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# NOAA Observing System Integrated Analysis (NOSIA-II) Methodology Report

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# PREFACE

Over the last 6 years, NOAA has developed gap analysis and prioritization schemes to inform observing system investment decisions. With budgetary pressures and the increasing size, complexity, and rising costs of both individual systems and the observing enterprise as a whole, the question of which systems or combination of systems yields the greatest value has become paramount. Understanding the relationship between the cost of available data sources and their impact on mission outcomes is fundamental to informing current and future observing system investments and managing NOAA's observing system architecture.

To answer this need for a portfolio management process, TPIO conducted the NOAA Observing Systems Integrated Analysis (NOSIA-I) pilot study to develop a repeatable integrated analysis capability in December 2011. The success of this pilot led to the use of the NOSIA methodology for the first Federal Earth Observations Assessment (EOA 2012), under the direction of the White House Office of Science and Technology Policy. EOA 2012 encompassed 12 Societal Benefit Areas and was a key element in the development of the first National Plan for Civil Earth Observations published in July 2014 (NTSC 2014). As a result of the success of both NOSIA-I and EOA 2012, the NOSC directed the completion of NOSIA-II, a NOAA-centric repeatable integrated capability.

This report describes the technical approach for developing NOSIA-II, a capability NOAA uses to document and analyze the relationship between available observing systems and their impact on the agency's diverse services and scientific objectives.

At the direction of the NOSC, this document was prepared by TPIO and then approved by the NOSC for release as a NESDIS Technical Report and public dissemination.

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# Executive Summary

## Overview

This paper describes the technical approach for developing the NOAA Observing System Integrated Analysis (NOSIA-II), a capability used to document the relationship between available observing systems and their impact on NOAA's diverse services and scientific objectives. Understanding the relationship between the cost of available data sources and their impact on mission outcomes is fundamental to informing current and future observing system investments and managing NOAA's observing system architecture. This executive summary is written to be an abbreviation of the full report, see subsequent chapters for expanded technical detail, citations, caveats, and terms and definitions (NOSIA-II 2015).

## Key Points

Managing observing system investments through an integrated architecture is critical to maximize the impacts across NOAA's missions and to minimize cost.

No single assessment capability existed to assess impact from individual observing systems across all of NOAA's diverse missions before the NOAA Observing System Integrated Analysis (NOSIA-II) capability was developed.

NOSIA-II was developed to support complex observing system architecture value assessments and significant architecture trades by providing analysis of system costs and service impact.

NOSIA-II was developed at the direction of the NOAA Observing Systems Council (NOSC), which serves as the principal advisory body to the NOAA Administrator and the lead council for managing the agency's observing system architecture (NOSC 2015).

NOSIA-II has demonstrated maturity and reliability, and the NOSC has endorsed NOSIA-II's corporate adoption to be used to inform observing system architecture decisions.

## NOAA's Environmental Intelligence Infrastructure

NOAA services influence more than one-third of America's gross domestic product (Dutton 2002), or about $5.7 trillion of $17.4 trillion (World Bank 2014). To provide these critical services, NOAA's complex mission requires substantive investment in environmental intelligence. NOAA spends about $2.7 billion of its approximate $5.5 billion annual budget to develop, acquire, and utilize operational and research-oriented earth observing systems. NOAA observing systems include ships, aircraft, satellites, radar, remotely operated vehicles, buoys, observers, and towers. These sensors monitor our environment including the sun and the Earth's ecosystems, atmosphere, land, and oceans.

Based on this substantive investment and the criticality of NOAA services to the nation, an integrated approach is needed to assess the observing system impacts and determine the value of its observing system architecture towards the fulfillment of NOAA's critical mission.

## Towards An Observing System Architecture Assessment Capability

An observing system architecture maps mission requirements and service impacts to observing system capabilities. Managing observing system investments through an integrated architecture is critical to maximize the impacts across NOAA's missions and to minimize the cost.

The objective of NOAA's observing system architecture assessment capability is to support decision-making for the following:

- Maximize return-on-investment for new capabilities and adjustments to portfolio capabilities based upon NOAA high-priority services
- Minimize impact to services from budget reductions upon NOAA high-priority services
- Identify and assess trades across NOAA's observing system architecture and alternatives within the value chain against NOAA's core services
- Assess the architecture's satisfaction of observing system requirements.

An optimized observing system architecture will be attained when all significant architecture trades are assessed from a value perspective, which includes consideration of system cost, service impact and policy mandates. The NOSIA-II capability was developed to support these complex value assessments.

The NOSIA-II capability documents the relationship between data sources, including observing systems, mission requirements, and respective mission service impacts to inform corporate business questions. Within NOSIA-II, "data sources" include information provided by observing systems, databases, and products. The NOSIA-II capability is based on surveys, which incorporated inputs from about 500 NOAA Subject Matter Experts (SMEs) knowledgeable on observing system impacts upon the products and services for which they are responsible, as well as input from NOAA Mission Service Area (MSA) portfolio managers who provided the structure and priority of functionally aligned services.

## Background

The development of NOSIA-II is aided by precursor decision support capabilities including NOSIA-I and Federal Earth Observations Assessment (EOA). Completed in 2011, the NOSIA-I pilot study demonstrated a repeatable integrated analysis capability to assess NOAA's observing system architecture. The success of the NOSIA-I approach was so noteworthy that the White House Office of Science and Technology Policy (OSTP) directed use of the NOSIA approach for the first Federal Earth Observations Assessment (EOA I), now known as EOA 2012. This effort extended across multiple Federal agencies and was a key element in the development of the first *National Plan for Civil Earth Observations* published in July 2014 (NTSC 2014).

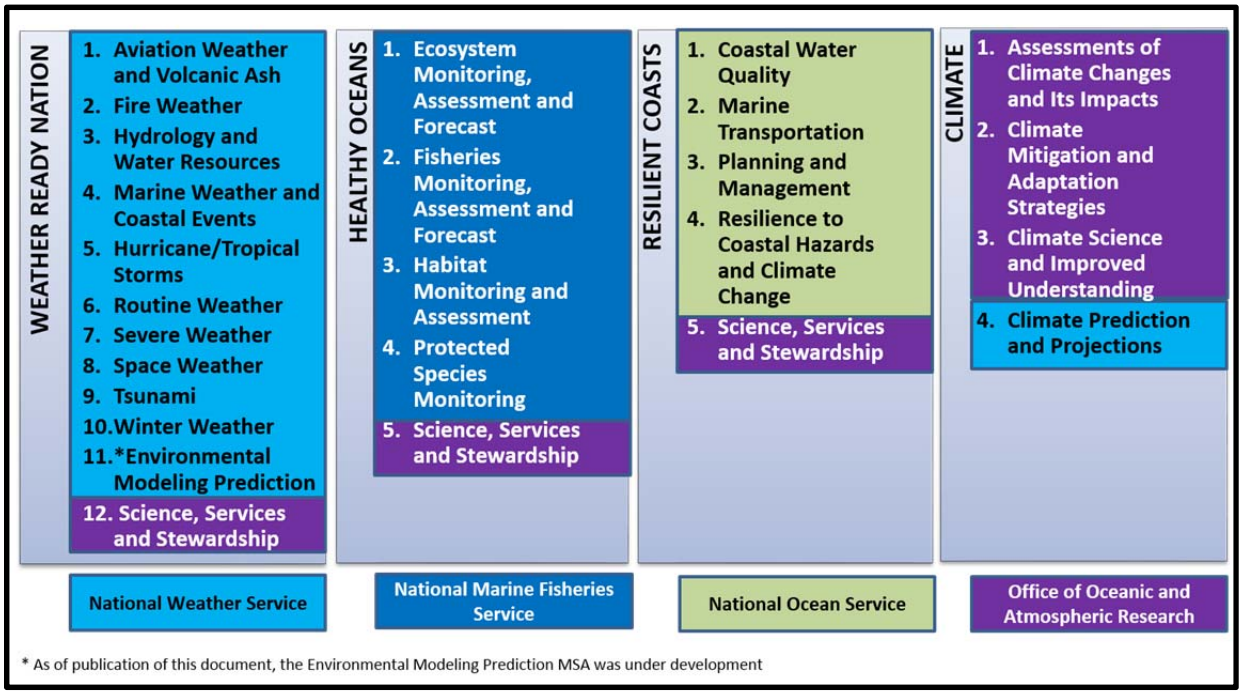
Building on the success of NOSIA-I and EOA 2012, the NOSC directed its technical support organization, the Technology Planning and Integration for Observations (TPIO) office, to develop a full-scope version of NOSIA (NOSIA-II) representing data source impacts for all NOAA's service areas (TPIO 2015). NOSIA-II surveys, data integration, and sensitivity testing occurred from May 2013 to November 2014. NOSIA-II's initial capability provides a snapshot of the impact from all currently available observing system impacts on current NOAA services. NOSIA-II's initial capability includes observing system operational cost; development cost is not included in the initial NOSIA-II capability, but will be considered as the NOSIA-II capability evolves and is further developed.

## NOSIA-II Value Tree

The NOSIA-II Value Tree is a hierarchical model containing top-level NOAA Goals, associated 26 Mission Service Areas (MSA), and respective functionally aligned products and services. The concept of establishing a Value Tree for supporting complex value assessments is based on Decision Analysis Theory (Keeney 1992). Keeney describes the Value Tree as a logic process which documents the strength of relationships between fundamental objectives underpinned by a hierarchy of intermediate "means" objectives and their data sources. Trades within "means" objectives and their data sources provide the basis for value-focused thinking to solve problems.

The top of the NOSIA-II Value Tree is based on NOAA's Next Generation Strategic Plan (NGSP), which defines NOAA's long-term mission Goals and Objectives (NGSP 2010). Within the NOSIA-II Value Tree, Mission Service Areas are structured after NGSP Objectives. The Value Tree represents NOAA's functional service architecture, where NOAA Line Offices directly or indirectly contribute to the Goals and MSAs as a matrix organization. Each Mission Service Area is managed by a Line Office portfolio manager, who identifies products and organizational priorities within the MSA. Figure A provides the functional and organizational alignment within the Value Tree.

**Figure A. Long-Term Goals and Mission Service Areas (MSAs), managed by NOAA Line Offices**




The objective of the MSA product selection is to survey data sources that support the diversity of NOAA services, including regional informational needs. To accomplish this, the NOSIA-II development team conducted substantial dialog with MSA portfolio managers to identify a *representative sample of products* which define an MSA's core suite of services and ultimately yield observing system impacts. If the MSA includes products and priorities representative for that MSA, then the resultant observing system impact will also be representative.

## Data Collection

Product surveys collected from NOAA business units are the foundation of the Value Tree model. Seventy-two NOAA site surveys were conducted over an 8-month period. Site surveys included input from about 500 SMEs, providing observing system impacts to about 1,100 products. The NOSIA-II surveys included both operational and research products and services to determine impacts from observing system data.

Site surveys systematically collected product performance (status quo scores), data sources and impacts, and data source satisfaction for products created by site Subject Matter Experts (SMEs). The Status Quo Score is a current snapshot of overall satisfaction of the surveyed product and is based on the performance scale in Figure B. SMEs were asked to perform a self-assessment to consider how well their products met users' and stakeholders' needs and expectations. This scale was used throughout the surveys to enable a comparative analysis across the options.

**Figure B. Translating Status Quo Score Product Performance into Numerical Values**

| Performance (Satisfaction) Scale | | |
|---|---|---|
| **100** | **Ideal** | Meets all requirements and exceeds some |
| **90** | **Fully Satisfied** | Meets all requirements |
| **80** | **Good** | Meets all major requirements, with minor limitations |
| **60** | **Fair** | Meets most major requirements, with significant limitations |
| **40** | **Poor** | Fails to meet many major requirements, but provides some value |
| **20** | **Very Poor** | Fails to meet most major requirements, but provides minor value |
| **1** | **No Capability** | Provides no value |

A site survey template, called a Data Collection Worksheet (DCW), was customized to reflect the products and data sources at a particular site before the site survey; see example, Figure C.

**Figure C. Sample Survey Data Collection Worksheet**

| Survey Products | Fishery Stock Assessments | Climate Vulnerability Assessments for Fish and Fisheries | |
|---|---|---|---|
| Status Quo Intermediate Product Performance >>> | 70 | 40 | Overall Satisfaction |
| Fish Stock Assessment Models (Single and multi-species pop dyn models) | 20 | 20 | 70 |
| Ocean Circulation Models | | 30 | 50 |
| Socio-Economic Models | | | 60 |
| Ecosystem Models (e.g. FEAST, Food-Web) | 65 | | 60 |
| Climate Models (SST, Winds, Ice Formation) | | 20 | 60 |
| Fisheries Independent Surveys (NOAA ships) | 30 | 25 | 60 |
| Fisheries Independent Surveys (NOAA Charters) | 25 | 25 | 80 |
| Fisheries Independent Surveys (State & Univ ships & Charters) | 60 | 25 | 80 |
| Socio-Economic Surveys | | 20 | 60 |
| Commercial Fisheries Dependent Biological Samples & Catch/Bycatch (includes regional observer program) | 5 | 20 | 80 |
| Biological Samples from shore-side landings | 40 | 40 | 80 |
| Observer-based catch/bycatch & bio sampling | 56 | 56 | 80 |
| State Fish-ticket programs & species composition sampling | 4 | 4 | 80 |
| Ecosystem Surveys | | 30 | 50 |
| Recreational Fisheries Survey | | 30 | 60 |
| Buoy Data (Eco FOCI) | | 30 | 70 |
| Polar SAR Satellites | | 35 | 70 |

Surveys were typically conducted "live" using facilitated survey teams with data entry completed during the survey, and not filled out prior to the interview. In addition to impact from observing system and NOAA analysis and predictions, surveys captured the impact on NOAA services from several dozen products and services from other U.S. Federal, international, academic, State/Local, and commercial entities.

## Organizational Data

Organizational data are quantitative weights and groupings of products structured within a Mission Service Area hierarchy used to capture organization priorities. Priorities may include providing a higher weight for a lifesaving warning versus a routine weather forecast, or a Congressionally mandated stock assessment above an ecosystem model. Observing systems which support high priority products are given greater influence in the NOSIA-II derived observing system impact assessments. Line Office portfolio managers are the source of Organizational data.

While products within MSAs are prioritized using organizational data, Goals are equally weighted within NOAA, and MSAs are equally weighted within each Goal.

## Observing System Cost

The NOSIA-II capability includes an annualized cost for every "option", i.e., observing systems and databases. Cost data are an essential aspect of the NOSIA-II model assessment capability for generating the Efficient Frontier portfolio analysis. An Efficient Frontier portfolio analysis is a graphical representation of combinations of assets or investment options that provide the highest possible performance or goal satisfaction for a range of cost or budget constraints.

Cost data are provided by NOAA Line Offices for systems operated by NOAA, or estimated by TPIO for systems operated by a non-NOAA organization. The NOSC Observing System Committee (OSC) System of Record (SoR) database is the primary source of NOAA observing system cost data within the NOSIA-II model. OSC SoR costs generally include the full cost of operation, including facilities, expendables, labor, and associated contracts. The NOSIA-II initial capability does not include developmental costs. Observing system cost data are very important within the NOSIA-II capability; therefore, the NOSC is working with the NOAA Chief Financial Officer (CFO) Council to improve cost data collection procedures.

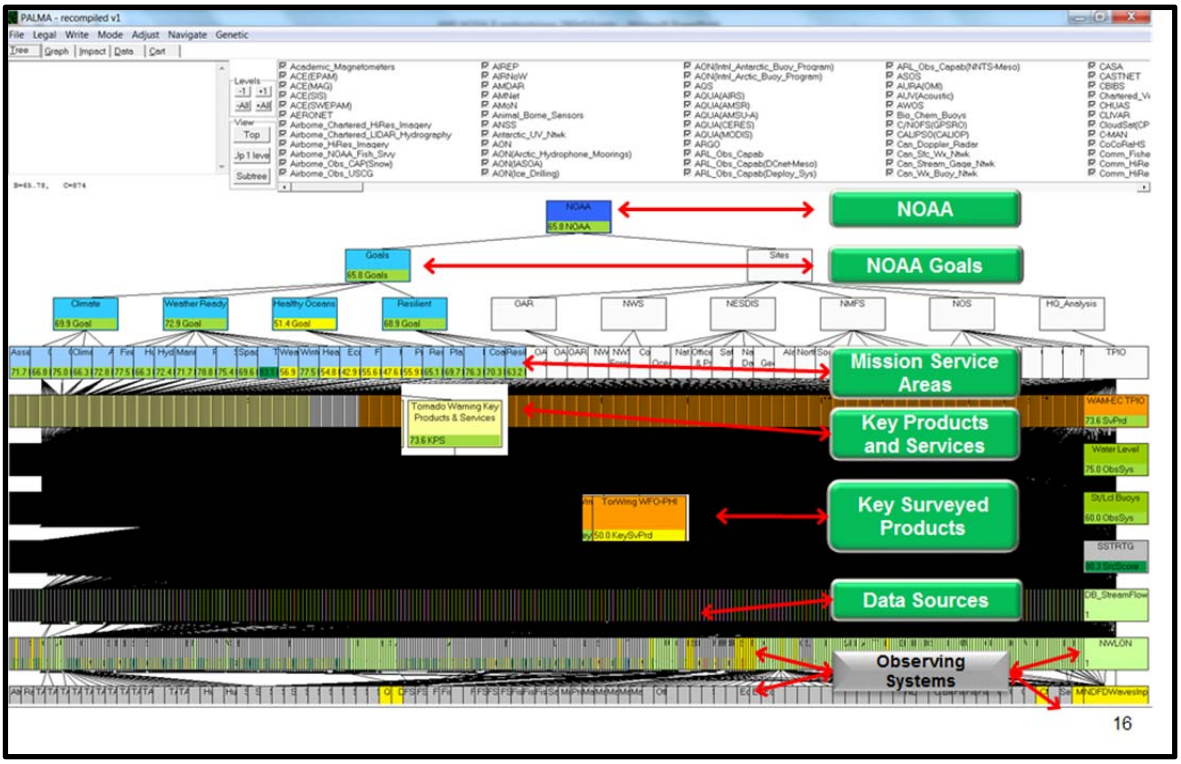
## NOSIA-II Model Integration

Assembling the product survey data and organizational data into a coherent NOSIA-II model required about 9 months. The NOSIA-II model includes over 20,000 nodes; a node is a relationship between data source and downstream product impact. Figure D depicts the full NOSIA-II model, including the "Value Tree" (left side) and the "Site" (right side) of the model. The "Value Tree" represents NOAA services which Line Offices contributes as a matrix, while the "Site" model represents specific business units surveyed within each NOAA Line Office.

Initially, the model was created by grouping products within MSAs, but without including organizational prioritization data. Organizational data were incrementally incorporated, Goal by Goal, over a 1-year period, and associated observing system impacts assessed by Line Office leadership.

The NOSIA-II survey and organizational data are coded into Microsoft Excel spreadsheet format called a "Model Building Workbook" (MBW), which is read into the NOSIA-II analytic engine, PALMA application (developed by MITRE). The PALMA application uses the MBW to create summary impact per observing system or "option" from across the entire Value Tree.

**Figure D. NOAA Value Tree - Defining the relationship between observing systems and NOAA Goals and Mission Service Areas**




*(Note: Details in Figure D. are not intended to be legible; main emphasis is on the hierarchy.)*

The NOSIA-II model complexity required rigorous configuration management by establishing procedures to test model consistency and to track and review the impact of model changes.

Standardized taxonomies were established for the NOSIA-II Value Tree. Nomenclature standardization within the model was a major challenge for NOSIA-II given the more than 1,100 survey products, 300 observing systems, and 200 Federal, commercial, and international data providers. Standardized taxonomies included observing system names, SME-defined names, product and data sources names, and site identifiers,

## Decision Support Capability

NOAA's satellites, ships, aircraft, ocean and surface observing systems represent tens of billions of dollars in needed re-capitalization over the next 20 years. The primary objective of developing an observing system architecture decision support capability, with NOSIA-II as a key component, is to improve these life-cycle performance and budget decisions.

Many NOAA business questions cannot be addressed by the NOSIA-II capability output alone. TPIO is integrating the full scope of observing system architecture portfolios to respond to a greater range of NOAA's business questions. These observing system architecture portfolios include requirements, system capabilities, and product sensitivity to data sources. For example, NOSIA-II's initial planning considerations for survey process and granularity of observing system impacts were structured to inform NOAA's response to the Science Advisory Board (SAB) Satellite Task Force.

Developing the NOSIA-II decision support capability begins by understanding the target user's (e.g., persona) budget, performance, and trade questions and organizing available information resources to respond to these business questions.

TPIO has identified several personas seeking insight into specific business questions. Examples of these personas include:

- NOAA Senior Leadership - Strategic Planning
- NOAA Line Office and Staff Office Leadership - Portfolio Budget Formulation and Planning
- Observing System Program Managers - Program Plan Support
- NOAA Research - Research Portfolio Management
- External NOAA - Provide Transparency into NOAA and Federal Business Practices
- Product Generation - Resource Management

Additional applications for the NOSIA-II approach within the Federal Agencies are likely to include use by OSTP and United States Group on Earth Observations (USGEO).

## NOSIA-II Product Generation

Supporting the identified personas with the NOSIA-II capability output requires sophisticated graphical tools to mine the data, extract, and integrate the data at a level familiar to the user, and display the data in unambiguous depictions. TPIO is developing visualization capabilities for the identified personas with the objective of supporting a range of client and web-based applications. Example visualizations are provided below.

