land_NASA	1.38	20	INTL_cost_NASA	0.26
8	SCI_know_solid_NASA	1.38	21	DEF_coop_NASA	0.26
9	SCI_know_water_NASA	1.38	22	INTL_plans_NASA	0.25
10	SCI_know_weather_NASA	1.38	23	AGN_plans_NASA	0.13
11	IND_sys_NASA	1.19	24	AGN_coop_NASA	0.13
12	SCI_sys_NASA	1.01	25	AGN_cost_NASA	0.11
13	SCI_know_health_NASA	0.79	26		

Figure 68: Relative importance of science categories using value loop analysis

Science category	Weighted Occurrence Score
Weather	8.65
Climate change	8.33
Land-use	8.33
Water	6.31
Human health	4.49
Solid Earth	4.31

Figure 72: Most important stakeholders using different threshold values

Stakeholders	thr = 0.01 Weighted Occurrence Score	thr = 0.03 Weighted Occurrence Score	thr = 0.05 Weighted Occurrence Score
Agencies	0.03	0.02	0.01
Com. Data Users	0.16	0.11	0.06
Com. Industry	0.09	0.08	0.06
Defense	0.07	0.06	0.04
Educators	0.13	0.10	0.07
Government	0.63	0.57	0.52
Int'l Partners	0.13	0.11	0.09
Media	0.11	0.04	0.0
NASA/NOAA	1.0	1.0	1.0
NGOs	0.05	0.02	0.01
Public	0.27	0.23	0.18
S&T Advisory	0.21	0.20	0.18
Scientists	0.57	0.52	0.52

Figure 73: Most important value flows using different threshold values

	Value Flow	thr = 0.01 Weighted Occurrence Score	thr = 0.03 Weighted Occurrence Score	thr = 0.05 Weighted Occurrence Score
1	GOV_dir_NASA	20.10	14.38	9.99
2	GOV_fund_NASA	15.65	9.85	6.71
3	PUB_votes_GOV	8.22	5.38	3.30
4	NASA_data_SCI	8.15	6.04	4.73
5	EDU_work_NASA	5.95	3.65	2.30
6	NASA_access_SCI	5.43	4.19	3.28
7	NASA_fund_SCI	5.43	4.07	3.32
8	SCI_know_STA	4.55	3.31	2.43
9	NASA_plans_STA	4.03	3.14	2.75
10	STA_report_SCI	4.00	2.04	1.34
11	NASA_plans_SCI	3.96	2.91	2.30
12	PUB_opin_GOV	3.87	2.03	1.07
13	DEF_sec_PUB	3.16	1.64	0.95
14	NASA_plans_DATA	2.87	1.90	0.95
15	INTL_data_SCI	2.76	1.93	1.21
16	SCI_know_EDU	2.62	1.57	0.82
17	GOV_news_MED	2.57	0.32	0.05
18	PUB_stud_EDU	2.56	1.72	1.08
19	NGO_opin_GOV	2.53	0.92	0.24
20	SCI_know_climate_NASA	2.41	2.20	2.10

Figure 74: Top 20 value flows using threshold value of 0.05

	Value Flow	Weighted Occurrence Score		Value Flow	Weighted Occurrence Score
1	GOV_dir_NASA	9.99	11	SCI_know_climate_NASA	2.10
2	GOV_fund_NASA	6.71	12	STA_advice_NASA	1.93
3	NASA_data_SCI	4.73	13	SCI_know_climate_GOV	1.34
4	NASA_fund_SCI	3.32	14	STA_report_SCI	1.34
5	PUB_votes_GOV	3.30	15	INTL_data_SCI	1.21
6	NASA_access_SCI	3.28	16	PUB_stud_EDU	1.08
7	NASA_plans_STA	2.75	17	SCI_know_land_NASA	1.08
8	SCI_know_STA	2.43	18	SCI_know_solid_NASA	1.08
9	EDU_work_NASA	2.30	19	SCI_know_water_NASA	1.08
10	NASA_plans_SCI	2.30	20	SCI_know_weather_NASA	1.08