**Figure E. Sample NOSIA-II Output: Observing System Impacts to the NOAA and the Long-Term Mission Goals**

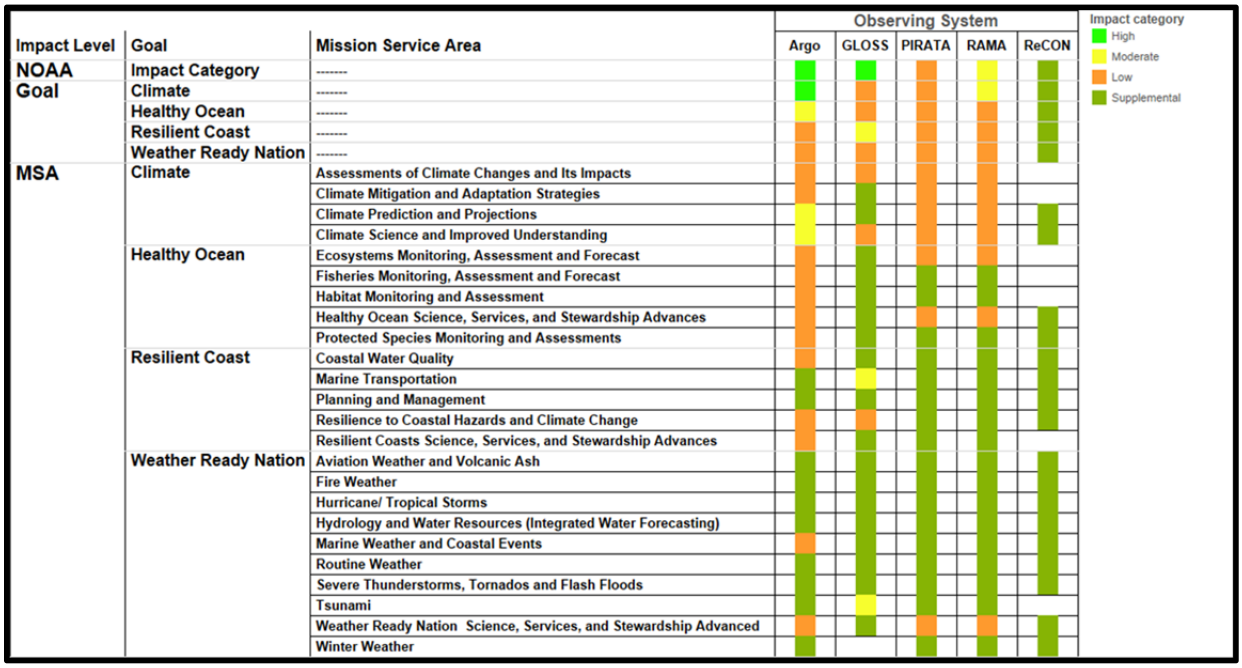
| NOAA | | Climate Adaptation and Mitigation | | Healthy Oceans | | Resilient Coastal Communities and Economies | | Weather Ready Nation | |
|---|---|---|---|---|---|---|---|---|---|
| Data Source | Impact Category | Data Source | Impact Category | Data Source | Impact Category | Data Source | Impact Category | Data Source | Impact Category |
| NOAA Ships Program | Very High | JASON Platform/Program | Very High | NOAA Ships Program | Very High | NOAA Ships Program | Very High | GOES NOP Platform/Program | Very High |
| GOES NOP Platform/Program | Very High | POES Platform/Program | Very High | NMFS CFS | Very High | NWLON Program | Very High | NEXRAD Program | Very High |
| NEXRAD Program | Very High | METOP Platform | Very High | UNOLS Program | Very High | NERR SWMP Program | Very High | METOP Platform | High |
| METOP Platform | Very High | Argo Program | Very High | Protected Resources Program | Very High | CREIOS Program | Very High | RAWINSONDE Program | High |
| NWLON Program | Very High | NOAA Ships Program | Very High | NOP Program | Very High | NOAA Aircraft Program | Very High | ASOS/AWOS Group | High |
| POES Platform/Program | Very High | OCO Drifting Buoy Program | Very High | Habitat Survey Program | Very High | SWiM Program | High | POES Platform/Program | High |
| UNOLS Program | Very High | NWS COOP Platform/Program | Very High | Fish Surveys Program | Very High | GLOSS Program | High | NSNSN Program | Moderate |
| JASON Platform/Program | Very High | TAO Program | Very High | Science Field Collection Program | Very High | State & Local Water Quality Monitoring | High | NWLON Program | Moderate |
| NMFS CFS | Very High | DMSP Platform | Very High | Animal Borne Tagging and Bar Coding system | Very High | CORS Program | High | State Mesonets Program | Moderate |
| Argo Program | High | GOES NOP Platform/Program | High | GLERL Program | Very High | GPS Platform | High | National Lightning Data Network | Moderate |
| NOAA Aircraft Program | High | UNOLS Program | High | MRIP Program | High | Repeat Hydrography Program | High | SNPP Platform | Moderate |
| RAWINSONDE Program | High | NOAA Aircraft Program | High | Fisheries Science Center Observing and Lab Equipment | High | UNOLS Program | High | ACE Platform/Program | Moderate |
| Protected Resources Program | High | SNPP Platform | High | SNPP Platform | High | Marine and Estuarine Goal Setting for South Florida | High | Spotter Program | Moderate |
| NOP Program | High | State & Local LIDAR | High | Socio-Economic Surveys Program | High | HYDRO Program | High | DART Program | Moderate |
| ASOS/AWOS Group | High | Repeat Hydrography Program | High | Ecosystem Surveys Program | High | IOOS Program | High | MDCRS/AMDAR Group | Moderate |
| SNPP Platform | High | NWLON Program | High | Marine Sounding Program | High | NEXRAD Program | Moderate | GPS Met Program | Moderate |

Rank Impact

| Very High | High | Moderate | Low | Supplemental | No Impact |
|---|---|---|---|---|---|

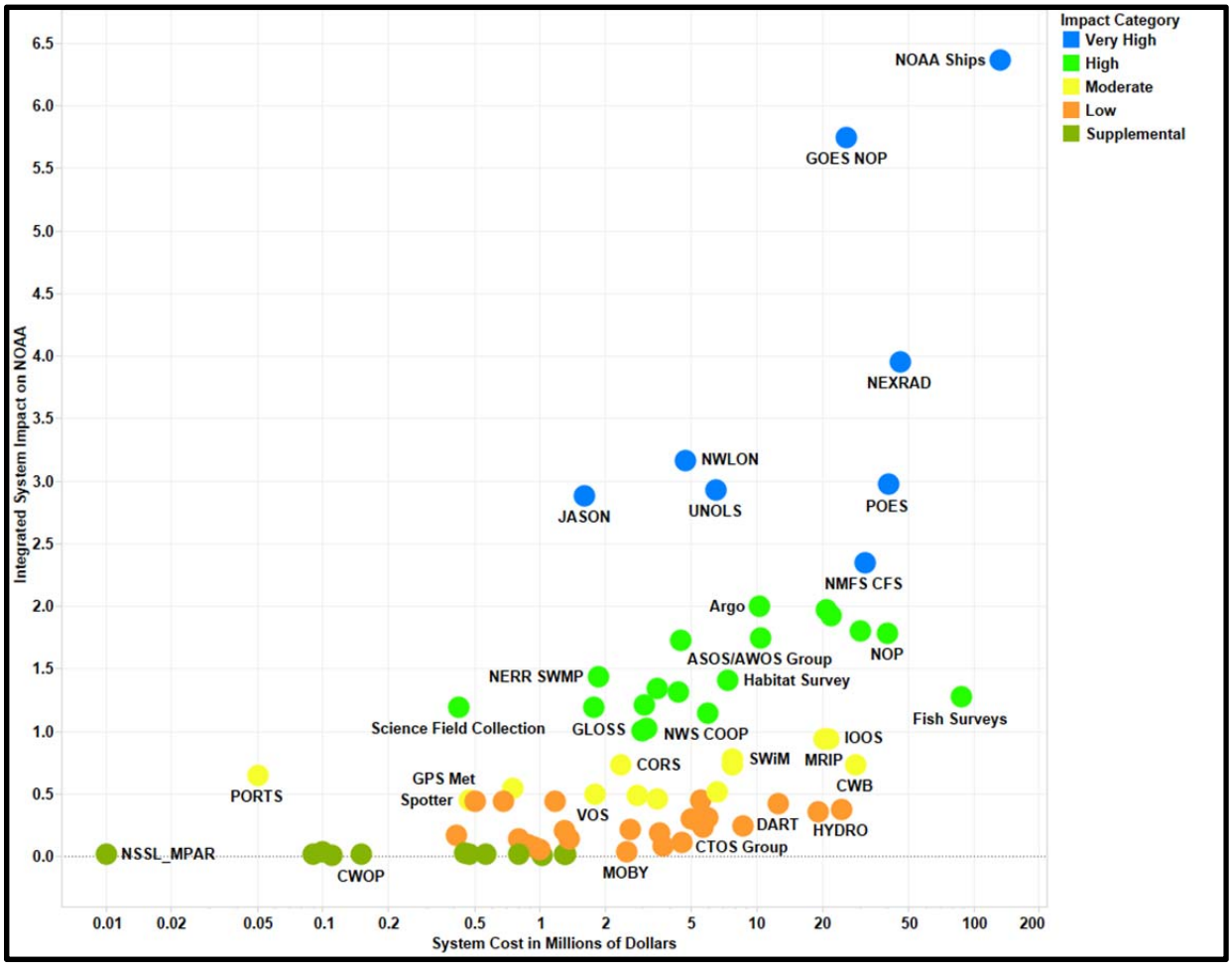
The observing system impacts table in Figure E. offers a simple, high level view of how NOAA's observing systems impact NOAA's mission and then by each of the Long-Term Mission Goals. The colors used in the sample data describe in plain language the level of impacts from Very High to No Impact.

**Figure F. Sample NOSIA-II Output: Heat Map Visualization Showing Observing System Impacts Across NOAA, by Long-Term Mission Goals, and then by MSA**




The heat map table in Figure F. allows users to see the impact of observing systems at various levels of the Value Tree. It is a quick way to identify an observing system's distribution of impacts and to simultaneously compare and contrast with other observing systems across NOAA, then by Long-Term Mission Goals, and then by MSA.

**Figure G. Sample NOSIA-II Output: Observing System Cost/Impact Scatterplot Diagrams for Observing System Capability Groups**




The scatterplot in Figure G. provides an easy way to visualize relationships between numerical variables. The sample data in the depiction allows users to view the observing system operational costs (x-axis) versus the observing system impacts (y-axis), while simultaneously compare and contrast with other observing systems.

## Next Steps

To sustain NOSIA-II for the purpose of on-demand strategic observation system architecture assessments, NOAA must monitor substantial changes to the observing system portfolio and the impact upon those products which are sensitive to the observing system portfolio changes. Therefore, the Value Tree, e.g., NOAA services, will be reviewed and updated every 4 years, and the observing system architecture will be updated annually.

Additional NOSIA-II development is focused on support to budget formulation and strategic planning associated with observing system life-cycle changes. Specifically, TPIO is developing a NOSIA-II Multi-Period Model (MPM) which will estimate how NOAA's Value Tree will be

impacted as a consequence of observing system changes over the next 20 years, including changes to data sources, the cost of the data source, and magnitude of impact to NOAA products and services by data source changes. The NOSIA-II MPM will be calibrated by available observing system sensitivities studies and incorporate expected architecture performance data obtained through industry requests for information.

## Key Limitations

The full NOSIA-II Methodology report contains an expanded list of limitations and caveats which readers are encouraged to review to understand and appropriately use the NOSIA-II capability. Primary capability limitations include:

- NOSIA-II capability assesses all observing system impacts have upon a sample of *NOAA products and services*. If the primary user of a NOAA observing system is external to NOAA, then that observing system's total impact to the nation will be under-valued by the NOSIA-II capability.

- NOSIA-II should be used as guidance and not as a sole source data point for observing system investment decision making.

## Recommendations

In May 2015, the NOAA Office of Program Planning and Integration (PPI) and Technical Plans and Integration for Observation (TPIO) provided the following conclusion: NOSIA-II provides key foundational information that can be used to identify and investigate opportunities for improving NOAA observing system portfolio efficiency.

Based on the PPI and TPIO findings that NOSIA-II has a demonstrated maturity and reliability, the NOSC has endorsed NOSIA-II's corporate adoption to be used to inform observing system architecture decisions.

## Future Updates

NOSIA-II is an analytic capability which will be enhanced as NOAA's mission and data sources evolve and new applications are developed. Follow-on publications will be developed to document the evolution of the NOSIA-II capability.

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# 1. Introduction

The National Oceanic and Atmospheric Administration (NOAA) is an agency that enriches the safety of our citizens and vitality of our economy through science. NOAA's products and services, which include daily weather forecasts, severe storm warnings and climate monitoring to fisheries management, coastal restoration and maritime commerce, support economic vitality, influencing more than one-third of America's gross domestic product (Dutton 2002). NOAA's dedicated scientists use cutting-edge research and high-tech instrumentation to provide citizens, emergency managers, planners, and other decision makers with reliable information.

In support of this science-driven mission, NOAA spends about $2.7 billion of its approximate $5.5 billion annual budget to develop, acquire, and leverage operational and research-oriented earth observing systems (World Bank 2014). NOAA observing systems include ships, aircraft, satellites, remotely operated vehicles, buoys, and towers. These sensors monitor our environment including the sun and the Earth's ecosystems, atmosphere, land, and oceans. NOAA's definition of observing system includes a collection of one or more sensing elements (human and/or instrument) that reside on fixed or mobile platforms; directly or indirectly measuring environmental parameters on a defined basis meeting data user objectives (NOSC 2015).

NOAA provides a broad and diverse mix of essential mission services to the nation, and as such, faces the key challenge of assessing which systems or combination of systems provide the greatest impact to NOAA products and value to the public. To address this challenge, NOAA developed an analytical capability to assess and guide observing system portfolio investments with the primary focus on mission outcomes. The NOAA Observing System Integrated Analysis (NOSIA-II) is a key component of NOAA's observing system portfolio analytical capability. NOSIA-II considers information user needs, observing system cost and capabilities, and the impact of this information on the quality of NOAA's products and services.

The intent of this document is to summarize the NOSIA-II methodology for assessing the impact and estimating the value derived from NOAA's observing system portfolio. The target audience for this document are interagency individuals and offices seeking information on the NOSIA-II methodology to include program managers, senior leadership and staff in NOAA, Department of Commerce, Office of Management and Budget, Executive Office of the President, including Congress, and NOAA's peers in the international community who may contemplate using the NOSIA-II approach to inform business decisions.

NOSIA-II is an analytic capability which will be enhanced as NOAA's mission and data sources evolve and new applications are developed. Follow-on publications will be developed to document the evolution of the NOSIA-II capability.

**This document contains technical terms and definitions unique to NOSIA-II. Readers are encouraged to familiarize themselves with the terms and definitions contained in Appendix D to facilitate understanding of material provided in subsequent sections.**

## 2. Background

The NOAA Business Operations Manual (BOM) defines the roles and responsibilities of NOAA's corporate advisory bodies which analyzes and recommends proposed capital investments as part of budget formulation (BOM 2013). As defined in the BOM, the NOAA Observing Systems Council (NOSC) serves as the principal advisory body to the NOAA Administrator and the focal point for the agency's observing system activities (NOSC 2015). The NOSC coordinates observational and data management activities across NOAA, proposes priorities and investment strategies for observation-related initiatives, identifies programs that might benefit most from integration, and coordinates NOAA's Enterprise objective for accurate, reliable data from integrated Earth observations. NOAA's Technology, Planning, and Integration for Observations (TPIO) staffs the NOSC to accomplish this mission within its corporate mandate (TPIO 2015).

Over the last 6 years, NOAA has significantly improved collection, verification, validation, and documentation of observation requirements and observing system capabilities, and developed gap analysis and prioritization schemes to inform investment decisions. This has significantly improved NOAA's ability to evaluate the degree to which each observing system satisfies multiple requirements. However, these processes have proven inadequate from an integrated portfolio management perspective to provide an assessment of the integrated, collective whole, and a way to optimize the efficiency, effectiveness, and cost of the entire NOAA system of observing systems. With budgetary pressures and the increasing size, complexity, and rising costs of both individual systems and the observing enterprise as a whole, the question of which systems or combination of systems yields the greatest value has become paramount. To help answer this question, NOAA needed an effective observing system portfolio management approach that can trace the effects of increased or decreased observing capability all the way to the level at which Line Offices provide products to satisfy stakeholder requirements.

In December 2011, to answer this need for a portfolio management process, TPIO completed the NOAA Observing Systems Integrated Analysis (NOSIA-I) pilot study to develop a repeatable integrated analysis capability. The study was confined to observing systems that observe upper air moisture, temperature, and winds. The success of this approach was so noteworthy that the White House Office of Science and Technology Policy (OSTP) directed use of the NOSIA process for the first Federal Earth Observations Assessment (EOA I), now known as EOA 2012. This effort extended across multiple Federal Agencies and was a key element in the development of the first National Plan for Civil Earth Observations published in July 2014 (NTSC 2014).

As a result of the success of both NOSIA-I and EOA 2012, the NOSC directed the completion of the NOSIA-II observing system impact analysis as a repeatable integrated capability.

## 3. Purpose

The primary purpose of NOSIA-II is to fill the gap in NOAA's observing system portfolio analytical capability and to understand the impact of data sources (observing systems, databases, and products) on the quality of NOAA's products and services, while taking into account the full spectrum of NOAA services, cost of observing system data, and organizational relationships and priorities dependent upon environmental information.

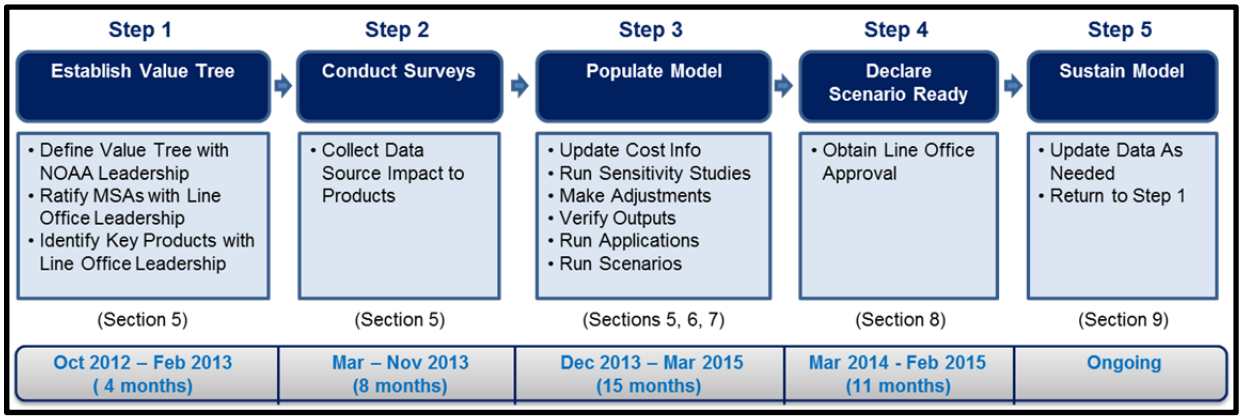
The specific objectives of NOSIA-II include:

- Support observing system architecture value assessments for NOAA's current and future missions
- Provide a scenario-ready capability for conducting observing system architectural trade analyses referenced from the current baseline
- Provide guidance for execution and budget formulation
- Provide system impacts to Observing System Portfolio and Program Managers, and key stakeholders
- Respond to specific business questions 4. Methodology Overview

## 4. Methodology Overview

A description of the NOSIA-II methodology begins with an overview of the analysis process, see Figure 4.1. Step 1 describes the process used to create NOAA's Value Tree, a hierarchical model containing top-level Goals, associated Mission Service Areas (MSA), and products and services. Surveyed data from field site Subject Matter Experts (SMEs) and organization data collected from Line Office Headquarters were used to create the NOSIA-II model. The underlying analysis tool of NOSIA-II is the Portfolio Analysis Machine (PALMA™) computer program, developed by the MITRE Corporation. It relates the performance to goals and MSAs to observing systems portfolios.

**Figure 4.1. Overview of NOSIA-II Analysis Process**



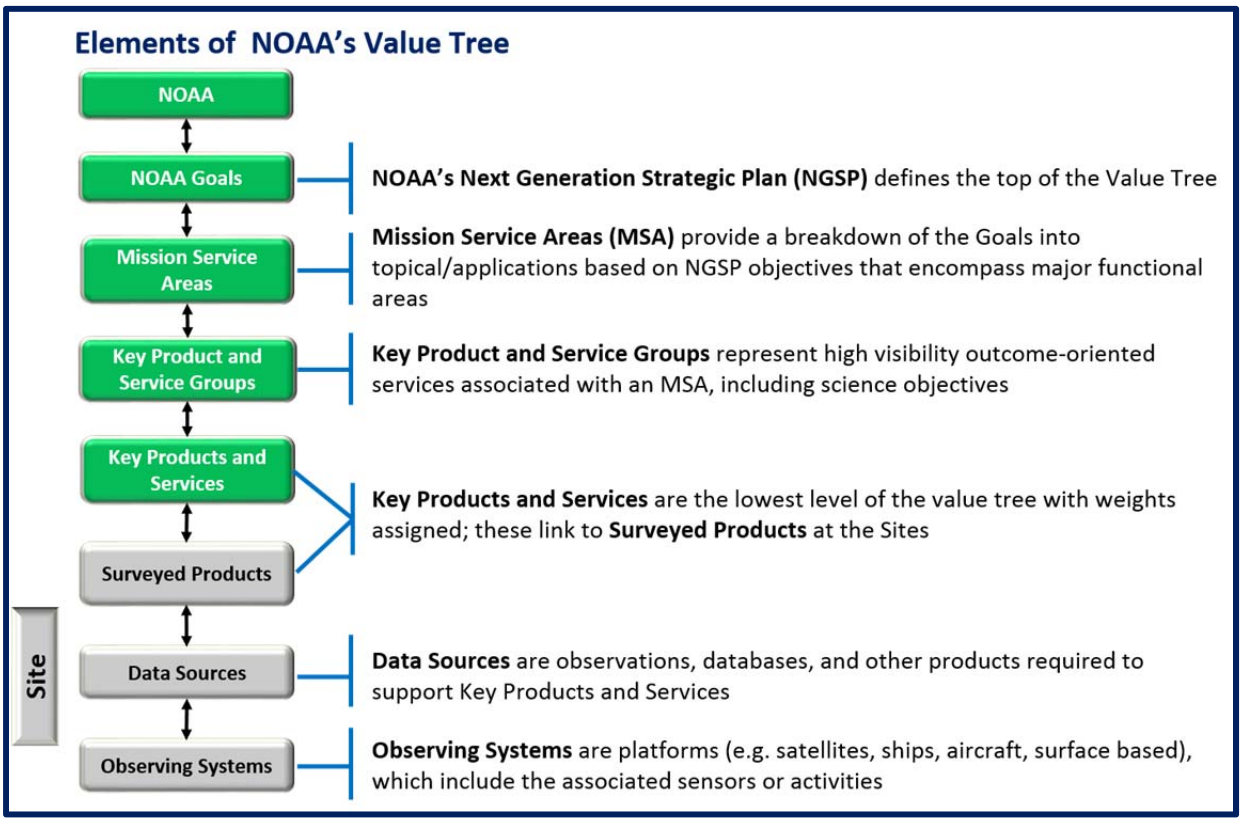
Each step is discussed in detail in this report, as referenced in the above referenced sections. In total, the entire NOSIA-II Analysis process took over 2 years to complete due to the complexity of the large number of products surveyed and the inclusion of organizational data.

## 5. Foundational Architecture

The starting point of the NOSIA-II Analysis is the Value Tree. While literature suggests that a Value Tree model should be built either top-down or bottom-up (Keeney 1992), NOSIA-II used a hybrid approach, which consists of both the top-down and bottom-up methods, since the middle layer of the NOAA Value Tree had yet to be created. The concept of establishing a Value Tree for supporting complex value assessments is based on the Decision Analysis Theory (Keeney, 1992). Keeney describes the Value Tree as a logic process, which documents the strength of relationships between fundamental objectives underpinned by a hierarchy of intermediate "means" objectives and their data sources. Trades within "means" objectives and their data sources provide the basis for value-focused thinking to solve problems. While NOAA will use NOSIA-II as a key tool to solve specific problems such as observing system architecture value assessments, value-focused thinking can also be used to identify desirable decision opportunities and create alternatives.

Using the Value Tree hierarchy, a model of NOAA's top-level foundational services architecture was defined, along with its current performance and its sensitivity to available data sources (environmental observations). Within NOSIA-II, this foundational service architecture is referred to as NOAA's "Value Tree" (see Figure 5.1). The Value Tree architecture is used to assess the impacts that available data sources (bottom of the Value Tree) have in supporting NOAA's Strategic Plan (top of the Value Tree).

**Figure 5.1. NOSIA-II Value Tree**




NOSIA-II also developed an organizational model of NOAA's business units (surveyed sites), which fund and execute environmental services. The organizational side of the model is called the "Site" architecture, referred to in Figure 5.1. The architecture is based off surveys conducted by SMEs, who are appointed by the NOAA Line Office. SMEs assessed the sensitivity that individual products have on data sources. NOAA Line Offices provided the costs data for observing systems from which observing system "value" is assessed, i.e., impact as a function of cost. They also defined organizational relationships and priorities within the NOSIA-II Value Tree.

Information from Line Offices, when combined with NOAA strategic plans and SME survey input on the impact of observing systems on products, enables NOSIA-II to make an objective assessment of the relationship between observing system data and organizational objectives. The linkage between the Value Tree hierarchy and NOAA's business units is from NOAA Line Offices to Value Tree MSAs, see Appendix B for more details.

In summary, the "Value Tree" provides the aggregate impacts from data sources across NOAA, Goals, and MSAs, while the "Site" side of the model provides the specific data source impact product through SME surveys and observing system cost. The rest of this section discusses how NOAA's services architecture "Value Tree" was created, and how site data were collected to populate the Value Tree.

## 5.1. Modeling NOAA's Business Practices and Mission Service Areas (MSA)

NOAA's Value Tree Model is based on NOAA's Next Generation Strategic Plan (NGSP). The NGSP defines NOAA's major functions with four long-term goals (NGSP 2010):

- Climate Adaptation and Mitigation
- Weather-Ready Nation
- Healthy Oceans
- Resilient Coastal Communities and Economies

Products and services supporting the NOAA long-term goals, as described in the NGSP and modeled within NOSIA-II, are ultimately promulgated by numerous Federal Public Laws and Presidential Executive Orders.

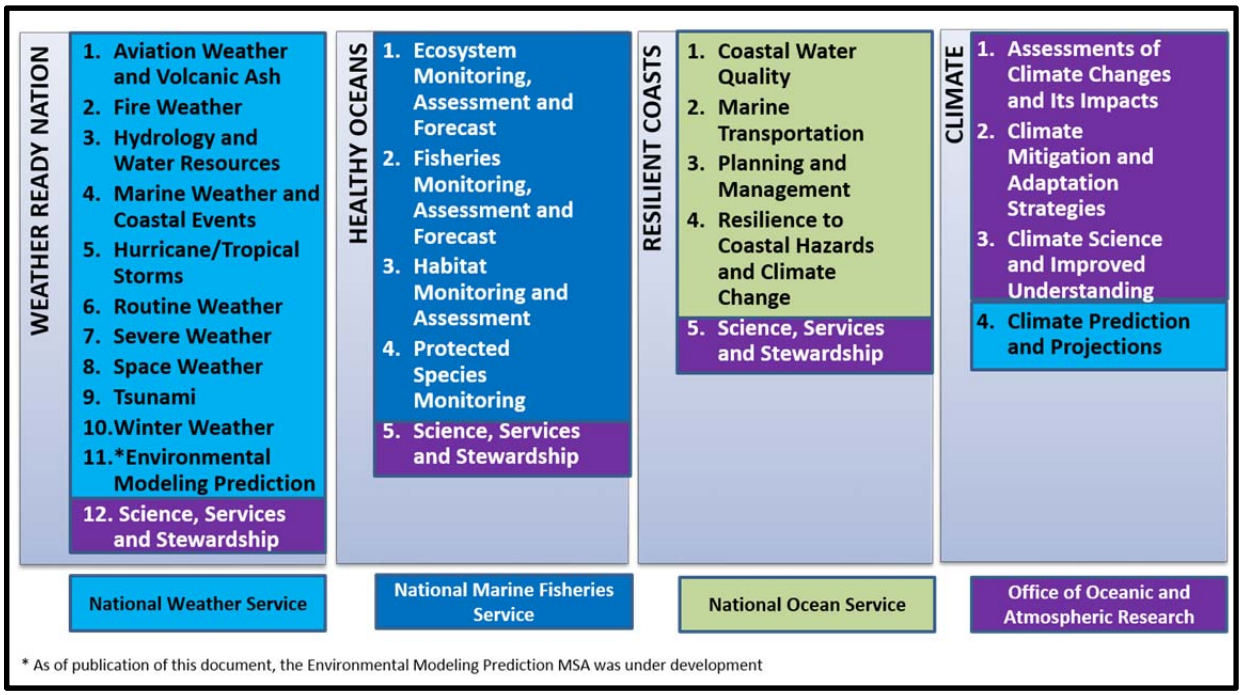
A few examples of public law underpinning NOAA's long-term goals are:

- Endangered Species Act of 1973
- National Marine Sanctuaries Act of 1972
- Magnuson-Stevens Fishery Conservation and Management Act of 2006
- Coast and Geodetic Survey Act of 1947
- National Climate Program Act of 1978
- Organic Act of 1890

NOSIA-II's Value Tree establishes the relationship between observation data and the impacts they have on the products and services supporting NOAA's goals. From the bottom of the tree, NOAA seeks to determine the impact that observing systems and combinations of systems have on the products, and the integrated impact of observing systems on each hierarchy above the product level. These relationships work their way up through MSAs and then to NOAA's Goals. MSAs are structured after NOAA's NGSP Objectives, with the exception of the Weather Ready Nation Goal. Figure 5.1. depicts a simplified view of a single branch in the Value Tree as the fundamental step to assessing the benefits of investments in observing systems.

Within the NOAA Goals, the Line Offices identified 26 MSAs (Figure 5.2.). These MSAs are a representation of NOAA's core services which rely on environmental information.

**Figure 5.2. Goals Related to Mission Service Areas (MSAs)**




Determining which products to survey and ultimately whether a product should be included in a particular MSA, its grouping, and its tiering was a significant challenge. NOSIA-II could not survey all of NOAA's products, as this would have taken years, nor was this necessary for the Value Tree to estimate observing system impacts across NOAA.

In defining products to survey, the objective was to capture the information sources that support the diversity of NOAA services, including regional informational needs. To accomplish this, NOSIA-II conducted substantial dialog with portfolio managers to identify a representative sample of products which define an MSA's core suite of services and ultimately yield observing system impacts. For example, NOSIA-II surveyed 13 out of 122 Weather Forecast Offices (WFO) and 3 of 13 River Forecast Centers (RFC) to capture sufficient data source variance for coastal sites (Marine Weather), tropical sites (Hurricane), inland and northern sites (Winter Weather), and the central U.S. (Severe Weather). For Healthy Oceans, NOSIA-II surveyed all six Fisheries Science Centers (FSC) to capture regional focus areas, including stock assessments and protected species. Line Offices or Goal Leads recommended inclusion of selected survey products into MSAs as Key Product and Services (KPS), see Appendix D for full definition.

As a result of this process, about 1,100 products were surveyed (number of products surveyed by site including proxies, as of the publishing date of this document based on NOSIA-II_MBW_v1.0.21). Given the level of effort and subsequent review by NOAA leadership, NOSIA-II provides a reasonable representation of the agency's capabilities and services.

**See Appendix C for a listing of primary caveats, model limitations and uncertainty for understanding and interpreting the NOSIA-II results.**

## 5.2. Site Survey Data Collection

### 5.2.1. Survey Summary Overview

Once the Value Tree framework was established and preliminary survey products identified, the Line Offices determined the appropriate sites and SMEs across NOAA to survey. Survey site selection to capture regional variation of information needs for products created at multiple locations was an additional consideration and an iterative process. TPIO conducted on-site and virtual site surveys with 72 NOAA sites over an 8-month period (number of sites consists of identifiers created within the NOSIA-II model representing NOAA business units responsible for product generation). During these sessions, many of which required multiple follow-up discussions, TPIO consulted with about 500 SMEs (contributing to at least one product surveyed). Prior to the interview sessions, TPIO collaborated with the SMEs at NOAA sites to determine the suite of products that best captures that site's core missions. The initial objective was to verify and confirm the scope and diversity of products to be surveyed.

At the end of the data collection effort, the number of products surveyed totaled about 1,100 (number of products surveyed by site including proxies, as of the publishing date of this document based on NOSIA-II_MBW_v1.0.21). As new products were identified, TPIO worked with the SMEs to assign them to primary MSAs. There was not a complete enumeration of all of NOAA's products and services. However, due to the broad inclusion of SMEs at the Goal, Line Office, MSA and site levels, and the large number of products surveyed, TPIO considers that NOSIA-II contains a representative sample of NOAA products. In addition, the sample selection reflects Line Office guidance as to a representative sample of sites to survey. The directors of those surveyed sites also provided guidance as to their most important products and services. In the process of interviewing SMEs at the sites, many additional NOAA products and services were identified and surveyed.

In addition to non-NOAA observing systems, the surveys captured the impact of several dozen products and services from other U.S. Federal, international, academic, State/Local, and commercial entities. Most of the external products assessed were relevant to the interrelationships of products and services within NOAA. Ultimately, TPIO obtained Line Office concurrence on the inclusion of survey products and their assignment to a primary MSA.

### 5.2.2. Data Collection Worksheet

Using an initial set of sites and products recommended by Line Offices, TPIO commenced the survey phase of the NOSIA-II data collection. TPIO conducted surveys at 72 sites using the following systematic process to establish a nominal product performance (status quo score), data sources and impacts, and data source satisfaction, see Terms and Definitions for complete description.

A site survey template, called a Data Collection Worksheet (DCW), was customized to reflect the products and data sources at a particular site before the site survey. In preparation for each site survey, TPIO reviewed available site strategic plans and other documentation to augment Line Office-provided information on products and data sources. Additionally, DCWs were reviewed by site liaisons before the SME interviews to establish survey products and potential data sources in pre-survey briefing interviews with the site SMEs.

Figure 5.3. is an example of a typical site survey data entry form, called a Data Collection Worksheet (DCW). A standardized DCW was developed from lessons learned from initial surveys.

**Figure 5.3. Survey Data Collection Worksheet (Example)**

| Survey Products | Fishery Stock Assessments | Climate Vulnerability Assessments for Fish and Fisheries | Overall Satisfaction |
|---|---|---|---|
| Status Quo Intermediate Product Performance >>> | 70 | 40 | |
| Fish Stock Assessment Models (Single and multi-species pop dyn models) | 20 | 20 | 70 |
| Ocean Circulation Models | | 30 | 50 |
| Socio-Economic Models | | | 60 |
| Ecosystem Models (e.g. FEAST, Food-Web) | 65 | | 60 |
| Climate Models (SST, Winds, Ice Formation) | | 20 | 60 |
| Fisheries Independent Surveys (NOAA ships) | 30 | 25 | 60 |
| Fisheries Independent Surveys (NOAA Charters) | 25 | 25 | 80 |
| Fisheries Independent Surveys (State & Univ ships & Charters) | 60 | 25 | 80 |
| Socio-Economic Surveys | | 20 | 60 |
| Commercial Fisheries Dependent Biological Samples & Catch/Bycatch (includes regional observer program) | 5 | 20 | 80 |
| Biological Samples from shore-side landings | 40 | 40 | 80 |
| Observer-based catch/bycatch & bio sampling | 56 | 56 | 80 |
| State Fish-ticket programs & species composition sampling | 4 | 4 | 80 |
| Ecosystem Surveys | | 30 | 50 |
| Recreational Fisheries Survey | | 30 | 60 |
| Buoy Data (Eco FOCI) | | 30 | 70 |
| Polar SAR Satellites | | 35 | 70 |

**Step 1) Identify the Survey Products in Figure 5.3. Produced by the Site.** These are products the site generates (refer to Figure 4.1., Overview of NOSIA-II Analysis Process, Step 1 - Establish Value Tree).

**Step 2) Identify the Data Sources.** Data sources contribute to the production of the surveyed products and include other surveyed products generated at the Site being surveyed or at other Sites, Observing Capabilities (groups of similar observing capabilities), and individual observing systems. If a data source is another product (i.e., is created with inputs from other sources) or is a model; the data collection process is repeated for these products and models at the appropriate site. In other words, each product used as a data source at one site becomes a survey product at another site. This decomposition continues until every data source is resolved into investment options (e.g. observing systems, databases, models). Databases, in principle, should also be surveyed to determine their observing system contributions. This was not accomplished in every case, and there are 116 unresolved databases in the NOSIA-II option list. NOSIA-II identified the impact at the system level with the exception of satellites and aircraft where impacts were documented at the sensor level.

**Step 3) Identify the Relevant Components of the Observing Capabilities**. NOSIA-II subdivides observing capabilities for satellites, aircraft, and ships. Space-based and Airborne capabilities are disaggregated at the sensor level. Ships are disaggregated at the activity level, such as fishery surveys, hydrography, and research. Other kinds of observing capabilities are also formed for streamlining the number of data sources, which require a second disaggregation step. For example, in Figure 5.3., Commercial Fisheries Dependent Biological Samples and Catch/By-Catch (includes regional observer program) are broken down into more specific observing capabilities such as Biological Samples from Shore-Side Landings, Observer-based Catch/Bycatch and Biological Sampling, and State Fish-ticket Programs and Species Composition Sampling. In other cases, collections of smaller capabilities were aggregated; for example, the Arctic Observing Program is represented as a program with multiple activities such as repeat hydrography, weather balloons, and ice buoys.

**Step 4) Assess Status Quo Score of the Survey Product with all Available Data Sources**. The Status Quo Score is a current snapshot of overall satisfaction of the survey product and is based on the performance scale in Figure 5.4. SMEs were asked to perform a self-assessment to consider how well their products met users' and stakeholders' needs and expectations. This scale was used throughout the surveys to enable a comparative analysis across the options without the need to rescale each SME's assessment. Product status quo (SQ) scores less than 90 (meets all requirements) may be due to the following:

- Shortfalls in product development or delivery infrastructure. These include limitations in timeliness, funding, computing resources, facilities, and work force.
- Shortfalls in observing the physical phenomena that enable NOAA to respond effectively with highly performing products and services. These include ensuring NOAA has observations that are relevant to the phenomena, are at the appropriate spatio-temporal resolution, are accurate, and are amenable to decision analysis (e.g., efficiently assimilated and processed to provide actionable intelligence).
- Shortfalls in understanding the physical phenomena that enable NOAA to respond effectively with highly performing products and services. Phenomena studies include hurricane research core dynamics and particulate matter deposition research.

**Figure 5.4. Translating Performance into Numerical Values**

- **Performance Evaluation**
  - Performance score leveraged scale, swing weighting and SME assessments
    - Surveyed Products Status Quo* Performance
    - Data Source Impact Swing Score
    - Data Source Satisfaction
- **Swing Weighting Ground Rules**
  - Remove one Data Source at a time
    - All other Data Sources remain unchanged & available
  - Direct use of Data Source only
    - Assume everyone else has the data
  - Score normal/operational impacts
  - Integrate impact over a yearly/climatic cycle

| Performance (Satisfaction) Scale | | |
|---|---|---|
| 100 | Ideal | Meets all requirements and exceeds some |
| 90 | Fully Satisfied | Meets all requirements |
| 80 | Good | Meets all major requirements, with minor limitations |
| 60 | Fair | Meets most major requirements, with significant limitations |
| 40 | Poor | Fails to meet many major requirements, but provides some value |
| 20 | Very Poor | Fails to meet most major requirements, but provides minor value |
| 1 | No Capability | Provides no value |

* *Current performance*

For example in Figure 5.3., SMEs assessed the overall status quo performance of the Fishery Stock Assessment as 70, meaning between fair and good. (Rationale for these assessments were captured in Site Survey Notes.) This is conducted for each survey product, and this performance level becomes the basis for the "swing weighting" in Step 5.

**Step 5) Assess Impact of Individual Data Sources on Product Performance (Reduced Product Score).** SMEs are asked to consider the impact of removing each data source from production (refer to Figure 4.1., Overview of NOSIA-II Analysis Process, Step 2 - Conduct Surveys). Characterization of data source impacts to products is known as "swing weighting" in NOSIA-II. For example, in Figure 5.3, the question to the SMEs was: "What is your status quo performance of the survey product Fishery Stock Assessments <u>if</u> the Fish Stock Assessment Models are not included as a data source, using the status quo performance as a starting point." In this example the SMEs assessed that the reduced product score of the Fishery Stock Assessment would be 20, Very Poor, without the Fish Stock Assessment Models versus a 70 with the models, for a 50 point drop in satisfaction. Removing a Data Source will decrease the performance score in Step 4. This is completed for each data source.

**Step 6) Assess Percent Contributions of Capabilities within the Data Sources**. In cases where a data source is broken down into capabilities, the SMEs assess the percent contribution of the various capabilities within the data source. Later in the analysis, the satisfaction score of the data source is allocated to these capabilities by these percentages. For example in Figure 5.3, Biological Samples from Shore Side Landings, Observer Based Catch/By Catch Bio Sampling, and State Fish Ticket Programs and Species Composition Sampling are given percent contributions of 40, 56, and 4 percent relative to Fishery Stock Assessments survey product. Clearly, the Observer Based contribution is much more significant than State Ticket. These percentages must sum to 100.

**Step 7)**. **Assess Overall Satisfaction of Each Data Source.** In this step, satisfaction with the data source is assessed as it relates to production of the survey product. This assessment is accomplished using the same performance scale. This assessment is an opportunity for the site to rate their satisfaction with data sources necessary to produce their survey products thereby highlighting where improvements in these data sources are of value. The completed Data Collection Worksheet is called a "Swing Table" in NOSIA II. Swing tables contain the complete set of parents (products) and children (data sources) and the numerical scores (status quo scores, reduced product scores, percent contributions of capabilities within data sources and overall satisfaction scores. Swing tables are embedded in the NOSIA II model building workbook. (see Section 6 for more information.)

### 5.2.3. Survey Background

**Survey and SME Sources:** Surveys and SMEs were limited to NOAA business units, including some Cooperative Institute principal investigators. The interviewers preferred small survey groups to provide a consensus on performance scores. Sometimes a single individual was surveyed depending on availability.

**Limits of SME Input:** First-hand knowledge of data sources was required; no hearsay was accepted. In some cases, collaboration was necessary with other SMEs to confirm data source capabilities. This added to the time required to complete a survey.

**Survey Time Constraints:** Time required for site surveys ranged from 4 to 8 hours depending on the number of products to be surveyed per site and the complexity of products. Survey data collections were scheduled to maximize availability of SMEs.

**Data Collection Worksheet Setup:**

- **Elicitation of Reduced Product Scores:** Reduced product scores were typically limited to data source capabilities to expedite the data collection and reduce the SME's effort as well as to force explicit data source selection.
- **Choice Architecture:** Survey goal is to limit the number of data source choices to seven or less. The ability of SMEs to resolve data source impacts accurately has been shown to diminish as the number of choices increases (Thaler and Sunstein, 2008). To apply Choice Architecture principles, NOSIA-II used Product and Observing Capability Groups (also referred to as Functional Groups) to drill down to explicit data sources.
- **Opt-in as Default**: DCW configuration did not "lead" the SMEs into explicit data source choices, forcing SMEs to identify sources and not pick data sources al-la-carte. Functional Groups were used as top-level categories to avoid bias of ownership. Forcing SMEs to opt-in their data source attribution helped limit over-attribution and quantity of low impact data sources.
- **DCW Continuity:** A standardized DCW template was developed for sites with similar missions, such as those associated with Weather Ready Nation and Healthy Ocean Goals. While this was an evolving process, the template aided in standardizing data sources, product names and provided consistency from site survey to site survey.

**Survey Team Members:** Surveys were typically conducted "live" using survey teams with data entry completed during the survey, and not filled out prior to the interview.

Survey teams were composed of the following members to optimize data collection and enhance data quality:

- **Facilitato**r: Reviews available strategic plans and conducts pre-meetings with site liaisons; drafts the DCW based on the Line Office identified key products; helps SMEs reach consensus on DCW population, and monitors SME inputs for bias or exaggeration. In most cases the appointed Facilitator is an individual familiar with the selected site's workflow.
- **Scribe**: Records remarks related to product SQ scores, Data Source impacts and Data Source Satisfaction, and documents score disagreements among SMEs.
- **DCW Data Entry:** Captures the quantitative data associated with DCW entry and ensures the data are consensus scores.

## 5.3. Collection of Organizational Data

The purpose of collecting organizational and prioritization data from NOAA leadership on the elements of the NOSIA-II Value Tree (primarily KPS groups) was to validate the NOSIA-II Value Tree structure and accurately reflect the relative importance-weights of NOAA's core mission services as represented by products, services and science objectives. Initially, KPS within the Goals were not grouped or assigned importance weights. By not grouping or weighting, the initial model did not reflect the importance of each product group with respect to NOAA's overarching mission objectives. NOAA Goal and MSA leadership were asked to review the ungrouped and unweighted KPS and then were given the opportunity to group products into KPS groups, and assign importance weights to the groups and to the members of these groups. Goals remain equally weighted, and MSAs are equally weighted within each Goal.

The collection of organizational and importance weight data involved the following steps:

1. Goal and/or MSA leadership were asked to organize (group) the survey products (the individual products surveyed at the sites) into Key Product and Service groups within each MSA. These KPS groups are aligned with product suites and mission outcomes within the MSAs. In some MSAs, secondary sets of product groups were also identified, subsidiary to the KPS groups. (See Figure 5.5.)
2. Ground rules for grouping and assigning importance weights were established by each Goal and/or MSA leadership. Although similar, Goals and MSAs did not use exactly the same approach.
3. KPS are allowed to be mapped to a single MSA.
4. NOAA Goal leadership and/or MSA leadership were then asked, within each MSA, to define the relative importance weights of the KPS groups within a range of 1 to 5, where a "5" is five times as important as a "1" (see Figure 5.5.). Where subsidiary product groups were formed within the KPS groups, the representatives were asked to assign importance weights to these groups in the narrow context of each KPS group.
5. Finally, within each KPS group or product group, the Goal and MSA leadership were

asked to assign importance weights to the members of each group. In the case of KPS groups of one, the lone product has the full weight of the KPS regardless of subsequent assignment of importance weight.

The importance weights assigned by NOAA leadership were used as weight factors in weighted-average functions. For example, if a KPS group had five members with importance weights of 5, 4, 3, 2, and 1 that sum to 15, these were converted into the following weights: 5/15, 4/15, 3/15, 2/15 and 1/15, thus preserving their relative importance. When two or more products have the same assigned importance weights, then they are equally important and still have the assigned importance relative to elements with different weights. In the notional example of a group of 10: 5, 5, 4, 4, 3, 3, 3, 2, 2, 1, (summing to 32) we have the following conversion: 5/32, 5/32, 4/32, 4/32, 3/32, 3/32, 3/32, 2/32, 2/32, and 1/32. Thus, the two elements with a weight of "5" are equally important, and both are five times as important as the element with a weight of "1."

Because these importance weights are organized into the Value Tree's hierarchical structure, the impact of any node in the value tree on any higher-level node for which a valid path exists, can be calculated by tracing the connections and weights from the lower level node to the higher node in the Value Tree. A simple model has been constructed to illustrate this calculation, and how these weights play into the calculation of observing system impacts. In this model there is only one Mission Goal and two MSAs. (See Figures 5.5 and 5.6.)

- Top Node (NOAA) has a weight of unity;
- The single Mission Goal also has a weight of unity. (In the actual NOSIA-II model the four Mission Goals are equally weighted: (¼, ¼, ¼, ¼);
- The two MSAs are equally weighted within the Mission Goal,: (½, ½);
- The first MSA has two KPS groups with weights of 5 and 4; these sum to 9 and yield weight factors of 5/9 and 4/9;
- The second MSA has a KPS group-of-one, so its weight is unity.
- The first KPS group has two KPS, and the second KPS group has only one KPS, with a weight of unity;
- In this simple model, each KPS has only one Data Source. (In the actual NOSIA-II model, KPS typically have multiple data sources).