Figure 75: Most important NASA/NOAA outputs for varying threshold values

		thr = 0.01	thr = 0.03	thr = 0.05
	Value Flow	Weighted Occurrence Score	Weighted Occurrence Score	Weighted Occurrence Score
1	NASA_data_SCI	8.15	6.04	4.73
2	NASA_access_SCI	5.92	4.19	3.28
3	NASA_fund_SCI	5.43	4.07	3.32
4	NASA_plans_STA	4.03	3.14	2.75
5	NASA_plans_SCI	3.96	2.91	2.30
6	NASA_plans_DATA	2.87	1.90	0.95
7	NASA_plans_INTL	2.36	1.38	0.88
8	NASA_coop_INTL	2.13	1.23	0.73
9	NASA_cost_INTL	2.13	1.23	0.73
10	NASA_plans_IND	1.85	1.29	0.82
11	NASA_fund_STA	1.15	0.84	0.38
12	NASA_fund_IND	1.11	0.91	0.70
13	NASA_comp_GOV	1.01	0.86	0.77
14	NASA_data_land_DATA	0.99	0.74	0.43
15	NASA_data_weather_DATA	0.99	0.74	0.43
16	NASA_plans_GOV	0.79	0.66	0.59
17	NASA_products_land_PUB	0.75	0.61	0.57
18	NASA_products_water_PUB	0.75	0.61	0.57
19	NASA_products_weather_PUB	0.75	0.61	0.57
20	NASA_emp_PUB	0.73	0.58	0.51
21	NASA_coop_AGN	0.69	0.37	0.22
22	NASA_sci_climate_GOV	0.67	0.59	0.53
23	NASA_edu_EDU	0.63	0.32	0.16
24	NASA_cont_PUB	0.63	0.52	0.49
25	NASA_cont_MED	0.54	0.33	0.10

Figure 76: Most important NASA/NOAA inputs for varying threshold values

	Value Flow	thr = 0.01 Weighted Occurrence Score	thr = 0.03 Weighted Occurrence Score	thr = 0.05 Weighted Occurrence Score
1	GOV_dir_NASA	20.10	14.38	9.99
2	GOV_fund_NASA	15.65	9.85	6.71
3	EDU_work_NASA	5.95	3.65	2.30
4	SCI_know_climate_NASA	2.41	2.20	2.10
5	STA_advice_NASA	2.19	2.12	1.93
6	IND_launch_NASA	1.68	0.93	0.74
7	SCI_know_land_NASA	1.38	1.23	1.08
8	SCI_know_solid_NASA	1.38	1.23	1.08
9	SCI_know_water_NASA	1.38	1.23	1.08
10	SCI_know_weather_NASA	1.38	1.23	1.08
11	IND_sys_NASA	1.19	0.77	0.61
12	SCI_sys_NASA	1.01	0.90	0.61
13	SCI_know_health_NASA	0.79	0.62	0.53
14	NGO_opin_NASA	0.67	0.15	0.26
15	MED_info_NASA	0.41	0.03	0.26
16	DEF_cost_NASA	0.38	0.33	0.25
17	DEF_plans_NASA	0.31	0.18	0.22
18	INTL_launch_NASA	0.27	0.26	0.22
19	INTL_coop_NASA	0.26	0.26	0.06
20	INTL_cost_NASA	0.26	0.26	0.06
21	DEF_coop_NASA	0.26	0.15	0.06
22	INTL_plans_NASA	0.25	0.25	0.05
23	AGN_plans_NASA	0.13	0.13	0.05
24	AGN_coop_NASA	0.13	0.13	0.0
25	AGN_cost_NASA	0.11	0.11	0.0

Figure 78: Relative importance of science categories for varying threshold values