Figure 5.6 shows the example of calculating the impact of removing a single data source (Option MG1_3) on the top node. In this simple model all of the inputs have performance scores of 100, so all the nodes above them have Status-Quo performance scores of 100. In this example, removing this single option reduces the top-node score by 22 points, from 100 to 78.

**Figure 5.5. Simplified Example of the NOSIA Value Tree and Roll-up Rules**

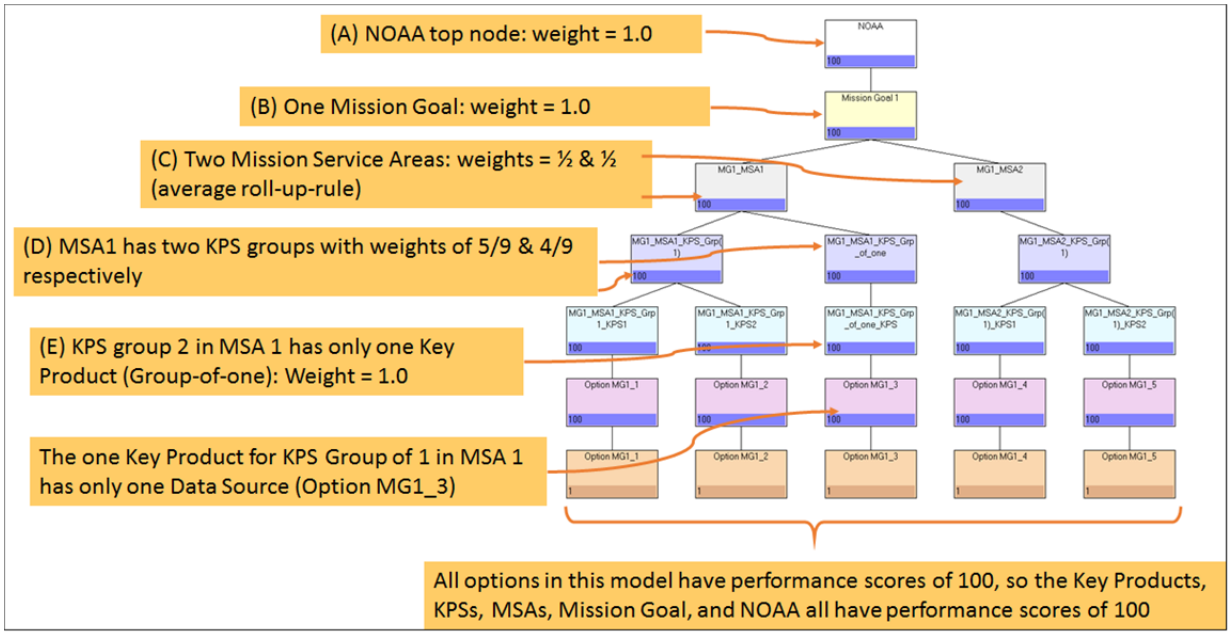
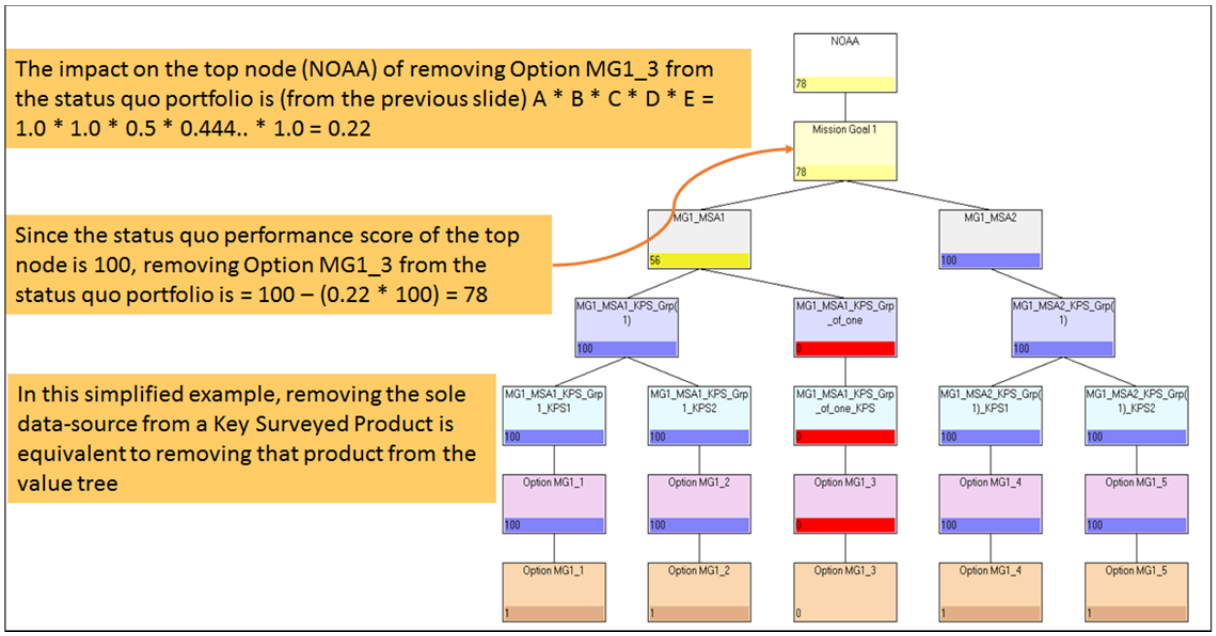



**Figure 5.6. Simplified Example of the NOSIA Value Tree and Roll-up Rules Removing One Data Source (option)**




Within each MSA, groupings and importance weights were coordinated by the lead Line Office with other contributing Line Offices. Once the data was collected on groupings and importance weights, TPIO applied these data to the model and requested Line Office leadership review the results for concurrence and acceptance.

It is important to note that organizational priorities characterized in the inter-MSA Value Tree are relative. The priorities per KPS or KPS Group are only relevant within the context of the "parent node" above these elements. It is also important to bear in mind that the organizational priorities were collected in order to better estimate the true impact of the data sources (observing systems and databases). In the end, asymmetries were revealed with respect to the number of products surveyed and ultimately identified as KPS; some KPS Groups contained only one or a few products and other KPS groups had as many as 30 members. Nonetheless, NOAA Line Offices were able to assign importance weights to these groups. This has the effect that some groups with only a few members are as important as groups with many members. KPS Groups were also used to average together products with the same name that were surveyed at several sites (e.g. the Terminal Aerodrome Forecasts at Weather Forecast Offices). While inter-MSA Value Tree asymmetries are allowed and necessary, they do cause some products to have much greater influence on the model than others. The consequences of differential product weights on integrated observing systems impacts were examined during Model Output Validation.

The consequences of groupings and priorities on MSA and Goal performance scores and their respective integrated observing system impacts were not immediately quantified and known to Line Office leadership. In some cases, the effect of groupings and priorities provided the potential for allowing some observing systems too much influence on the model. The quantitative impacts were reviewed, and groupings and priorities adjusted on a case-by-case basis to resolve observing system impact anomalies during Model Output Validation, discussed in Section 8.1. In particular, the impacts of "product groups-of-one" have been scrutinized in consultation with NOAA leadership, and in some cases adjustments to the model structure (changing group composition or importance weights) were made to reduce the impact of these products. Periodically re-evaluating and adjusting these compositions and/or weights may be warranted and appropriate methodology for doing so is being considered.

## 5.4. Collection of Observing System Cost

The NOSIA-II model has a cost for every "option", i.e., observing systems and databases. Cost data are an essential aspect of the NOSIA-II model assessment capability for generating the Efficient Frontier portfolio analysis, combinations of assets or investment options that provide the highest possible performance or goal satisfaction for a given cost or budget constraint. Cost data are a potential source of uncertainty, as noted in Section 6.5. Cost data were provided by NOAA Line Offices for systems operated by NOAA, or estimated by TPIO for systems operated by a non-NOAA organization.

NOAA Line Offices coordinate observing system program data through the Observing Systems Committee (OSC), a subcommittee of the NOSC. The OSC maintains a validated observing system database called the NOAA Systems of Record (SoR). The SoR database includes accurate system descriptions and information on acquisitions, operations and maintenance (O&M) costs, and observing capabilities of these systems. For a public-access (no cost information) view of the OSC SoR with links to Observing System Summaries (OSS) for individual systems, see https://www.nosc.noaa.gov/OSC/oss.php. The OSC SoR database was the primary source of NOAA observing system cost data within the NOSIA-II model. OSC

SoR costs generally include the full cost of operation, including facilities, expendables, labor, and associated contracts. Only NOAA's Office of Marine and Aviation Operations (OMAO) included cost of depreciation for the NOAA Ship and Aircraft SoR Programs.

The cost of non-NOAA observing systems and databases was the estimated cost to NOAA; TPIO did not include cost of operations of a non-NOAA data source. NOAA's cost of leveraging non-NOAA data sources included data acquisition overhead associated with circuits, routing, formatting, quality control, and integration into Information Management Systems (IMS). In some cases, NOAA buys data from commercial providers; and the direct cost of these data-buys were used, where known.

Observing system costs are aggregated at the platform or program level, except for NOAA satellites, ships, and aircraft, as noted below. Observing system costs are tagged to either sustained systems in operations or systems in development (e.g., GOES R and JPSS). The cost for observing systems in operations are represented in the NOSIA-II model, while cost of observing systems in development are represented in the "multi-period" portion of the NOSIA-II model, which is to be developed at a later date.

### 5.4.1. Overview of Observing System Cost Methodology

Four categories of cost information in the NOSIA-II model:

- Category (1): Detailed information on costs of NOAA satellites, ship, and aircraft;
- Category (2): Summary information on other NOAA-funded observing systems;
- Category (3): External data sources NOAA leverages; and
- Category (4): Internal databases

**Category (1):** A large percent of NOAA's observing system costs are associated with its satellites, ships, and aircraft. While most NOSIA-II observing system costs are aggregated at the platform or program level, most of the satellite costs were aggregated at the sensor level and the ships and aircraft costs were aggregated at the activity level. The cost attribution for NOAA satellites, ships, and aircraft are described in more detail in Sections 5.4.2. and 5.4.3.

**Category (2):** The cost information for the SoR was collected via a data call to system owners and operators in coordination with Line Offices. The SoR cost information received further Line Office and Chief Financial Officer (CFO) scrutiny and refinement in 2012 as a result of a data-call by the Office of Management and Budget in connection with EOA 2012. The OSC collected updated cost information on the SoR list in 2013 in support of NOSIA-II. This data-call included specific cost elements, adapted from the NOAA Trade-Space Analysis Guide (TSAG), in an effort to obtain more consistent summary data across the range of SoR (TSAG 2012). SoR cost information was vetted by Line Office CFOs as a result of inquiries by the Government Accountability Office in 2013 as to the cost of ocean and coastal observing systems. For further details, refer to NOAA's Observing Systems: Additional Steps Needed to Achieve an Integrated Cost-Effective Portfolio at http://www.gao.gov/products/GAO-15-96.

Because NOSIA-II SMEs sometimes referred to components of SoR systems as separate data sources, and TPIO usually did not have disaggregated cost information for such components, the total annual cost of the SoR systems were divided equally amongst the components. For analysis purposes, the components and their costs are typically grouped so that results are shown at the SoR level.

**Category (3):** External data sources leveraged by NOAA are the category for which very little cost information is available. TPIO's approach to addressing these costs was to presume that they are not cost-free. Leveraging some external data sources may be as low-cost as simply accessing a product from an external source on the Internet and using the data with very low overhead or data management effort. Other external data sources are very large or complex, or require substantial communications resources and on-going effort to manage, assimilate, validate, and use.

Therefore, in lieu of direct information on the cost of accessing and using external data sources, TPIO employed the following assumptions:

- External Space Based (satellite) data sources were assigned a cost of $1M/year. When external satellite platforms have multiple sensors, the $1M/year cost is divided equally amongst the sensors.
- External, high data-volume sources such as Airborne LIDAR were assigned a cost of $0.05M/year.
- External in situ (surface-based and ocean) data sources were assigned a cost of $0.01M/year.
- External surface based remote sensing systems (e.g. radars) were assigned a cost of $0.05M/year.
- External databases were assigned costs ranging from $0.01M/year to $0.05M/year intending to indicate perceptions as to the relative size or complexity of the data.

**Category (4):** Internal NOAA databases were assigned costs of $0.03M/year.

### 5.4.2. Ship Fleet Cost Breakdown

The following steps were taken to estimate the cost of NOSIA-II "options" associated with the NOAA Ship Fleet:

1. Reviewed the Fleet Allocation Plans (FAPs) from FY 2012 - FY 2014 to determine the average number of Days At Sea (DAS) that were associated with each of the Fleet Recapitalization Plan functional activities for each year.
2. Developed a mapping between the functional activities and the types of ships that predominantly conduct that type of activity.
3. Multiplied the number of DAS assigned to each functional activity by the FY 2012 average daily cost for the type of ship that conducts that activity.
4. Developed a mapping between the functional activities and the NOSIA-II "options" related to NOAA Ships using the OMAO Ship Daily Activity Logs (SDALS) from FY2014.

5. Assigned the cost of the functional activity mapped to each "option" to determine the representative cost of each "option" in the NOSIA-II Value Tree.

### 5.4.3. Aircraft Fleet Cost Breakdown

The process similar to that described for the NOAA Ship Fleet was used to estimate the cost of NOSIA-II "options" associated with the NOAA Aircraft Fleet:

1. Reviewed the Aircraft Allocation Plans (AAP) from FY 2012 - FY 2014 and determined the number of Flight Hours for each aircraft type that was associated with each of the functional activities (i.e. Snow Survey and Coastal Mapping) for each year.
2. Using the OMAO provided "FY14 AOC Standard Rates" determined the cost per flight hour for each aircraft.
3. Multiplied the number of flight hours for each functional activity by the "FY14 AOC Standard Rates" for each type of aircraft that conducted that activity.
4. Developed a mapping between the OMAO identified functional activities and the NOSIA-II "options" related to NOAA aircraft.
5. Assigned the cost of the functional activity mapped to each "option" to determine the representative cost of each "option" in the NOSIA-II Value Tree.

# 6. NOSIA-II Model Integration

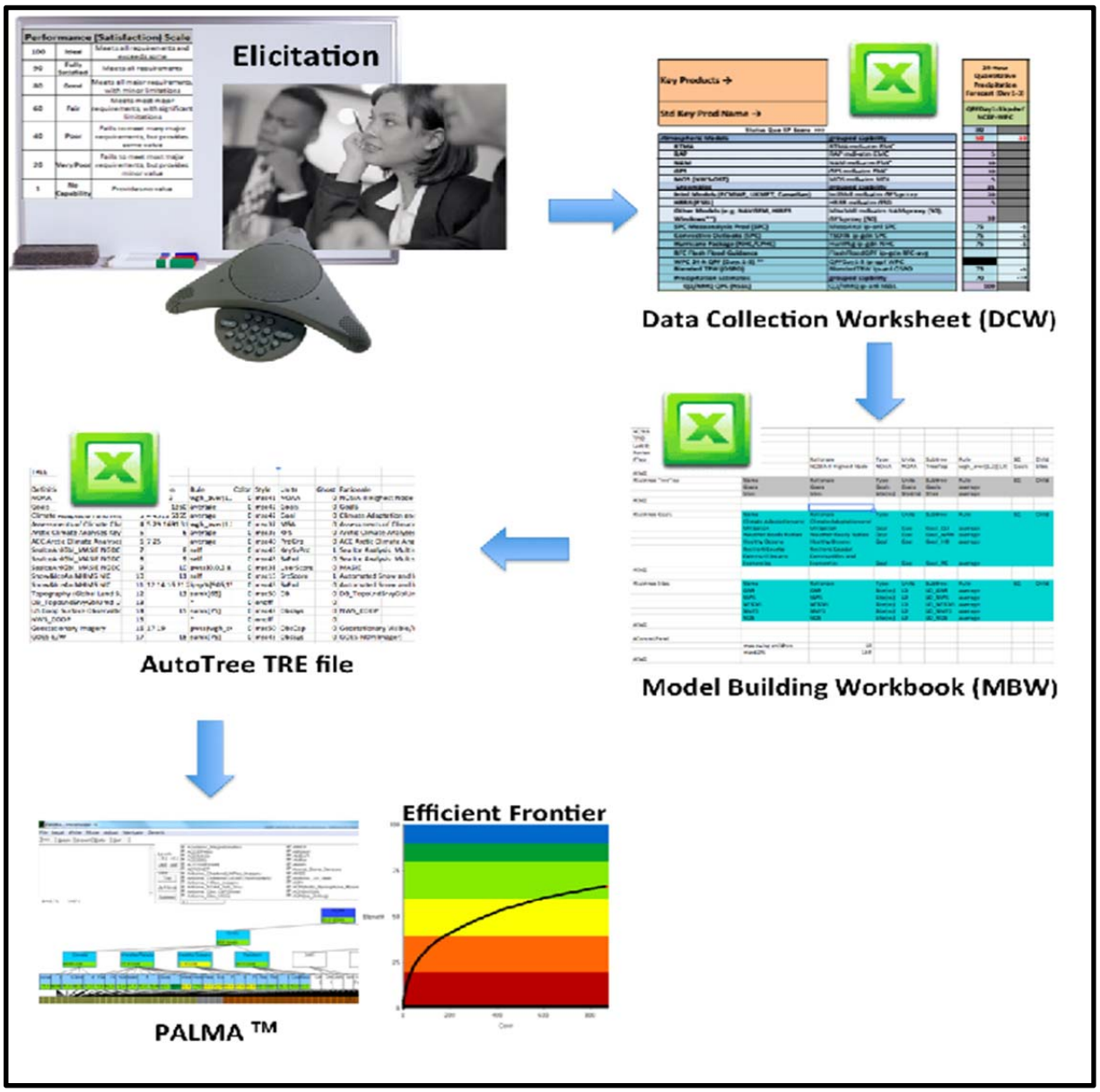
The integration of site survey data, organizational data, and cost data was not a trivial phase of the NOSIA-II model development process. This was the first time NOAA identified key products, used MSAs, and used a value tree approach to understanding the importance of observing platforms. Further, the relationship between other products (such as models) and downstream products needed to be established. Post-survey meetings were required to create a standardized set of data sources and product names.

## 6.1. NOSIA-II Model Building Workbook (MBW) Evolution

This section describes how the analysis was conducted by translating the data collected into the NOSIA-II model, and developing an initial capability for analysis (refer to Figure 4.1., Overview of NOSIA-II Analysis Process, Step 3 - Populate Model). Through an extensive configuration management activity, each DCW for each site was reviewed for accuracy, completeness, and consistency with respect to survey products, data sources, observing systems and databases. Once this activity was completed, the modeling team creates a second Excel™ spreadsheet, the Model Building Workbook (MBW), derived from the DCW.

The NOSIA-II MBW is a large Excel™ workbook with approximately 100 tabs that contains all the data, relationship information, and instructions for how the PALMA software should calculate the roll-up rules (see Section 6.2.) for the NOSIA-II model. The MBW is the main input into PALMA and it is constructed from the DCWs discussed in Section 5.2.2. Software developed by the MITRE Corporation called AutoTree automatically reads the MBW and compiles it into the PALMA model input format (called a .TRE file). MITRE developed the MBW/AutoTree approach to facilitate building and maintaining large PALMA models such as the NOSIA-II and EOA 2012 models, see Figure 6.1. for the process flow and Appendix D for the definition.

**Figure 6.1. NOSIA-II Model and PALMA Data Collection Workflow**




The first complete NOSIA-II MBW was successfully compiled into a functioning PALMA model in December 2013. At this point, the model functioned but still contained many structural and data consistency issues limiting model quality assessments, which were resolved during numerous model enhancements and tests in 2014. For example, TPIO, in collaboration with the Line Offices, developed additional meta-data types such as functional product combinations and Key Product and Services groups which were implemented into the MBW. These enhancements facilitated reflecting the Line Offices business model in grouping products and assigning importance weights as described in Section 5.3, and they enabled data reporting and quality control from within the MBW. The NOSIA-II model now includes over 20,000 model connections representing about 1,100 products and over 600 data sources.

In general terms, the MBW parallels the tree structure of the model. The first set of tabs contain the information and relationships pertaining to the value-side of the model; NOAA, Goals, MSAs, KPS, KPS Groups, and survey products. The second set of tabs contains all the site-specific model elements (one tab per site). The final set of tabs contain information on how PALMA presents the data, lists options and their costs, and sets option-dependencies to funding programs. The value-side of the model links each KPS to a survey product on a site tab via a modeling construct called a "ghost node." Ghost nodes greatly reduce the visual clutter of the model. The site-side also uses ghost nodes to link survey products (such as numerical models) produced to other sites where the products are used.

TPIO's efforts in model and data integrity are key to ensuring the model's credibility for observing system portfolio decision making guidance. TPIO formalized configuration management by establishing modeling and Data Integrity Teams, and utilizes a quality control tool using Excel-macros to test model consistency and to track and review the impact of model changes. These activities have enabled the modeling and Data Integrity Teams to scrutinize the MBW thoroughly through several top-to-bottom code reviews. The model has been re-structured to achieve consistency and clarity in product and data source relationships and to correct programming errors and questionable data. Although this type of formal code review is time and labor consuming it will become more efficient when the data elements and meta-data are managed via the database tools currently under development.

## 6.2. Grouping and Splitting (e.g., use of Roll-up rules)

Roll-up rules, which are mathematical and logical functions, represent the relationships between parent nodes and child nodes in the PALMA model. PALMA provides a flexible, powerful library of functions. To date, the NOSIA-II model relies on just a few functions including "average", "weighted-average;" used primarily on the value-side of the model; and the Interval-Preserving Symmetric Extended Average Power Function (IPSEA-P), which is a type of generalized average function to represent the non-linear relationships between survey products and the data sources for those products on the site-side of the model (Schmidt 2013).

During model development, TPIO needed to make trades to simplify SME surveys and model complexity. For example, grouping products and similar observing systems has the advantage of reducing the number of inputs to a given product and presents the SMEs with a more meaningful "data denial" scenario. However, using observing system and product capability groups increases model complexity. SMEs weight group members as a percentage contribution to the group as a whole, and we use a different rollup rule and sub-tree structure to generate the functions representing their individual contributions to the survey products.

## 6.3. Developing Standardized Taxonomies

The SMEs interviewed for NOSIA-II used a diverse set of terminology to define their specific products and data sources. The key to managing and analyzing this information was to establish relationships within the diverse NOSIA-II survey data by developing a way to identify, classify, and assign structure (taxonomies), thus providing a common language across all of the information.

To associate structure around the NOSIA-II surveyed information, the Data Integrity Team developed and implemented a NOSIA-II Standardized Taxonomy, consisting of many levels and sublevels, referred to as nodes and sub nodes, each aligned with a specific type, group or category of the NOSIA-II surveyed data.

Much of the information collected is archived in Excel spreadsheets and Google Documents which are difficult to manage consistently and mine as a large set of independent 2-dimensional references. The NOSIA-II Analysis Databases which are an aggregation of the DCWs have been useful to mine model inconsistencies. These inconsistencies slowed model development.