Science category	thr = 0.01 Wtd. Occurrence Score	thr = 0.03 Wtd. Occurrence Score	thr = 0.05 Wtd. Occurrence Score
Weather	8.65	5.75	4.08
Climate change	8.33	6.40	5.36
Land-use	8.33	5.43	3.86
Water	6.31	4.52	3.59
Human health	4.49	3.01	2.26
Solid Earth	4.31	2.82	1.93

Figure 81: Most important value flows using two sets of International Partner scores

	Value Flow	Original Wtd. Occurrence Score	Increased Int'l Partners Wtd. Occurrence Score
1	GOV_dir_NASA	20.10	21.29
2	GOV_fund_NASA	15.65	16.44
3	PUB_votes_GOV	8.22	8.23
4	NASA_data_SCI	8.15	8.15
5	EDU_work_NASA	5.95	6.13
6	NASA_access_SCI	5.92	5.92
7	NASA_fund_SCI	5.43	5.48
8	SCI_know_STA	4.55	5.27
9	NASA_plans_STA	4.03	4.06
10	STA_report_SCI	4.00	4.33
11	NASA_plans_SCI	3.96	4.00
12	PUB_opin_GOV	3.87	3.87
13	DEF_sec_PUB	3.16	3.16
14	NASA_plans_DATA	2.87	2.87
15	INTL_data_SCI	2.76	4.65
16	SCI_know_EDU	2.62	2.80
17	GOV_news_MED	2.57	2.57
18	PUB_stud_EDU	2.56	2.56
19	NGO_opin_GOV	2.53	2.55
20	SCI_know_climate_NASA	2.41	2.78

Figure 82: Most important value flows using increased International Partner scores

	Value Flow	Wtd. Occurrence Score		Value Flow	Wtd. Occurrence Score
1	GOV_dir_NASA	21.29	11	NASA_plans_STA	4.06
2	GOV_fund_NASA	16.44	12	NASA_plans_SCI	4.00
3	PUB_votes_GOV	8.23	13	NASA_plans_INTL	3.94
4	NASA_data_SCI	8.15	14	PUB_opin_GOV	3.87
5	EDU_work_NASA	6.13	15	NASA_coop_INTL	3.58
6	NASA_access_SCI	5.92	16	NASA_cost_INTL	3.58
7	NASA_fund_SCI	5.48	17	DEF_sec_PUB	3.16
8	SCI_know_STA	5.27	18	INTL_access_SCI	3.05
9	INTL_data_SCI	4.65	19	NASA_plans_DATA	2.87
10	STA_report_SCI	4.33	20	SCI_know_EDU	2.80

Figure 87: Comparison of most important stakeholders using two value loop calculation methods

	abc	abc^2
Stakeholders	Weighted Occurrence Score	Weighted Occurrence Score
Agencies	0.03	0.03
Com. Data Users	0.16	0.17
Com. Industry	0.09	0.10
Defense	0.07	0.07
Educators	0.13	0.14
Government	0.63	0.70
Int'l Partners	0.13	0.12
Media	0.11	0.12
NASA/NOAA	1.0	1.00
NGOs	0.05	0.05
Public	0.27	0.30
S&T Advisory	0.21	0.23
Scientists	0.57	0.55

Figure 88: Comparison of most important value flows using two value loop calculation methods

		abc	abc^2
	Value Flow	Wtd. Occurrence Score	Wtd. Occurrence Score
1	GOV_dir_NASA	20.10	15.19
2	GOV_fund_NASA	15.65	8.66
3	PUB_votes_GOV	8.22	5.31
4	NASA_data_SCI	8.15	4.95
5	EDU_work_NASA	5.95	3.87
6	NASA_access_SCI	5.92	3.70
7	NASA_fund_SCI	5.43	3.40
8	SCI_know_STA	4.55	2.95
9	NASA_plans_STA	4.03	2.52
10	STA_report_SCI	4.00	2.44
11	NASA_plans_SCI	3.96	2.47
12	PUB_opin_GOV	3.87	2.49
13	DEF_sec_PUB	3.16	2.01
14	NASA_plans_DATA	2.87	1.74
15	INTL_data_SCI	2.76	1.72
16	SCI_know_EDU	2.62	1.66
17	GOV_news_MED	2.57	1.64
18	PUB_stud_EDU	2.56	1.66
19	NGO_opin_GOV	2.53	1.44
20	SCI_know_climate_NASA	2.41	1.55