The DCW spreadsheet template created challenges when creating and maintaining related NOSIA-II Value Tree taxonomies. Use of a spreadsheet for data collection added flexibility for entering and updating data during the NOSIA-II interview, and helped expedite the process, which took over eight hours for some sites. However, information that was defined in the Data Collection process including site produced products, input data sources, scores and comments were entered as free text during the interview process using SME-defined terminology. This often included naming by acronyms or a name that was not descriptive enough to be easily understood by a wider audience. While every effort was made to have consistent names between DCWs, this standard was difficult to maintain due to the diversity of SME input, different survey team composition, and background, and challenges of data collection in spreadsheets. Spreadsheets are not good at handling relationships between data and are also prone to copying and pasting errors and typos as data quality issues.

It became apparent that in order to improve the ability to relate and link the hierarchical pieces of information in the DCWs, taxonomy needed to be established for the NOSIA-II Value Tree. The DCW SME-defined names for products and data sources needed to be standardized for the NOSIA-II model to work properly and the output of the NOSIA-II model to be comprehensive and easily understood.

**Building Authoritative Source**

Lists of authoritative values for NOSIA-II Value Tree information (standard names) needed to be established for terms including MSA, Site, Product, SMEs, Scribe Notes, Data Sources (i.e., other surveyed products, observing systems, and databases).

The way the information was transferred from the DCWs to the PALMA model was through "block copying" to the NOSIA-II AutoTree Excel file called the Model Building Workbook. In AutoTree, the NOSIA-II model is structured in blocks that contain hierarchical relationships information in the Value Tree. In order to generate an easily understandable view of all the NOSIA-II Value Tree information including relationships, the NOSIA-II Analysis Database (ADB) was created using Feature Manipulation Engine software to aggregate the NOSIA-II MBW.

The NOSIA-II ADB is a spreadsheet of all the NOSIA-II survey information including the relationships between the NOSIA-II Value Tree information. The format and structure of the ADB allowed the NOSIA-II Data Integrity Team to execute queries to improve the quality of

the NOSIA-II data and generate reports to fix data inconsistencies. This led to the creation of the NOSIA-II Authoritative Source List, which contained tables and attributes for the entire NOSIA-II Value Tree.

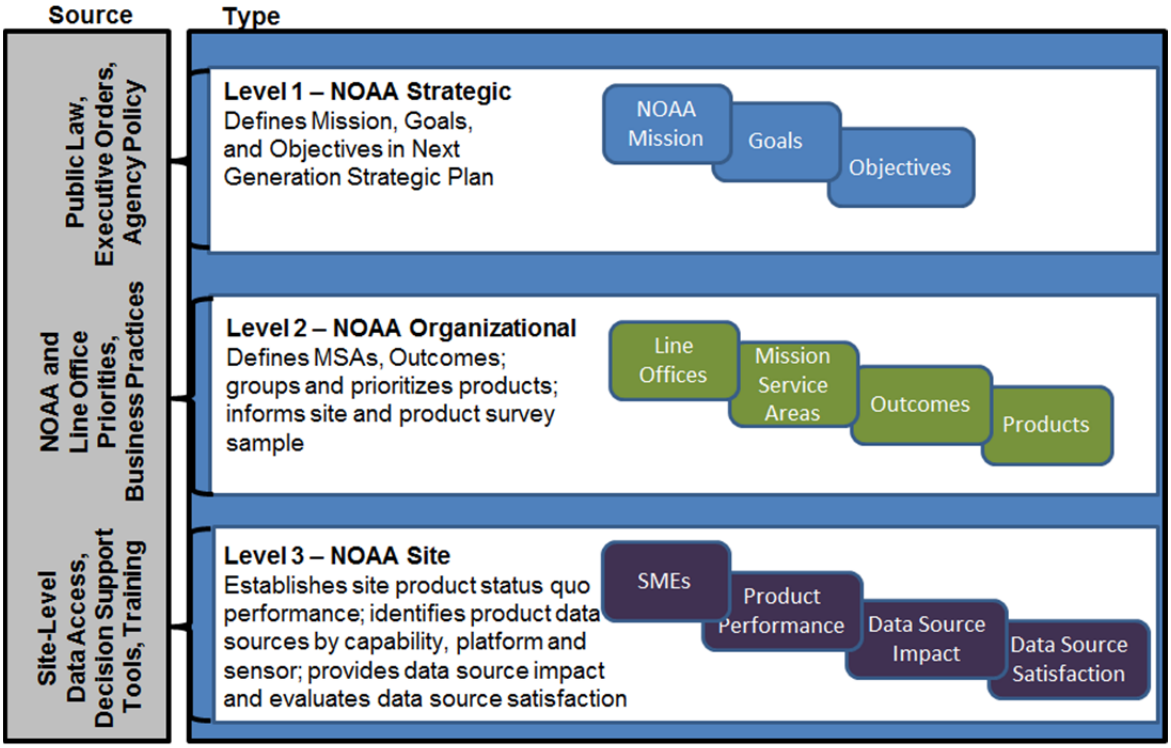
Attributes in the authoritative list were created to improve model integrity and generate model output that could be easily understood. Examples of critical attributes include data source owner, Site IDs, Observing System and Product Capability groups. All tables in the Authoritative Source List have identifiers, original surveyed names, and verbose names that use plain language.

The NOSIA-II standardized taxonomy was developed through an iterative process of improvements to the DCWs, MBW, ADB and model output products. The NOSIA-II Value Tree taxonomy will be improved and further refined as data is transitioned to the Earth Observation Requirements Evaluation System (EORES), follow-on to the Consolidated Observation Requirement List (CORL), NOAA Observing System Architecture (NOSA), and CasaNOSA Analysis System Requirements Tool (CasRT) database environment. There is the potential to link the NOSIA-II Value Tree to metadata in the NOAA Data Catalog. This will require refinement of the taxonomy, but the value of being able to relate NOSIA-II to NOAA datasets will enable linking to the users of NOAA data and a derived societal benefit.

The NOAA Data Catalog is a prototype under active development, providing data and information needed to improve safety, enhance our economy, and protect our environment. It assembles and provides access to NOAA's environmental data sets and promulgates spatial geographic information issued by the National Weather Service (NWS), and Data Management Plans, Cruise Plans, Cruise Summary Reports, Scientific "Quick Look Reports", Video Annotation Logs, Nautical Chart data and catalogs and Satellite data from other NOAA offices. To view the catalog, see https://data.noaa.gov/dataset.

The NOAA Value Tree, depicted in Figure 5.1, depicts the NOSIA-II model elements. Taxonomy types and sources associated with the NOAA Value Tree model elements are shown in Figure 6.2. NOSIA-II taxonomies include the Strategic Level, (from Public Law, Executive Orders, and Agency Policy), the Organizational Level (from NOAA and Line Office Priorities and Business Practices), and the Site Level Data Source impact on Products information (from SMEs). The NOSIA-II taxonomy types have their traceability or ownership associated with these levels.

**Figure 6.2. NOSIA-II Taxonomy Types and Sources**




NOAA plans to publish these standardized taxonomies to enable additional beneficial uses of the data. Types of NOSIA-II taxonomies include:

- Organizational Metadata
- Observing System Metadata
- Observing Capability Group Metadata
- Product Metadata
- Product Capability Group Metadata
- Survey Metadata (Survey input, Scribe notes)
- Value Tree Metadata (Goal, MSAs, grouping/tiering)

## 6.4. NOSIA-II Model Configuration Management

Managing the vast amounts of data collected during the NOSIA-II project requires a formal process to assure data fidelity. The first challenge was integrating the individual 72 NOAA site DCWs into a cohesive MBW ingestible by the PALMA software. This involved a strict level of coordination amongst the team members responsible for programming the MBW from the individual DCWs. The modeling team developed a system of checks and balances to ensure AutoTree could compile each independently constructed product tree and that PALMA could ingest the data before the data was incorporated into the MBW. This effort required tight coordination because stitching the data sources together across sites required traceability completely to the leaf nodes through all relevant site products. A leaf node is an option in the model. It is the outermost model element. Leaf nodes do not have input data sources. They are the only nodes associated with a cost.

Once the programming team completed building the MBW, TPIO leadership creates an MBW configuration management board to prioritize and schedule updates to the MBW. After a potential update is approved by the configuration management board, a programmer is assigned to implement the update by checking out the MBW. Further updates on the MBW are frozen until successful implementation of the update. This is necessary because the MBW is not presently in a database but instead exists as a document. This sequential program update methodology streamlines the work of multiple programmers simultaneously maturing different components of the model while allowing traceability for programming errors. All changes made to the MBW are documented in the MBW Configuration Management Tracker document. This document provides a concise description of factors motivating a change to the MBW. A separate MBW Change Log document provides a more detailed description of implemented updates and versioning.

## 6.5. Model Limitations

Like any model, NOSIA-II includes assumptions, strengths, limitations, and sensitivities in the algorithms, framework, and input data that will influence the outputs. Users must ensure these model outputs are properly understood, interpreted, and applied. A simple analogy is the "model guidance" output of weather models used in conjunction with other information, by the human forecasters to develop the actual forecast. Clearly, the raw model output is not the final product. Follow up scenario studies and pilot projects using these results are expected to shed considerable new light on the current output scores. Therefore, it is important that users not use NOSIA-II raw outputs in an uninformed manner. The present scores from the NOSIA-II model raw output should be used as model guidance and not for final decision making. Refer to Appendix C for the primary caveats for understanding and interpreting the results.

# 7. Initial Operating Capability (IOC)

Prior to NOSIA-II Initial Operating Capability (IOC), preliminary observing system impacts could be generated from a Value Tree without MSA organizational grouping and tiering. NOSIA-II achieved IOC on June 30, 2014, after 15 months of effort (refer to Figure 4.1., Overview of NOSIA-II Analysis Process, Step 3 - Populate Model). The primary purpose of IOC was to create a stable model build which is representative of NOAA's business practices, where Line Office representatives could review model output for expected observing system impacts.

## 7.1. IOC Description

IOC was achieved with the collection and incorporation of survey data, validated observing system costs, organizational product priorities within MSAs, and implementation of enhanced model and data integrity protocols.

With NOSIA-II IOC, NOAA was able for the first time to:

1. Create NOAA-wide observing system impact output by NOAA, Goal, and MSA and by survey product
2. Generate Observing System Cost/Impact Quad Charts
3. Generate Efficient Frontier portfolios

NOSIA-II model output is described in Sections 7.2. and 7.3.

## 7.2. Impact Calculation Description

Observing system impacts in the NOSIA-II data are determined by the observing system's removal as a data source to a product. These impacts are provided by the SMEs of the products that they are directly involved in creating or producing. The observing systems impact the performance of an MSA via their cumulative impact on individual products that fall within the NOSIA-II hierarchy. If a product does not fall within the hierarchy, its associated observing system data sources will not impact an MSA.

NOSIA-II observing system impacts can be provided in the following contexts:

- **Impact at the MSA, Goal, or NOAA Levels:** The observing system is impacted by platforms, sensors, and/or the capabilities of satellites, aircrafts, and ships. If an observing system is not available to MSA, Goal, or NOAA levels then it results in degradation.
- **Value:** The observing system value is calculated as a ratio of cumulative impacts to costs. Organizational data (e.g., Line Office grouping and tiering) are taken into account in the model resulting in the Efficient Frontier performing trades among these values. Observing system values can be shown at the MSA, Goal, and NOAA levels.
- **Site Usage:** NOSIA-II site SME surveys can be queried to determine how specific sites use (direct and indirect) observing system data.

- **Product Impacts:** NOSIA-II database can be queried to create reports on survey products impacted by a particular observing system.

The primary program for calculating impacts of observing systems on NOAA's core mission is the ComputeDelta capability developed by MITRE. This program takes the impacts and data source relationships captured implicitly in the .TRE file and represents them in an explicit manner. In particular, ComputeDelta allows one to view the impact value of any PALMA node on NOAA overall, the four goals, the 25 MSAs, or on any other PALMA node. The observing system impacts take into account both direct usage of these systems as a product data source, as well as second-order effects (i.e., impacts that result from an observing system that feeds into a product that is a data source for another product). To enhance the usefulness and readability of the ComputeDelta results, TPIO developed auxiliary analysis tools (AssessDeltas and AssessDeltaChanges).

The AssessDeltas program parses the ComputeDelta results in order to give a ranking of observing system sensors, activities, platforms, and programs for NOAA, the four goals, and the 25 MSAs as shown below in Figure 7.1.

**Figure 7.1. AssessDeltas Program Output**

| Rank | ☑ Sort Products by Impact NOAA | | CLI | |
|---|---|---|---|---|
| | Data Source | SQ Score 66.21 | Data Source | SQ Score 69.85 |
| 1 | NOAA Ships Group | 3.87 | JASON Platform/Program | 5.55 |
| 2 | GOES NOP Platform/Program | 3.77 | POES Platform/Program | 4.25 |
| 3 | NEXRAD | 2.59 | METOP Platform/Program | 3.94 |
| 4 | METOP Platform/Program | 2.17 | NOAA Ships Group | 3.66 |
| 5 | NWLON | 2.10 | NWS COOP Group | 3.55 |
| 6 | POES Platform/Program | 1.90 | ARGO | 3.48 |
| 7 | JASON Platform/Program | 1.89 | Drifting_Buoy_Ntwk | 1.93 |
| 8 | UNOLS Group | 1.83 | DMSP Platform/Program | 1.92 |

AssessDeltas also calculates the performance index of an option, which is its share divided by impact. Additionally, the products that a given system or program supports, along with the priority level assigned by the Line Office owners of these products, and the percentage impact of the option on the products are also calculated.

**Figure 7.2. AssessDeltasChanges Macro**

| Cost($M) | | NOAA | WRN | WRN_SWX |
|---|---|---|---|---|
| | Impact Category > | Moderate | High | High |
| | Performance Score > | 66.21091727 | 73.86898084 | 69.52636 |
| 0.01 | GONG | 0.04 | 0.17 | 1.88 |
| | Performance Index | 0.23 | 0.06 | 0.00 |

| Impact Key |
|---|
| Very High |
| High |
| Moderate |
| Low |
| Insignificant |

Performance Index = CostShare/Impact
Low values imply high efficiency.

| | GONG | % Impact |
|---|---|---|
| Priority 5 | | |
| Priority 4 | Wang-Sheeley-Arge (WSA)-Enlil M | 75 |
| Priority 3 | Geomagnetic Storm Forecast and V | 34 |
| Priority 2 | Solar Activity Forecast and Specific | 22 |
| Priority 1 | Solar Synoptic Analysis | 20 |
| No Priority Assigned | Auroral Activity Forecast | 7 |
| | Energetic Electron Forecast and Al | 4 |

The AssessDeltaChanges, Figure 7.2. allows one to compare changes between two different **.**TRE files. This tool enables TPIO to show observing system/program owners, Line Office Representatives and other members of NOAA's leadership the results of suggested changes in product priority and option impact. This creates transparency with managers, who are able to see the results of their business operations and any suggested changes to those operations.

## 7.3. Model Output Examples

The below examples represent a sampling of the NOSIA-II model output and data visualizations. **As such, the below graphics are not representative of the current model run and data sets.** These prototype visualizations are under development. Requests for current model outputs may be submitted via the TPIO web page (https://www.nosc.noaa.gov/tpio/).

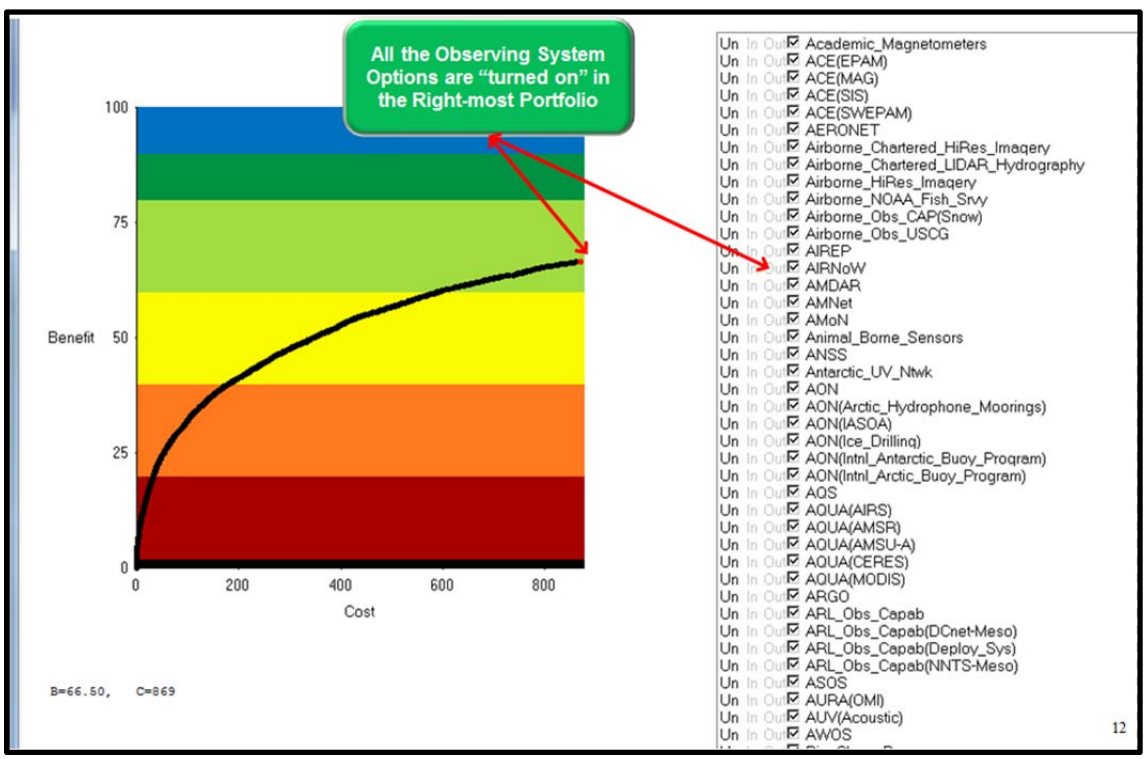
### 7.3.1. Efficient Frontier (EF)

PALMA has the capability to identify portfolios that satisfy a given budget constraint and estimate (with a high degree of confidence) which portfolio provides the highest possible performance (benefit) at the top (NOAA) node of the Value Tree. These are called optimal or efficient portfolios. PALMA goes further and identifies optimal portfolios for a broad range of budget constraints in fine-scale increments. This large sample of optimal portfolios is called an Efficient Frontier (EF), because it indicates the boundary between the most efficient (optimal) set of portfolios and all the inferior portfolios. The budget constraints in NOSIA-II range from near zero up to the total cost of all options in the options list. PALMA automatically divides this range into about 650 increments. In Figure 7.3, all the Options are selected to show a visualization of the EF. Different portfolios can be shown by choosing a selected number of options or budget constraints.

The mathematics of permutation imposes constraints on the optimization approach. PALMA can find an expansive range of solutions based on complete consideration of all possible portfolios for models with 25 options or less. For larger option sets, exhaustive analysis is not feasible due to the exponential increase in the number of possible portfolios; the number of possible portfolios is approximately $2^N$, where $N$ is the number of options. For large option sets, PALMA provides two optimization algorithms that find close approximations of the exact solution; Genetic Algorithm (GA) and a Strength Pareto Evolutionary Algorithm (SPEA) (Schmidt 2013, Zitzler, 1998). SPEA is relatively new to PALMA and is more efficient than GA, providing equivalent EFs in about half the time as GA. What GA provides is useful for validating SPEA results because it has been extensively used and tested for more than 10 years.

Results based on the PALMA optimization algorithm are fully consistent with common sense. For example, observing system options with high impact and low cost are found in low-cost portfolios (lower left), and high-cost, high impact systems are found in the higher-cost portfolios, towards the right-hand end of the EF. Compiling the count of how many times each option appears in the EF is a powerful metric, which provides Portfolio Managers useful insight into the relative cost efficiency of observing system options.

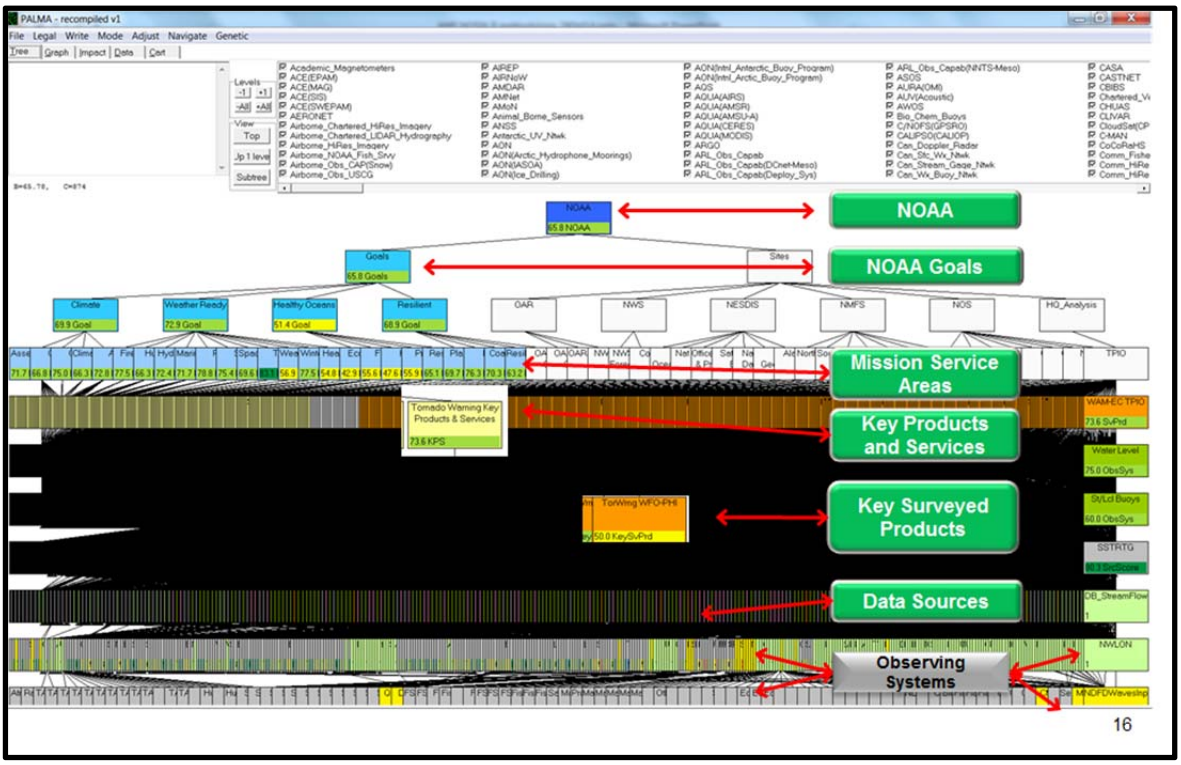
**Figure 7.3. Efficient Frontier Visualization with Options Choices**



### 7.3.2. PALMA™ Visualization of Value Tree

PALMA provides a quick and powerful way to visualize the Value Tree. Users can select any node (the boxes), starting at the top of the Value Tree and then view the portion of the tree that supports that node. The performance of each node based on the selected options is shown in terms of numerical scores and a user-selectable color scale. Once an Efficient Frontier run has been completed, any portfolio on the frontier can be selected and the tree view used to visualize performance levels of nodes at that budget constraint; see Figure 7.4. For a small model (e.g. around 100 nodes, the entire model can be seen on one screen. For large models such as NOSIA-II, visualizing specific relationships requires traversing through multiple screens.

**Figure 7.4. Sample Value Tree Visualization**

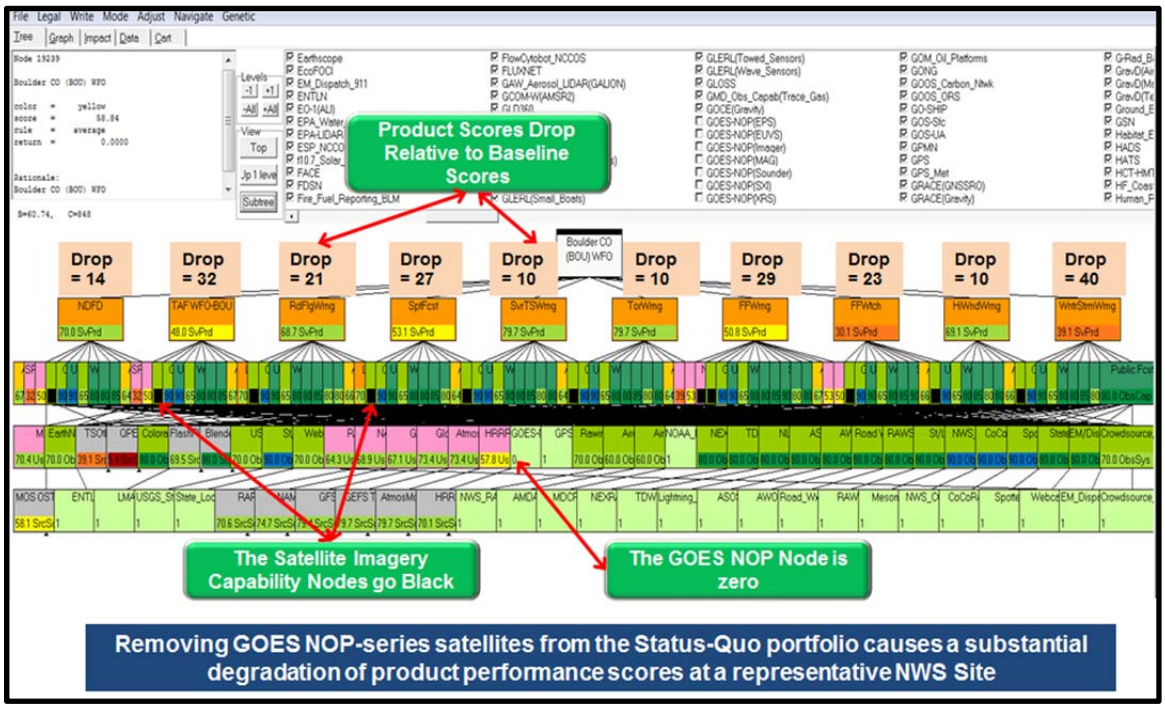



(Note: Details in Figure 7.4. are not intended to be legible; main emphasis is on the hierarchy.)

### 7.3.3. PALMA™ Visualization of Option Impacts to Value Tree

The PALMA 'tree-view' provides a quick way to visualize nodes that are impacted by removal of observing system options. For example, selecting a node of interest such as a Goal, MSA or Site node, and toggling a system such as Geostationary Operational Environmental Satellite (GOES) NOP Series on and off, the user can quickly see via the color changes on the nodes and how the survey products are affected. In the example shown here, Figure 7.5, turning off GOES NOP has a substantial impact on the survey products at the Boulder, CO Weather Forecast Office.

**Figure 7.5. PALMA Tree View of Impacts of GOES NOP Satellites**




Note: Details in Figure 7.5. are not intended to be legible; main emphasis is on the call-outs.)

### 7.3.4. Additional Data Visualization Outputs and Options

TPIO is developing a web-based application to enable users to visualize and explore the NOSIA-II dataset. The application will allow users to analyze and visualize networks and interconnections within a dataset. The following visualizations are currently being prototyped.

The observing system impacts table (Figure 7.6.) depicts the top observing system impacts from different perspectives and levels of the Value Tree. Using sample data, the table offers a simple, high level view of how NOAA's observing systems impact its mission.

**Figure 7.6. Sample NOSIA-II Output: Visualization Table Showing Observing System Impacts Across NOAA then by Goal**

| NOAA | | Climate Adaptation and Mitigation | | Healthy Oceans | | Resilient Coastal Communities and Economies | | Weather Ready Nation | |
|---|---|---|---|---|---|---|---|---|---|
| Data Source | Impact Category | Data Source | Impact Category | Data Source | Impact Category | Data Source | Impact Category | Data Source | Impact Category |
| NOAA Ships Program | Very High | JASON Platform/Program | Very High | NOAA Ships Program | Very High | NOAA Ships Program | Very High | GOES NOP Platform/Program | Very High |
| GOES NOP Platform/Program | Very High | POES Platform/Program | Very High | NMFS CFS | Very High | NWLON Program | Very High | NEXRAD Program | Very High |
| NEXRAD Program | Very High | METOP Platform | Very High | UNOLS Program | Very High | NERR SWMP Program | Very High | METOP Platform | High |
| METOP Platform | Very High | Argo Program | Very High | Protected Resources Program | Very High | CREIOS Program | Very High | RAWINSONDE Program | High |
| NWLON Program | Very High | NOAA Ships Program | Very High | NOP Program | Very High | NOAA Aircraft Program | Very High | ASOS/AWOS Group | High |
| POES Platform/Program | Very High | OCO Drifting Buoy Program | Very High | Habitat Survey Program | Very High | SWiM Program | High | POES Platform/Program | High |
| UNOLS Program | Very High | NWS COOP Platform/Program | Very High | Fish Surveys Program | Very High | GLOSS Program | High | NSNSN Program | Moderate |
| JASON Platform/Program | Very High | TAO Program | Very High | Science Field Collection Program | Very High | State & Local Water Quality Monitoring | High | NWLON Program | Moderate |
| NMFS CFS | Very High | DMSP Platform | Very High | Animal Borne Tagging and Bar Coding system | Very High | CORS Program | High | State Mesonets Program | Moderate |
| Argo Program | High | GOES NOP Platform/Program | High | GLERL Program | Very High | GPS Platform | High | National Lightning Data Network | Moderate |
| NOAA Aircraft Program | High | UNOLS Program | High | MRIP Program | High | Repeat Hydrography Program | High | SNPP Platform | Moderate |
| RAWINSONDE Program | High | NOAA Aircraft Program | High | Fisheries Science Center Observing and Lab Equipment | High | UNOLS Program | High | ACE Platform/Program | Moderate |
| Protected Resources Program | High | SNPP Platform | High | SNPP Platform | High | Marine and Estuarine Goal Setting for South Florida | High | Spotter Program | Moderate |
| NOP Program | High | State & Local LIDAR | High | Socio-Economic Surveys Program | High | HYDRO Program | High | DART Program | Moderate |
| ASOS/AWOS Group | High | Repeat Hydrography Program | High | Ecosystem Surveys Program | High | IOOS Program | High | MDCRS/AMDAR Group | Moderate |
| SNPP Platform | High | NWLON Program | High | Marine Sounding Program | High | NEXRAD Program | Moderate | GPS Met Program | Moderate |

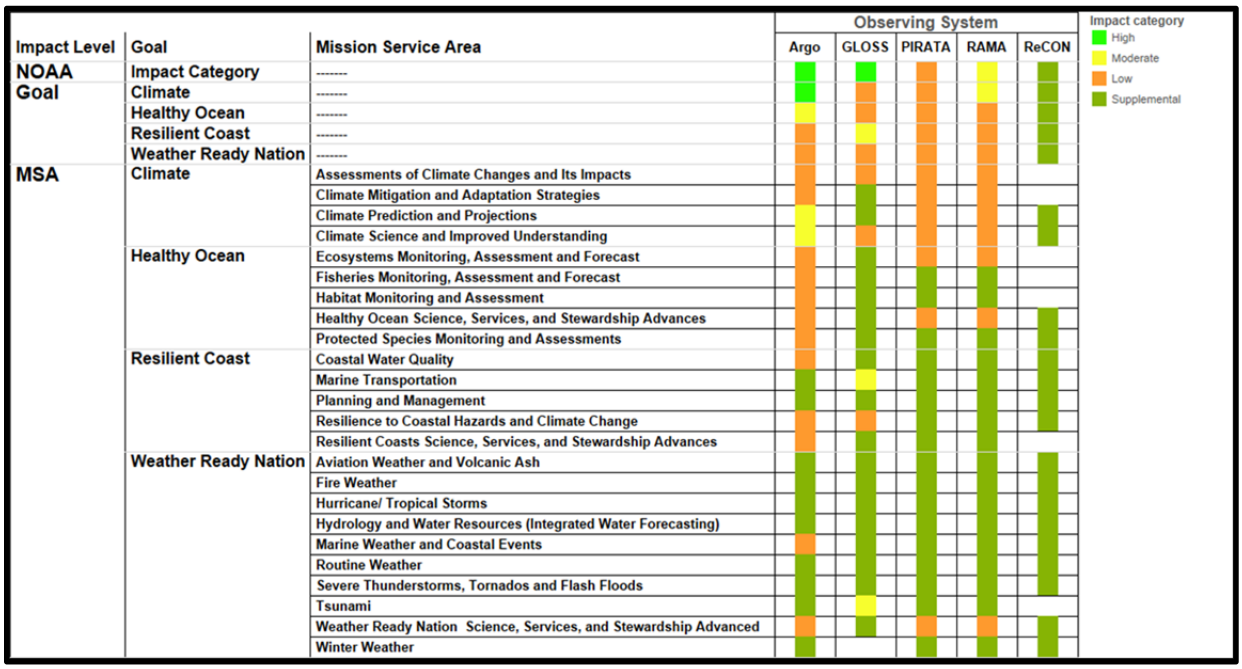
Rank Impact

Very High | High | Moderate | Low | Supplemental | No Impact

(NOTE: Figure 7.6. is an example and does not depict current NOSIA-II data.)

A heat map table (Figure 7.7) allows users to see the impact of observing systems on functional groups and programs at various levels of the Value Tree. The sample data in the depiction allows users to identify an observing system's distribution of impact quickly and to compare and contrast different observing system impacts simultaneously. The table depicts observing system impacts across NOAA, then by Goal, and then by MSA.

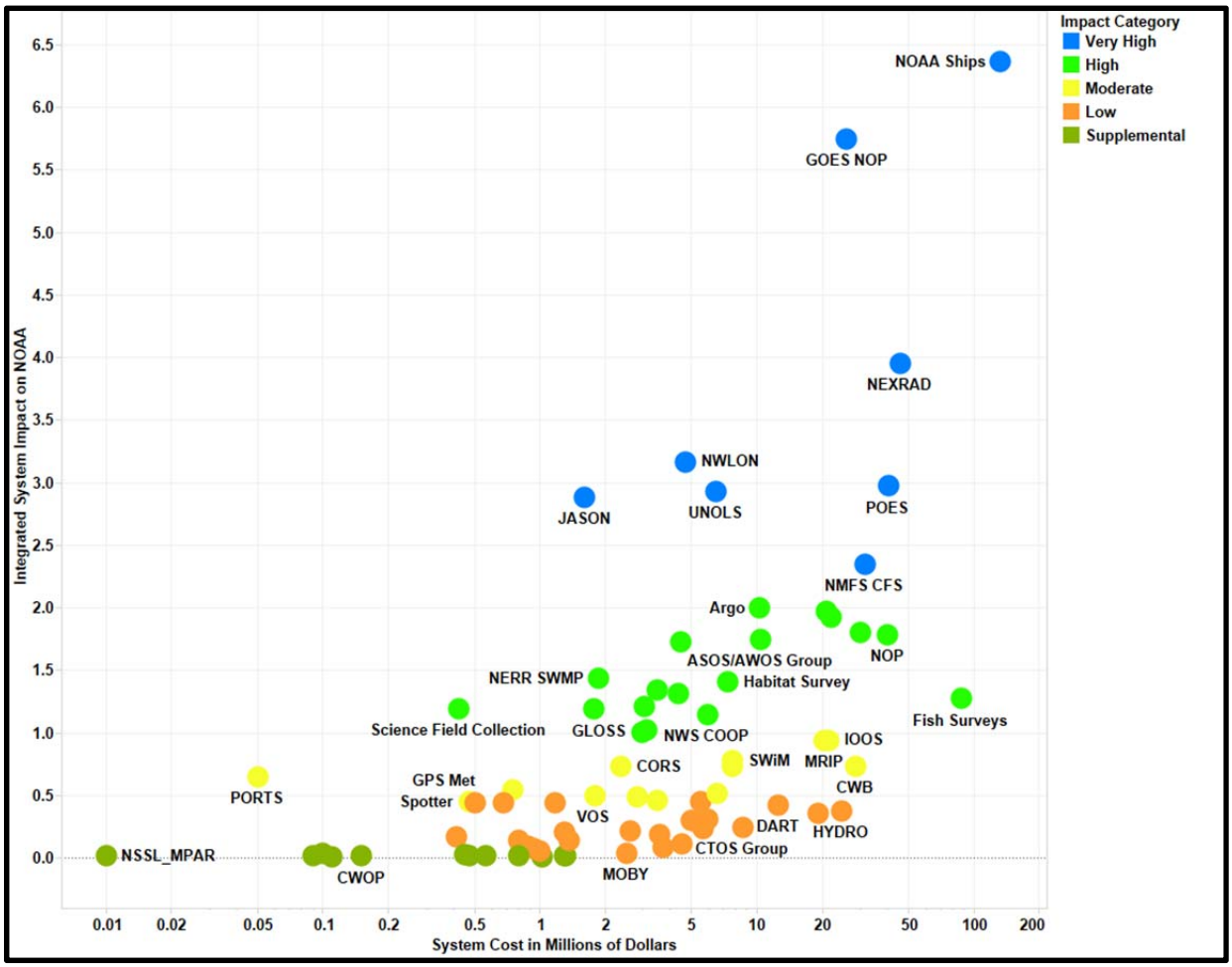
**Figure 7.7. Sample NOSIA-II Output: Heat Map Visualization Showing Observing System Impacts Across NOAA, then by Goal, and by MSA**




(NOTE: Figure 7.7. is an example and does not depict current NOSIA-II data.)

A scatterplot (Figure 7.8) provides an easy way to visualize relationships between numerical variables. The sample data in the depiction allows users to view the observing system operational costs (x-axis) versus the observing system impacts (y-axis), and then apply filters to focus on specific functional and program groupings. The two above examples showed the impact of observing systems; the scatterplot adds the operational cost data as another layer.

**Figure 7.8. Sample NOSIA-II Output: Scatterplot Visualization Showing Observing System Impacts and Costs Across NOAA**




(NOTE: Figure 7.8. is an example and does not depict current NOSIA-II data.)

# 8. Scenario Ready – Application of Model and Sample Products

"Scenario Ready" is a reference to NOSIA-II model's maturity as a capability to provide meaningful and reliable input for leadership towards management of NOAA's observing system portfolio (refer to Figure 4.1., Overview of NOSIA-II Analysis Process, Step 3 - Populate Model and Step 4 - Declare Scenario Ready). Achieving the "Scenario Ready" milestone required review of NOSIA-II IOC output gained through several iterations of model review, and feedback with periodic updates from NOAA Leadership.

## 8.1. Validation of IOC Model Output

In conjunction with Line Office leadership, TPIO validated model output by performing assessments that identified observing systems having impact anomalies within MSAs, Goals, and NOAA-wide. This validation process required a strategic understanding of the use of observing systems for key products, a product's priority, and the grouping and tiering of products within each service category. The scope of the observing system's capabilities was also reviewed. This validation was inherently qualitative, with anomalies identified by Line Offices and TPIO by inspection, often starting with a judgment that a particular observing system's rank order appeared inappropriate within the objective of the MSA Key Product Groups (e.g. mission outcomes). Analysis of potential observing system rank order anomalies required a review of product surveyed with SME comments referencing the observing system as a data source to determine appropriate attribution. TPIO and the Goals also assessed if an observing system was given too much or too little ability to influence the MSA impacts as a function of grouping and tiering. Additionally, the assignment of products to an appropriate MSA was also reviewed.

Examples of anomalies included double credit from data sources, contributions from historical databases which are not being updated, credit for products that are not data sources, observing systems having anomalously large impacts as a consequence of a small number of data sources per survey product, observing systems having a small number of KPS per KPS Group, and observing systems having a relatively high priority for the KPS Groups within an MSA.

TPIO analyzed issues, recommended mitigation actions, provided options to Goal or Line Office leadership, and provided a summary of observing system ranking changes for their approval. Once Goal leadership concurred that the Value Tree model was yielding reasonable observing system impacts with the implementation of above changes, then the model was deemed ready for application use and sample product analysis.

With the completion of leadership review of model output and implementation of changes which resulted in more predictable and intuitive model output, NOSIA-II entered a "Scenario Ready" phase of development.

## 8.2. Responding to NOAA Portfolio Management Needs

The NOSIA-II team is building on the "scenario ready" stable model with validated output to enhance capabilities which support decision making. Developing NOSIA-II decision support capability begins by understanding the target user's budget, performance, and trade questions and organizing TPIO's information resources to respond to these business questions. A decision support capability which delivers actionable intelligence in a timely manner is a critical phase of development. Ultimately it is this capability which justifies NOAA's continued investment in the NOSIA-II.

NOSIA-II's initial planning considerations for survey process and granularity of observing system impacts were structured to capture sufficient detail to address specific business questions, including input to NOAA's response to the Science Advisory Board (SAB) Satellite Task Force (see Section 9.1.2).

As development of NOSIA-II progresses, TPIO has identified several user types, or personas, seeking insight into specific business questions. Examples of these personas include:

1. NOAA Senior Leadership - Strategic Planning:
    a. Who: Corporate leadership and staff involved in assessment of strategic planning input from Observing System Portfolio Managers. Corporate staff includes the Chief Financial Officer (CFO), Chief Information Officer (CIO), Director of Program Planning and Integration (PPI), NOAA Executive Council (NEC), NOAA Executive Panel (NEP), Chief Scientist, and NOAA Councils specifically in this case the NOAA Observing Systems Council (NOSC).
    b. Why: Support budget scenarios involving NOAA's observing system architecture versus other budget options across NOAA and the Federal enterprise
2. NOAA Line Office and Staff Office Leadership - Portfolio Budget Formulation and Planning:
    a. Who: NOAA Line Office, and top level office NESDIS, NOS, NWS, NMFS, OAR, and OMAO) Assistant Administrators (AAs), CFOs, and Observing System Portfolio Managers
    b. Why: Support portfolio budget planning and execution
3. Observing System Program Managers - Program Plan Support:
    a. Who: Line Office and Staff Office Program Managers
    b. Why: Support development and execution of program plans for current and future observing systems
4. NOAA Research - Research Portfolio Management:
    a. Who: NOAA Research Council, Lab Managers, grant solicitation writers, and science planners
    b. Why: Support development of research portfolio management, strategic plans, Cooperative Institute grant solicitations, and recommendations for development of observing systems which fill gaps in NOAA services and scientific understanding
5. External NOAA - Provide Transparency into NOAA and Federal Business Practices:
    a. Who: Public, Government Accounting Office (GAO), Office of Management and

Budget (OMB), Federal Agencies, World Meteorological Organization (WMO), and potentially many other organizations
    b. Why: Provide insight into and documentation of NOAA's observing system architecture as it relates to NOAA's value tree
6. Product Generation - Resource Management
    a. Who: Product producers/developers/evaluators (e.g. National Centers for Environmental Prediction (NCEP), Office of Systems Architecture and Advanced Planning (OSAAP), NESDIS Office of Satellite Products (OSPO), algorithm developers, etc.)
    b. Why: Provide insight into product dependencies, usage, and impacts to essential services
7. SME Knowledge Base
    a. Who: Concept developers (e.g., NASA)
    b. Why: Provide SMEs who can inform development of a new observing systems
8. Validation of Observing System Knowledge Portfolios:
    a. Who: NOAA Observing System Council (NOSC)
    b. Why: Provide consistency check and accounting control between requirements, impacts, and observing system capability database

Additional applications for the NOSIA-II approach within the Federal Agencies are likely to include use by OSTP and United States Group on Earth Observations (USGEO).

Most persona business questions cannot be addressed by NOSIA-II model output alone. TPIO is integrating its information portfolios to respond to a greater scope of NOAA's personas. Core TPIO information portfolios include requirements (CORL), system capabilities (NOSA), and product sensitivity to data sources (NOSIA-II).

In the future, TPIO plans to leverage observing system trade studies and model sensitivity studies into NOSIA-II, as available to support NOAA's observing system portfolio management.

# 9. Next Steps

The NOSIA-II analysis is the critical link in assessing the relative impact of different observing capabilities on NOAA's mission areas, products, and services. As the development of NOSIA-II matures, next steps include analysis support to the NOAA Research Council and the Office of Program Planning and Integration, and data mining support to the U.S. Geological Survey (USGS) Land Remote Sensing Program, including data management transition to the Earth Observing Requirements Evaluation System (EORES). NOSIA-II will also be the basis for NOAA's contribution to EOA 2016.

## 9.1. Initial Applications of Model

NOSIA-II capability is supporting NOAA Leadership in a variety of ways. NOAA Administrator, Dr. Kathryn Sullivan, stated "NOSIA-II will be an important capability for leadership to ask more insightful questions regarding NOAA's business practice." For example, the capability is being applied to identify NOAA's high priority parameters which are provided from environmental satellites. NOAA's budget formulation process is being informed by the NOSIA-II capability to identify observing system architecture efficiencies. The following are examples of the NOSIA-II capability's initial applications.

### 9.1.1. Assessing Space-Based Observation Parameter Impacts

**Response to Satellite Task Force Recommendation**

NOAA received a recommendation from the Satellite Task Force (SATTF), an ad hoc working group of the NOAA Science Advisory Board (SAB) in late 2012 that stated NOAA should:

- Establish a prioritized list of threshold space-based observational requirements that maintains high impact capabilities;
- Define NOAA core functions and align them with national space policy and agency guidance;
- Coordinate with all stakeholders (including national and international), with respect to prioritization of requirements and architectural tradeoffs; and
- Update the prioritization process database regularly with current information from SMEs.

In its response to the SAB regarding this recommendation, NOAA indicated that the agency concurred with the recommendation and stressed that understanding and prioritizing NOAA's observing requirements was critical to many of the activities being conducted in response to the other recommendations in the SATTF report. The NOAA response further stated that in order to establish a prioritized list of observational requirements and better understand the impact and value of NOAA's observing portfolio, including space-based systems, the NOSC tasked its Observing System Committee, supported by TPIO, to complete the development of a NOAA-wide "Value Tree."

Once completed, this Value Tree will provide a foundation for assessing the value and impact of each component of NOAA's observing system portfolio as well as the relative priority of NOAA's observing requirements in order to assess trade-offs.

Now that NOSIA-II assessment has been completed, TPIO will begin to mine this dataset to support the development of a prioritized list of threshold space-based observational requirements to complete the action of responding to the SATTF recommendation.

### 9.1.2. Data Mining

The value and complexity of the data collected as part of the NOSIA-II assessment and previous value-tree assessments (e.g. NOSIA-I and the first Earth Observation Assessment) has highlighted the need to store and manage this data in a more comprehensive and user-friendly manner.