Figure 93: Comparison of most important NASA/NOAA outputs using two value loop calculation methods

		abc	abc^2
	Value Flow	Weighted Occurrence Score	Weighted Occurrence Score
1	NASA_data_SCI	8.15	4.95
2	NASA_access_SCI	5.92	3.70
3	NASA_fund_SCI	5.43	3.40
4	NASA_plans_STA	4.03	2.52
5	NASA_plans_SCI	3.96	2.47
6	NASA_plans_DATA	2.87	1.74
7	NASA_plans_INTL	2.36	1.40
8	NASA_coop_INTL	2.13	1.26
9	NASA_cost_INTL	2.13	1.26
10	NASA_plans_IND	1.85	1.17
11	NASA_fund_STA	1.15	0.73
12	NASA_fund_IND	1.11	0.69
13	NASA_comp_GOV	1.01	0.61
14	NASA_data_land_DATA	0.99	0.59
15	NASA_data_weather_DATA	0.99	0.59
16	NASA_plans_GOV	0.79	0.48
17	NASA_products_land_PUB	0.75	0.46
18	NASA_products_water_PUB	0.75	0.46
19	NASA_products_weather_PUB	0.75	0.46
20	NASA_emp_PUB	0.73	0.45
21	NASA_coop_AGN	0.69	0.36
22	NASA_sci_climate_GOV	0.67	0.42
23	NASA_edu_EDU	0.63	0.40
24	NASA_cont_PUB	0.63	0.40
25	NASA_cont_MED	0.54	0.32

Figure 94: Comparison of most important NASA/NOAA inputs using two value loop calculation methods

		abc	abc^2
	Value Flow	Weighted Occurrence Score	Weighted Occurrence Score
1	GOV_dir_NASA	20.10	15.19
2	GOV_fund_NASA	15.65	8.66
3	EDU_work_NASA	5.95	3.87
4	SCI_know_climate_NASA	2.41	1.55
5	STA_advice_NASA	2.19	1.53
6	IND_launch_NASA	1.68	1.20
7	SCI_know_land_NASA	1.38	0.73
8	SCI_know_solid_NASA	1.38	0.68
9	SCI_know_water_NASA	1.38	0.51
10	SCI_know_weather_NASA	1.38	0.51
11	IND_sys_NASA	1.19	0.51
12	SCI_sys_NASA	1.01	0.51
13	SCI_know_health_NASA	0.79	0.18
14	NGO_opin_NASA	0.67	0.12
15	MED_info_NASA	0.41	0.10
16	DEF_cost_NASA	0.38	0.10
17	DEF_plans_NASA	0.31	0.09
18	INTL_launch_NASA	0.27	0.09
19	INTL_coop_NASA	0.26	0.08
20	INTL_cost_NASA	0.26	0.08
21	DEF_coop_NASA	0.26	0.06
22	INTL_plans_NASA	0.25	0.05
23	AGN_plans_NASA	0.13	0.05
24	AGN_coop_NASA	0.13	0.03
25	AGN_cost_NASA	0.11	0.02

Figure 95: Comparison of science category rankings using two value loop calculation methods

	abc	abc^2
Science category	Wtd. Occurrence Score	Wtd. Occurrence Score
Weather	8.65	4.56
Climate change	8.33	5.23
Land-use	8.33	4.84
Water	6.31	3.48
Human health	4.49	2.95
Solid Earth	4.31	2.59

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