In order to address this requirement, TPIO has undertaken a collaborative development effort with the USGS Land Remote Sensing Program to develop a web-based application and relational database infrastructure to support management of data collected as part of a "value-tree" assessment. This system known as the Earth Observing Requirements Evaluation System (EORES) is being developed to assist in managing the NOSIA-II data as well as data being collected by the USGS and data planned to be collected by the White House Office of Science and Technology Policy (OSTP) as part of the second Earth Observation Assessment (EOA 2016).

Anticipated benefits of EORES include the ability to:

- Quickly query the NOSIA-II dataset and find information of interest;
- Associate Value Tree information to observing system capability information currently stored in the NOAA Observing System Architecture database;
- Associate Value Tree information to observational requirements information currently stored in the CORL database;
- Associate additional metadata, contextual information, and notes and comments made by SMEs during site elicitations to the scores in the NOSIA-II dataset; and
- Inform other high priority national assessments such as the upcoming Decadal Survey in 2017.

## 9.2. Multi-Period

NOSIA-II IOC delivered a functional model of the impact of currently available observing systems data upon current services. NOSIA-II IOC captured about $0.9 billion of approximately NOAA's $2.7 billion in observing portfolio investments. with the difference ($1.8 billion) being the cost of systems in development, which include GOES-R and JPSS satellite programs. The NOSIA-II Full Operational Capability (FOC) will be achieved when the model includes on-going observing system development, the timeframe for introduction of these systems into operations, the development and resulting operations and maintenance costs, and estimated impact to the Value Tree as a consequence of new or replacement observing systems.

The objective of NOSIA-II FOC from a strategic planning perspective is to create a Multi-Period Model (MPM) which estimates how NOAA's Value Tree will be impacted as a consequence of observing system changes over the next 20 years, including changes to data sources, the cost of the data source, and magnitude of impact to NOAA products and services by data source changes. Once the NOSIA-II MPM is established, alternative observing system portfolios can be created to test their cost effectiveness against the baseline. Additional applications of NOSIA-II MPM include the potential to model the "die-off" performance curve resulting from gaps in satellite coverage and decreased system availability.

Building a NOSIA-II MPM requires identification of new observing systems and their associated products. Only high-confidence data will be used to change the baseline Value Tree within the NOSIA-II MPM. NOAA will assess the maturity of new observing system developments or product impacts for inclusion into the NOSIA-II MPM using the following replacement or new system guidelines:

- Technical Readiness Level of 7 (e.g., system prototyping in operational environment);
- Reliable budget data, including development and O&M costs;
- Validated Key Performance Parameters (KPP) based on fulfillment of requirements from NOAA's CORL;
- System's data has reliable sources of observing system impacts on products; and
- System's data has a moderate or greater change to requirements coverage, per TPIO impact assessment.

Where high-confidence data are not available, existing observing systems and products identified in the initial NOSIA-II survey in 2013 are assumed to persist at surveyed cost and impact levels into the future unless there is a defined end-of-life expected during the analysis period.

As available, NOAA will leverage environmental model sensitivity experiments and simulations to characterize impacts to NOAA's Value Tree from new observing systems. Otherwise, SME input will be used to assess estimated impacts to future Value Trees resulting from new observing systems.

The NOSIA-II MPM is planned to extend the baseline (current) period through a 20 years (2033), with two year time-steps. The first version of NOSIA-II MPM is expected to be completed by the end of 2015. NOSIA-II MPM time-steps and temporal domain can be adjusted as needed to resolve planned changes to data sources and budget.

## 9.3. Model Refresh

NOSIA-II is the culmination of 4 years of effort, starting with the NOSIA-I Pilot Project (2011), demonstrating the full-scale model at the Federal level methodology (2012-2013) through EOA 2012, and eventually the development of a detailed multi-period model characterizing the relationship of observing system impacts, current and those in development, to the full scope of NOAA services with NOSIA-II.

A key objective of NOSIA-II was the achievement of "scenario ready," which enabled rapid response to observing system portfolio business questions from NOAA Leadership. As such, the NOSIA-II Value Tree must reflect the relationship between the current observing system portfolio and its influence upon NOAA services. To keep the model up-to-date and be able to respond to on-demand strategic observation system architecture assessments, NOAA must monitor substantial changes to the observing system portfolio and the impact upon those products which are sensitive to the observing system portfolio changes (refer to Figure 4.1., Overview of NOSIA-II Analysis Process, Step 5 - Sustain Model).

The NOSIA-II model refresh process is in the early stage of formulation. A crucial element of model refresh is managing the maintenance overhead involved in keeping the model relevant.

Identifying NOSIA-II model elements requires refresh actions to:

- Identify product changes (new or terminated)
- Assess product survey gaps within MSAs, using Line Office inputs and deltas between documented requirements and capabilities
- Review and update product prioritizations
- Target significant changes to observing system (cost and performance)
- Assess the model for efficacy; e.g., not modeled if impacts are insignificant
- Assess the model for maturity; e.g., SMEs must have substantial familiarity/exposure to the use of data in operational context to avoid speculative changes
- Leverage on-going observing system and product performance monitoring:
  - NOSC Observing Systems Committee (OSC): SoR updates and system availability data
  - NOAA Product GPRA changes
- Work with Line Offices to identify new or terminated services; and
- Review and incorporate recent sensitivity studies (from NOAA's Quantitative Observing System Assessment Program or as available in scientific literature) to update data source impact to survey products where appropriate

Model refresh will be conducted on a four-year cycle (one Line Office per year):

- Year 0: Updates to baseline data sources and products
- Year 1: Updates to observing systems and products in development targeted for operations (SoR Critical and Innovative)
- Year 2: Expanded applications development and focus on emergent technology trades

Creating a process to maintain the model will be a balance between adding ever greater detail, with the risk of making the model too complex to test and maintain, and selectively updating the model in areas that will keep the model representative of NOAA's evolving business practices and the advance of observing system capabilities and emergent applications. Lack of effective model maintenance has the risk of the model generating unrepresentative data.

Ultimately, the long-term success of NOSIA-II will be judged by NOAA's ability to sustain the capability, while informing NOAA's science-based environmental information decisions.

## 9.4. Data Releasability

A subset of the metadata and observing system impacts derived from the NOSIA-II analysis will be released in accordance with the OSC communication and publications plan to include surveyed products, observing system data sources, site names, SMEs, product and observing capability groups. Instructions to access these data will be posted on the TPIO web site, https://www.nosc.noaa.gov/tpio/

## 9.5. Future Updates of this Report

In conclusion, as NOAA's mission and data sources evolve, the NOSIA-II analytical capability will be updated and associated documentation published.

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Figure APP.C.1. NOSIA-II and EOA Observing System Impact Application Domains

Figure APP.C.2. EORES Contents and Outputs

# Appendix B - Mission Service Areas (MSA) Definition

A MSA is a NOAA core function that is focused on a specific environmental process, socioeconomic sector or activity to achieve societal outcomes aligned with NOAA's mission.

MSAs have the following attributes:

1. Suite of products and services
    a. Established performance measures and goals
    b. Documented inputs, data sources, and budgets
    c. Documented economic impacts and societal stakeholders
2. Research area focused on operational impacts

MSAs are derived from the following sources:

1. NOAA Next-Generation Strategic Plan
2. Strategy Execution and Evaluation (SEE) Goal/Objective Implementation Plans and Logic Models
3. Corporate GPRA Goals and Annual Operating Plans (AOP)
4. Line Office Procedural and Policy Directives and Instructions
5. As coordinated with gaining MSA OPRs in conjunction with workshops or SMEs (e.g. NOSIA-II and EOA)

TPIO used MSAs to document:

1. The information requirements and priorities (e.g., Consolidated Observation Requirements List (CORL)) needed to satisfy the suite of products and services
2. Priority of individual MSAs within an objective
3. Cost of delivering services as a function of observing system requirements (e.g., NOSA/OSS)
4. Impact upon MSA products and services as a function of information availability and quality (e.g. NOSIA-II, EOA)
5. Alignment of MSA within budget (execution and planning) and administrative hierarchies

Legacy TPIO documents, such as Program Operational Requirement Documents (PORD) and NOAA Observing System Integrated Analysis (NOSIA) impact assessments have been cross-walked into the MSA framework. TPIO completed the NOAA observation requirements and impact assessments using the new MSA hierarchy, filling-in and updating gaps requirements.

## Appendix C - Primary Caveats, Model Limitations and Uncertainty for Understanding and Interpreting the NOSIA-II Results

1. **Scope of Interviews Limited to NOAA:** The most important caveat is recognizing that the scope of NOSIA-II interviews was bounded within NOAA. While the practicality of this constraint is understood for this version of the model, it is paramount to acknowledge that many of NOAA's observing systems and data sets have significant customer bases in the external community. For example, many of these data sets are foundations of laws, international treaties, and policy statements (e.g. IPCC).

2. **New To NOAA - Mission Service Areas (MSAs) Framework:** The use of MSAs was a new framework used for NOSIA-II that had not been formally adopted by the NOAA NEP or NEC. Therefore the MSAs may not be completely understood and consistently used with respect to governance in the context of NGSP Goals and Line Offices. Steps to institutionalize and formally adopt the NOSIA-II analysis (including MSAs) at the NEP/NEC level are underway.

3. **New To NOAA - NOSIA-II Value Tree:** The Value Tree's cascading elements from goals, objectives, MSAs, key products, data sources, and observing systems was also new for NOAA. It should be noted that these inputs can be considerably refined over time. For example, improved guidance to Line Offices and more consistency in what constitutes an observing system, network, program, data set, and instruments.

4. **Model Stability And Sensitivities Have Not Been Documented:** Analysis indicated that small sample sizes, as well as uneven number of products artificially skew scores in some MSAs. Some sensitivities were observed for the results by moving key products between MSAs. This is a significant point since products had varying degrees of granularity, and were restricted to a "one to one" mapping which could not support multiple MSAs. Including the capability for multiple mappings is a suggestion for future improvements.

5. **Subject Matter Inputs Have Not Been Calibrated Against Quantitative Analysis:** The inputs to the NOSIA-II model were largely based on the judgment of SMEs. NOSIA-II, like any model, should be calibrated and validated (e.g., against results from quantitative observing system experiments).

6. **Scores Of Operational Observing Systems May Be Systematically Higher Than Emerging Systems And Technologies:** The NOSIA-II methodology favors systems that have impacts on larger populations of products. This will naturally lead to higher scores and ranks for existing operational systems relative to emerging technologies that may have significant advancements.

7. **Cost Analyses For Operations Verses Full Costs For The System:** Comparisons between low daily operations costs for different systems, observing systems with large up-front development costs (i.e., R&D, launch, and orbit stabilization) are skewed when

compared with observing systems with relatively low up-front costs but large daily operating costs in the final frontier analysis and other decision-making products.

8. **Model Uncertainty:** Several of the identified sources of uncertainty in the NOSIA-II model include whether or not all the significant KPS have been identified and included in the model, whether all the significant inputs (data sources) have been identified for each survey product, whether or not data sources have been grouped appropriately, whether the SMEs provided consistent assessments of the status quo performance scores for their survey products, and whether they provided accurate reduced product scores , percentage scores, and overall satisfaction scores for the data sources.

   a. In addition to configuration management to control data and model programming quality, TPIO works to control these sources of uncertainty. These controls include careful selection of KPS groups, extensive consultation with Goal and Line Office leadership, interviewing a large and diverse set of product-level SMEs, a rigorous and structured interview process, and a thorough review of results by TPIO staff and Goal and Line Office staff.

   b. For a given data source contributing to a given product, the "product delta" is the difference between the product's status quo score and the reduced product score corresponding to the data source. The "total product delta" of a product is the sum of the product deltas of its data sources, expressed as a percent of the product status quo score. In a minority of cases, SMEs identified a large number of data sources or tended to reduce product scores by a large amount for several data sources. The result of these factors was a swing table where the total product delta was a large number (in a few cases as much as 2000 percent). In general, the typical total product delta was more than 100 percent, which is indicative of a significant degree of dependency between data sources for typical survey products (i.e. non-linear relationships). Inspection of these product specific cases showed that very high total product deltas clearly causes implausible results in the model at the product level (although the impact at the top of the tree was much less significant, to not detectable).

   c. To address excessive total product deltas, PALMA has the capability to compress the inputs in these cases so that the total product deltas do not exceed a user-selectable limit (generally 150 percent). This approach moderates the behavior of the roll-up-rules and makes the signal for individual data sources logically consistent.

   d. SMEs also introduce other types of uncertainty. Variations in SME nomenclature resulted in TPIO expending great effort to standardize the names of products and data sources and establish the correct connectivity throughout the model. Also, SMEs varied the granularity of their dependent data sources. For example, some SMEs would evaluate the impact of an entire multi-faceted observing program, while other SMEs would evaluate the impact of only one capability within that program. Finally, cost information appears to be reliable for many of the SoR, but cost attribution for external data sources (e.g. the cost to acquire, assimilate, and manage external data), was based on a set of assumptions described in Section 5.4.

9. **NOSIA-II Value Tree Scope:** The scope of NOSIA-II related observing system impact assessments is limited to the application areas surveyed as shown in Figure APP. C.1. The estimated observing system impacts application areas and users ranges from good (green) to limited (yellow) or none (pink):

   a. **NOAA:** Completed NOSIA-I and NOSIA-II; assessed observing system and product impact and satisfaction within NOAA. Cost estimated for observing systems.

   b. **Federal**: Completed EOA 2012 and EOA 2016 (in progress); assessed observing system and product impact and satisfaction within Federal enterprise associated with broad Societal Benefit Areas, but not at the granularity of NOSIA-II.

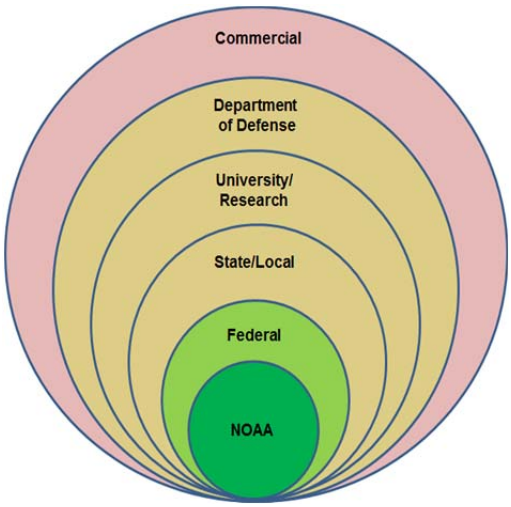
   c. **Department of Defense**: Limited impact assessment for U.S. DoD applications; directly through US Army Corps of Engineers (USACE), and indirectly through environmental modeling (e.g., Air Force Weather Agency (AFWA) and Fleet Numerical Meteorological and Oceanographic Center/Naval Oceanographic Office (FNMOC/NAVO).

   d. **State/Local**: Limited impact assessment data for NOAA/Federal services on state/local services; captured indirectly via NOAA entities that closely partner with emergency management personnel and ecosystem/coastal resources managers.

   e. **University/Research**: Limited impact assessment data for NOAA/Federal services on research; NOAA OAR and a limited number of NOAA Cooperative Institute scientists participated in NOSIA-II.

   f. **Commercial**: Proprietary nature of commercial enterprise makes gathering data on impact of Federal services on commercial sector difficult.

**Figure APP.C.1. NOSIA-II and EOA Observing System Impact Application Domains**



The ability of NOSIA-II to estimate observing system impact is limited to the application areas surveyed. If the primary application of the observing system is not surveyed, then the impact will not be reflected in the model output. An example where observing system impact was not fully captured was the Environmental Systems Research Laboratory (ESRL) Global Monitoring Division's (GMD) Observatory Operations (OBOP), which are used primarily by the Intergovernmental Panel on Climate Change (IPCC) for climate monitoring and model validation, but more indirectly by NOAA.

10. **Representative Sampling:** NOSIA-II comprises a sample of products and services representative of each Line Office's key products and services and their dependence and linkage to observing systems. TPIO extensively consulted SMEs to identify and survey an array of products that represented the observing-dependent responsibilities and activities of each site. In the end, what started as a relatively compact sample of "key products" identified by Goal and Line Office leadership was substantially expanded in the data collection process to represent the output of the sites more fully. Representative sampling also characterizes option costs. Many options are aggregated from individual observing systems. Some examples include dozens of regional mesonets such as the U.S. Integrated Ocean Observing System - Regional Component observing platforms, or seismic networks that are aggregated into a single cost for one option.

11. **Factors Excluded from the Survey:** NOSIA-II implicitly excludes several factors relevant to observing capability portfolio decision making in order to focus on characterizing observing system impact. For this reason, NOSIA-II should be used as an input to observing portfolio decisions, but is not sufficient by itself. The following functions were not evaluated through this process but may affect portfolio management. They include production costs for the sampled survey products which include funding shortfalls, work force, facilities, and other logistical considerations. Examples include expertise, laboratory or ancillary equipment used to process biological samples.

    a. Explicit representation of data communications and processing elements are another factor excluded from the survey process. Data are assumed to be communicated and processed as needed. To some extent, SME comments indicating deficiencies in data communications and processing were captured in the scribe notes associated with the overall satisfaction scores for data sources. For example, SMEs sometimes said that data latency or assimilation was the reason for lowering the score of a data source.

    b. Another factor NOSIA-II excludes is the potential impacts that could be obtained from observing systems if gaps in fundamental understanding of underpinning phenomena were resolved. For example, fully meeting tornado warning lead-time objectives and full utilization of available observing systems, likely depend on fundamental understanding of the storm development.

    c. Additionally the single-period implementation of NOSIA-II does not explicitly model time-dependent changes in availability or performance of data sources (improvements or degradation).

    d. Other important factors excluded from NOSIA-II are impacts of NOAA's survey

products to the public or external stakeholders and partners. For example, NOSIA-II does not explicitly represent the IPCC, an important user of NOAA climate products and data. Similarly, some survey products have low incidence in the value model and are not inputs into other NOAA products, but provide critical information for external users. In general, NOSIA-II does not yet explicitly represent societal benefits (economic and otherwise).

e. Finally, one outcome that evolved consisted of identification of survey products that have minor relevance to MSA performance scores and were not considered as KPS with respect to the Value Tree. The roughly 60 "orphaned" products (about 5% of the survey products) which fit this definition do not have any impact on the NOSIA-II model.

12. **Subjectivity of Inputs (biases or uncertainty):** There are areas of subjectivity in the NOSIA-II process. These range from the variables in dealing with SME opinions to understanding the system engineering risks inherent with any data collection and analysis process. Subjectivity is addressed in the following paragraphs.

a. **SME Subjectivity**: This analysis, although executed objectively and mathematically, depend on the qualitative judgments and opinions of the SMEs. Although subjectivity can introduce uncertainty and bias, the NOSIA-II survey methodology gains credibility and validity due to the large number and wide-ranging points of the view of the SMEs, and the fact that most of the SMEs are not direct proponents of specific observing systems; they are instead unbiased users of the data from these systems. Even in cases where quantitative data denial experiments are available (such as for data sources used in numerical weather prediction models), SME judgments are valuable in integrating and extending these experimental results to a more generic and broad-scale representation that NOSIA-II can assimilate in its three principal scores: product status quo score, data source reduced product scores, and data source overall satisfaction score. SMEs estimate these three scores by relying on their experience and expertise to evaluate the performance of the products and data sources and the relevance of the data sources to the products - there is no direct quantitative measurement of these critical parameters. SME interviews are not generally one-on-one. To help minimize biases in the data, TPIO required SME interviews to provide consensus from more than one SME, and many of the data collection efforts include several SMEs in one interview where their objectivity and broad knowledge of the value of observing sources are corroborated. Wherever possible, TPIO also assessed the range of SME inputs given for similar products among different sites but taking into account the regional relevance of the various dependent observing systems.

b. **Ontology Subjectivity of Products and Services**: The ontology of terms SMEs use to represent products, services, and data sources is sometimes fuzzy. SME's often use different names for the same product or the same observing system. TPIO implemented a Data Integrity management process to interpret SME names consistently for products and services and for options. TPIO staff worked hard to standardize data source names before the interviews, but in many cases, names had to be standardized, grouped or split after the fact in the course of iterative data integrity sessions. In the

end, TPIO's Data Integrity Team carefully mapped these names to a standardized list of terms established by the OSC and to those terms traditionally used in TPIO's observing capability and observation requirements databases. These mappings are preserved in the DCW and MBW for traceability.

c. **Proxy Subjectivity:** During the course of our interviews, SMEs identified many non-NOAA products that they considered vital data sources to their products and services. NOSIA-II includes an assessment of the relevant set of observing systems for these non-NOAA products. Without the benefit of a survey for those products, the rich list of NOAA products surveyed permits temporarily using a "proxy" concept in which the non-NOAA data source is considered to be similar to a surveyed NOAA product. For example, TPIO used the GFS survey as a proxy for ECMWF because data sources were deemed similar. There are currently 166 of these proxies for products originating from other Federal agencies, international agencies, state and local governments, academia, and commercial sources. Roughly 10 percent of all products are currently proxies.

d. **Cost Subjectivity:** TPIO's interpretation of cost data is provided at a precision of $10K but accuracy varies for each observing system or database. In order to fully enable a portfolio assessment, NOSIA-II needs cost information for every option. SMEs often identified options at a granularity much finer than at the observing system of record program level. Such cost information for the disaggregation of options in the model is frequently unavailable even though cost accuracy of the funding at program level is very high. There are also many non-program options that require best-guess estimates such as non-NOAA databases and products that SMEs cited in the surveys.

e. **Risk Subjectivity:** The analysis includes an incomplete understanding and representation of program risks because it assumes systems perform as planned. No risk assessment is conducted on uncertainty of system performance. A comprehensive risk assessment (e.g., apply a risk discount, degrading value by some amount, and conducting sensitivities to impact on Efficient Frontier, etc.) may provide a more meaningful impact assessment in future multi-period versions of the model.

f. **Overly "Enthusiastic" Reduced Product Scores**: Some SMEs appeared to lose sight of the ground rules that specified that for each reduced product score all other sources remain available. Instead they indicated that many single-removals would take the product performance down to low or negligible levels. This tendency appeared to be exacerbated by having large number (e.g. more than 19) data sources as inputs to products. The modeler and interviewers strove to control this by grouping data sources to limit the first-pass set of inputs to be considered to 10 or less. Overly enthusiastic reduced product scores can be addressed after-the-fact by compressing the product deltas to conform to a selected maximum total product deltas (e.g. 150 percent) and by permitting no more than 19 of the highest impacting data sources to be included in the analysis.

g. **Option Impact Subjectivity:** Over-emphasis of data source impact by reliance on only a few data sources that rely on only a few options. For example, if a MSA relies on a few KPS, and those KPS rely on just a few options, then those options will tend to

have an impact out of proportion relative to the larger set of options that impact an MSA. Some of these instances have been identified and TPIO has iterated with Line Offices to rearrange the MSA and KPS structure to better reflect their business model.

13. **NOSIA-II Value Tree Hierarchy Sensitivity:** The NOSIA-II model output is sensitive to how the Value Tree is structured and to the weights assigned by SMEs to the parent-child relationships in the tree. An example of structural sensitivity can be seen near the top of the Value Tree where Weather Ready Nation (WRN) Goal has eleven MSAs and the other three Goals have four or five MSAs. Since each Goal has the same weight, the Weather Ready Nation MSAs each have a lower effective weight than the MSAs in the other Goals.

    a. The other factor that affects outputs are the importance weights assigned to the KPS and KPS Groups. Some MSA managers chose use of the full range of importance weights (1-5), while other MSA managers tended to rate all KPS and KPS Groups equally, often biasing the top of the range. When all KPS of a MSA are nearly equally weighted, the result approximates a simple average weight.
    b. In a few cases, model structure and assigned weights combine to excessively elevate certain data sources. For example, if an MSA depended on just a few highly weighted KPS, and these products depended on a few data sources, those data sources had implausibly high impact scores. In consultation with the Goal and Line Office leadership, the most common strategy was to reassign these outliers to larger MSAs where their impact was diluted. The lesson learned from these examples is to pay close attention to cases where there are few products for a given MSA or KPS, and seek a higher degree of symmetry.

14. **Limitations of PALMA:** PALMA provides a very flexible, efficient and powerful framework for modeling elements and relationships of a value model that is capable of high degrees of complexity and subtlety, but it does currently have a number of limitations that should be considered for future development:

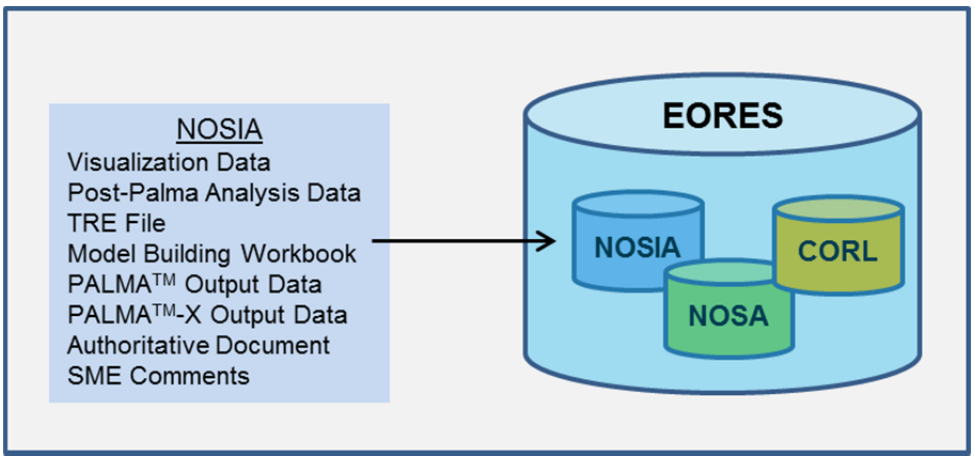
    a. **PALMA Does Not Accept Feedback Loops**: That is, it accepts first-order impact sequences such as A → B → C, but it rejects second order loops such as: A → B → C → A. In the process of compiling the NOSIA-II model, a number of valid feedback loops became evident. To address these feedback loops and compile the model, the modeling team disconnects the loops at the points of least-impact to the value model. There are ways to address second order loops using more complex math and programming approaches, but the team judged that the improvement in precision did not warrant the increased model complexity for NOSIA-II initial implementation.

    b. **Limited Ability to Tag Model Elements**: There is limited ability to tag model elements with metadata within an Excel-based MBW or to display in PALMA, which does not process all metadata of interest for its value calculations. Currently, metadata for model elements (e.g. products and data-sources) is managed externally to PALMA. Managing model metadata in EORES is expected to address these limitations.

    c. **Limitations in Displaying Relationships:** PALMA's ability to display relationships

has limitations; it works well for tracing linkages downwards, but has limited ability to display upwards or cross-linked relationships in the model. For example, there is no easy way to show all the products impacted by a data-source; this limitation is being addressed via add-on functionality based on PALMA/X queries, in the visualization tools and in the EORES-based queries. See Figure APP.C.2, below.

**Figure APP.C.2. EORES Contents and Outputs**




d. **No Current Capability to Combine Types of Multi-Period Analysis:** PALMA can currently be used to effectively model multi-period internal changes (e.g. new products, data-source impacts, or data source satisfaction) and changes to option performance over time. It can model changing availability and cost of options in future periods, but the ability to combine both types of multi-period analysis is still under development.

15. **Model Complexity, Consistency and Test Constraints:** The NOSIA-II model is highly complex. The number of connecting nodes in the model exceeds 20,000 with more than 120,000 active connections among the nodes with a unique impact function for each connection. Among these nodes, there were about 1,100 survey products from 72 survey sites and these products decomposed into about 600 options. An individual option can influence as many as 378 survey products. Product and option performance scores varied nearly over the entire range of possible scores less than 90. The number of data sources cited for each product varied from 1 to 80. SME names for the various product and option data sources often exceeded a dozen unique names for the same product or option. The NOSIA-II model requires three unique scores for each and every product-data source connection pair -- all subjectively assigned by the SME. Line Offices selected three quarters of the survey products as key to their MSAs. The Line Offices also reviewed each product to select those that are key and then grouped and prioritized them into three tiers to reflect their business models.

a. Managing such complexity derived from the SME's, the Line Offices, and from TPIO's project management, modeling, and Data Integrity Teams using the available staff,

time, computing and software development environment was challenging. Formality in crafting and scheduling elicitations, in following a detailed work breakdown structure, in model configuration management, in assembling teams with the right mix of expertise, and in maintaining open and frequent communication with the Line Offices was essential to building a credible, decision-quality model.

b. The sampling results were greatly influenced by the SMEs judgments with characteristic inferences on the data source value. Although SME inputs are subjective, we examined supporting/reinforcing inference throughout the model to check model quality. An example of a supporting/reinforcing inference is when Status Quo scores and Overall Satisfaction scores are in agreement. The inference is that data sources are the dominant determinant of product Status Quo Scores. Inferences leading to further investigation can be formed when the scores disagree. In particular, if a product's Status Quo score is significantly lower than the satisfaction scores for the data sources (especially the high impact sources) then other factors may be constraining product performance. In some cases the data source Satisfaction Scores are lower than the product Status Quo scores. In these cases, one inference is that the data sources are complementary and compensate for their deficiencies, resulting in product performance that exceeds the average satisfaction score. Another inference is that the SME's were inconsistent in their inputs. These contrasting inferences should also be checked via research and analysis or as a part of future data collection efforts.

c. We also used other metrics to challenge data quality. PALMA is able to provide an impact score for a product on an MSA, for an option on a product, and for an option on an MSA. Sorting and ranking such scores provides insights into the relevance of similar model elements. The large numbers of products and options provides sufficient statistical inference to question outliers for further examination. Such methods identified options or products with unrealistic impacts on MSAs. Line Office feedback on option rankings also helped to identify inappropriate functional groupings of data sources, or highly biased SME inputs.

## Appendix D – Terms, Acronyms, and Definitions

| Term | Acronym | Definition |
|---|---|---|
| CasaNOSA Analysis System Requirements Tool | CasRT | CasaNOSA Analysis System Requirements Tool is a capability maintained by TPIO to assess the ability of observing systems to satisfy validated NOAA observing requirements. |
| Center | | Centers are typically business units within NOAA which provide products in support of one or more MSAs. These business units were the source for SME input into product surveys (e.g., DCW). Examples of Centers include Fisheries Science Centers and River Forecast Centers. |
| Chief Financial Officer | CFO | Serves as the principal financial manager for NOAA or NOAA's Line Offices. |
| Climate Adaptation and Mitigation Goal | CLI | As part of NOAA Value Tree as defined in the NGSP, the Climate Adaptation and Mitigation Goal (aka Climate Goal) provides integrated services towards achieving an informed society anticipating and responding to climate and its impacts. http://www.ppi.noaa.gov/goals/ |
| Consolidated Observation Requirements List | CORL | A database containing NOAA's validated observing requirements maintain by TPIO. Requirements are established by NOAA to document environmental (observing system independent) information required to support a particular MSA. Each requirement includes a parameter (e.g. GCMD), priority, geographic coverage, horizontal resolution, vertical resolution, measurement accuracy, sampling interval, data latency and long-term stability. https://www.nosc.noaa.gov/tpio/main/aboutrap.html |
| Contiguous US | CONUS | Contiguous U.S. is a geographic domain which includes the lower 48 states of the United States. |
| CasaNOSA Analysis System Requirements Tool | CasRT | CasaNOSA Analysis System Requirements Tool is a capability maintained by TPIO to assess the ability of observing systems to satisfy validated NOAA observing requirements. |
| Database | DB | A database within NOSIA-II is an "option", which may impact a survey product. These databases do not have the observing system sources documented through a survey. |

| Term | Acronym | Definition |
|---|---|---|
| Data Source | DS | Generic reference to observing systems, databases and other products which impact survey products. |
| Data Collection Workbook | DCW | Spreadsheet used to collect data during site surveys, also referred to as a survey template. Completed DCWs are used to build the Model Building Workbook (MBW), which are used by PALMA to generate observing system impacts. |
| Earth Observation Assessment | EOA | The data collection and assessment supporting the National Strategy for Civil Earth Observations. This strategy is promulgated through the NASA Authorization Act of 2010, signed into law on October 11, 2010, which instructs the Director of the Office of Science and Technology Policy (OSTP) to establish a mechanism to ensure greater coordination of civilian Earth observations, including the development of a strategic implementation plan that is updated at least every three years. National Strategy for Civil Earth Observations establishes a three-year assessment and planning framework for Earth observations organized by major areas of societal benefit, initiates a prioritization of national observing systems according to those areas, and codifies guidelines for Federal Agencies concerning the effective management of Earth observation data. |
| Earth Observation Requirements Evaluation System | EORES | A relational database jointly developed by TPIO and U.S. Geological Survey (USGS). EORES will be the repository for NOAA's observation requirements (CORL), observing system impacts (NOSIA-II), and observing system capabilities (NOSA). EORES will support database management interfaces, report generation and visualization, analytics, and interfaces to external applications. |
| Efficient Frontier | EF | The term "Efficient Frontier" comes from economics and decision analysis and refers to a collection of portfolios of investment options arrayed on a graph where performance or satisfaction of goals is on the vertical dimension and aggregate cost is on the horizontal dimension. Using optimization techniques or algorithms, portfolios on the EF represent combinations of assets or investment options that provide the highest possible performance or goal satisfaction for a given cost or budget constraint. It is called "frontier" because the line or curve connecting the portfolios indicates the boundary between the optimal (efficient) portfolios and the non-optimal or inefficient portfolios. |

| Term | Acronym | Definition |
|---|---|---|
| Full Operating Capability | FOC | FOC is achieved when NOSIA-II model has the capability to generate Multi-Period Efficient Frontier products which includes impacts to the Value Tree as a consequence of projected loss or gain of major observing systems within a 20 year time horizon. |
| Global Change Master Directory | GCMD | A database which includes standardized set of vocabularies describing environmental parameters. TPIO maintains a database which is a modification of the NASA GCMD database. GCMD vocabularies are used to standardize product and observing system capabilities within NOSIA-II in addition to describing NOAA observing requirements (e.g., CORL). |
| Healthy Oceans Goal | HO | As part of NOAA Value Tree as defined in the NGSP, the Healthy Oceans Goal provides integrated services for stewardship of the nation's marine fisheries, habitats, and biodiversity sustained within healthy and productive ecosystems. http://www.ppi.noaa.gov/goals/ |
| Information Management System | IMS | Information Management Systems (IMS) are capabilities used to process, format, distribute and visualize survey products, observing system data and database information. While IMS capabilities enable NOAA mission services, characterizing their contribution to MSA performance was not an objective by NOSIA-II. |
| Initial Operating Capability | IOC | NOSIA-II IOC was achieved when product surveys were completed, Grouping and Tiering data were collected and integrated into the Value Tree, and preliminary NOSIA-II output products could be created. At this point, sensitivity studies were commenced documenting model behavior with MSA Leadership review and feedback. IOC and the subsequent sensitivity studies lead to a stable model supporting Scenario Ready business decisions. |

| Term | Acronym | Definition |
|---|---|---|
| Key Product and Service | KPS | KPS represent high visibility products which are directly associated with a Mission Service Area. KPS impact MSA, Goal and NOAA Status Quo Scores KPS are:<br>- Sourced from, and a sub-set of Survey Products<br>- Included within NOAA's Value Tree<br>- Unique to a MSA (shouldn't be duplicated in other MSAs)<br>- A component of NOAA's mission fulfillment, created by NOAA for a core constituent<br>- Discrete products that (typically) has performance characteristics (e.g., time, space, accuracy) and intended mission outcome/purpose<br>- Not an IT system which visualizes information or a dissemination capability, a KPS is the content itself33333<br>- Tiered (prioritized) and aggregated into KPS Groups within MSA hierarchies as determined by MSA Leadership |
| Key Product and Service Group | KPS Group | KPS Groups are the top-level groups within MSA hierarchy. Their function is to identify MSA outcomes similar to NGSP Objectives. A KPS Group may aggregate other KPS Groups and KPSs. KPS Groups are tiered (prioritized) by MSA Leadership. |
| Line Office | LO | Line Offices are NOAA's mission focused business units; consisting of the National Weather Service (NWS), National Ocean Service (NOS), National Marine Fisheries Service (NMFS), and NOAA Research (OAR). Line Offices, as MSA Leadership, manage the groupings and tiering within an MSA and identify Survey Sites, Subject Matter Experts and Survey Products. |
| Mission Service Area | MSA | NOAA's Mission Service Areas (MSA) are major topical/application areas serving society within NOAA's Long Term Goals. MSAs are part of the NOSIA-II Value Tree framework, and are derived from NGSP Objectives. |
| Model Building Workbook | MBW | The Model Building Workbook is a multi-table spreadsheet derived from NOSIA-II site surveys (DCW). The purpose of the MBW is to document the relationship information and instructions for how the PALMA software should calculate data source impact within the NOSIA-II model. The MBW is read by the PALMA formatting application, AutoTree, which compiles the MBW into PALMA model input format (called a .TRE file). |

| Term | Acronym | Definition |
|---|---|---|
| Multi-period PALMA Model | MPM | PALMA can be configured to generate two temporal types: single period or multi-period. Multi-period PALMA models are more complex, but allow the model to represent significant changes in capabilities and their impacts to Status Quo Scores over time. Programmable model changes include varying options such as loss or gain, enhancement or degradation, of observing systems, and changes to products and their sensitivity to options. Single period includes only current operations and maintenance (O&M) budget, while Multi-Period includes the full NOAA observations budget, both development and O&M. |
| Next Generation Strategic Plan | NGSP | NOAA's Next Generation Strategic Plan summarizes NOAA's mission, the societal outcomes that NOAA aims to help realize, and, consequently, the actions that the agency must take. The NGSP describes NOAA's role in responding to the Nation's most urgent challenges, ranging from climate change, severe weather, and natural or human-induced disasters to declining biodiversity and threatened or degraded ocean and coastal resources. http://www.ppi.noaa.gov/ngsp/ |
| National Oceanic and Atmospheric Administration | NOAA | National Oceanic and Atmospheric Administration is a Federal Agency within the Department of Commerce. NOAA includes the following Line Offices:<br>- National Environmental Satellite, Data and Information Service (NESDIS)<br>- National Marine Fisheries Service (NMFS)<br>- National Ocean Service (NOS)<br>- National Weather Service (NWS)<br>- Office of Oceanic and Atmospheric Research (OAR)<br>http://www.noaa.gov/about-noaa.html |
| NOAA Observing System Architecture | NOSA | NOAA Observing System Architecture is a planned, organized, and structured system of interoperable earth observing systems, which, when networked, provide an expanded range of capabilities satisfying user information and product needs. An integrated observing system architecture holds common goals and adopts common solutions to achieve them. NOSA is also a reference to a TPIO database which includes observing system capabilities. |

| Term | Acronym | Definition |
|---|---|---|
| NOAA Observing Systems Council | NOSC | NOSC serves as the principal advisory body to the NOAA Administrator and focal point for the agency's observing system activities and interests. https://www.nosc.noaa.gov/ |
| NOAA Observing System Integrated Analysis-I | NOSIA-I | NOSIA-I was pilot project undertaken by NOAA in 2011 to demonstrate the feasibility of using a social science Value Tree analysis to assess the impact of (upper air) observing systems on selected NOAA products and services (e.g., weather and climate). |
| NOAA Observing System Integrated Analysis-II | NOSIA-II | A repeatable process which results in a capability to assess the most cost-effective observing system architecture to best meet NOAA's requirements for Earth observations. The foundation of NOSIA-II is the completion of the NOAA-wide "Value Tree" developed in the NOSIA-I pilot in 2011. The Value Tree methodology was subsequently used as the basis for the White House Office of Science and Technology Policy (OSTP) directed Earth Observations Assessment (EOA) of Federal Agency information needs in 2012. |
| Observing System | ObsSys | A collection of one or more sensing elements (human and/or instrument) that reside on fixed or mobile platforms; directly or indirectly measuring environmental parameters on a defined basis meeting data user objectives. |
| Observing System Capability | ObsCap | Observing System Capability is a group of observing systems which may be related by the platform they are associated with (platform), the program that funds the data collection (program), or the derived parameters that the observing system sensors support (functional). ObsCaps are used to assessment integrated impacts, return on investment, and trades within NOSIA-II. |
| Observing System Committee | OSC | NOAA Line Offices coordinate observing system program data through the Observing Systems Committee (OSC), a subcommittee of the NOSC. https://www.nosc.noaa.gov/OSC/index.php |
| Observing System Experiment | OSE | Observing Sensitivity (or System) Experiment. A data denial study conducted on current numerical environmental model to assess the impact of current observing systems upon the model's forecast skill. |
| Observing System Simulation Experiment | OSSE | Observing System Simulation Experiment. An experiment testing hypothesized impacts of future observing systems upon numerical environmental models. |

| Term | Acronym | Definition |
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| Option | | An "option" is the type of data source considered by NOSIA-II to generate an Efficient Frontier for a given budget portfolio. Option data types are either an observing system or a database. All options have cost and impact associated with them. Options are called "leaf nodes" within the PALMA model. Options are the choices available to NOAA for investment considerations. |
| Overall Satisfaction Score | | SMEs provide an Overall Satisfaction Score (1-100) for every data source during product surveys which are recorded on survey product DCWs. Overall Satisfaction Score is based on the data source performance relative to intended design for monitoring a process or phenomena, as a function of its temporal and spatial resolution, and accuracy. Consideration of Overall Satisfaction Scores includes all limiting factors such as data availability and coverage based potential versus actual system deployment (example: LIDAR data coverage). The Data Source Overall Satisfaction Score is independent of its contribution to the survey product. SMEs assess future scores by considering improvements resulting from planned product improvement, or system degradations in system availability resulting from limited maintenance. SME comments amplifying comments for data source Overall Satisfaction Score are documented in site survey Scribe Notes. |
| Performance Measure | PM | Ongoing monitoring and reporting of program accomplishments, especially toward established goals. http://www.ppi.noaa.gov/program_evaluation_guide_reference_1/ |
| Portfolio | | A portfolio is a collection of programs, projects and/or operations managed as a group. The components of a portfolio may not necessarily be interdependent or even related—but they are managed together as a group to achieve strategic objectives. |
| Portfolio Manager | | Individual who centrally manages of one or more portfolios, which includes identifying, prioritizing, authorizing, managing, and controlling projects, programs and other related work to achieve specific strategic business objectives. |

| Term | Acronym | Definition |
|---|---|---|
| Portfolio Analysis Machine (trademark of The MITRE Corporation) | PALMA ™ | PALMA is an application used by TPIO in support of NOSIA-II that relates the performance of a high level objective to portfolios of investment options to:<br>1) Visualize the hierarchy of objectives and identify deficiencies in it, leading to the formulation of new investment options.<br>2) Find the portfolios of investment options that are the most cost effective.<br><br>PALMA provides a useful and appropriate framework for relating observing systems and their associated information management systems to NOAA climate, weather forecasting, and science products and, in turn, relating these products to NOAA Long-term Goals. PALMA provides the ability to represent a detailed hierarchy tree (a collection of value trees) starting with organizational goals branching down to products, with an intuitive visual representation of these relationships and performance of associated investment options. |
| Product Capability | PrdCap | Product Capabilities are a group of products which are be related by the derived parameters that the product capability support. Product Capabilities are used to assessment integrated impacts, return on investment, and trades within NOSIA-II. |
| Resilient Coastal Communities and Economies Goal | RC | As part of the NOAA Value Tree as defined in the NGSP, the Resilient Coastal Communities and Economies Goal provides services which enable Coastal and Great Lakes communities to be environmentally and economically sustainable. |
| Roll-up Rules | | Roll-up rules are mathematical and logical functions that represent the relationships between parent nodes and child nodes in the PALMA model. |
| Scenario Ready | | Reference to the maturity of the NOSIA-II model as a capability to provide meaningful and reliable guidance for leadership decision making towards management of NOAA's observing system portfolio. Scenario Ready is achieved through an iterative process which included sensitivity studies, Leadership feedback and finally consensus that the model performs in a stable and predictable manner. |

| Term | Acronym | Definition |
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| Status Quo Score | SQ | In NOSIA-II, Status Quo Scores refer to the impact an option or option group (observing system or database) has on NOAA, a Goal, MSA or a data source if the option or option group were removed from the Value Tree or survey product. It is a SME's assessment of how well their product meets users' and stakeholders' needs and expectations, based on the scale in Figure 5.4., Translating Performance into Numerical Values. |
| Strategy Execution and Evaluation | SEE | Strategy Execution and Evaluation (SEE) is a strategy implementation process that helps NOAA learn from its programs' results and achieve its objectives, while simultaneously responding to ever-changing economic, governmental, social and environmental forces. The process emphasizes results-based budgeting and evaluation. |
| Subject Matter Expert | SME | A Subject Matter Expert (SME) is a senior scientist or professional with direct experience in producing a Survey Product. Site Survey SMEs provide Survey Product DCW data, including Status Quo Score, Data Source Impacts (Reduced Product Scores) and Overall Satisfaction Score. Site Survey SME comments are recorded in Scribe Notes. |
| Survey Product | | Survey Products are collected during the site survey process and recorded on the Data Collection Worksheet (DCW). Survey Products are initially identified by MSA Leadership, but may be amended during the site survey process. Survey Products may become Key Product and Service (KPS) and/or other products. |
| Survey Site | | NOAA business units elicited during NOSIA-II (as selected by their Line Office) that are responsible for product generation. Survey Sites are the source for Subject Matter Experts (SME). |
| Swing Table | | The completed Data Collection Worksheet is called a "Swing Table" in NOSIA II when it has been incorporated in the Model Building Workbook. Swing tables contain the complete set of parents (products) and children (data sources) and the numerical scores (status quo scores, reduced product scores, percent contributions of capabilities within data sources and overall satisfaction scores. |

| Term | Acronym | Definition |
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| Reduced Product Score | | A reduced product score is the value provided by SMEs which indicates the performance of a survey product or similar node without the availability of a particular input data source. Reduced product scores are predicated on having first established a status-quo performance score. (**Product Swing Deltas** are the difference between the status-quo score and reduced product score. **Total Product Delta** is the sum of the product deltas over all data sources, expressed as a percent of the product's status quo score.) |
| System of Record | SoR | The OSC maintains a validated observing system database called the NOAA Systems of Record (SoR). The SoR database includes accurate system descriptions and information on acquisitions, operations and maintenance (O&M) costs, and observing capabilities of these systems. |
| Technology, Planning and Integration for Observation | TPIO | The NOAA Technology, Planning and Integration for Observation program (TPIO) manages the development of NOAA's Integrated Environmental Observation and Data Management System Architecture, otherwise known as NOAA's Integrated Architecture. This involves managing three major NOAA-wide capabilities:<br>(1) Observation System Architecture,<br>(2) Requirements and Planning, and<br>(3) Data Management Architecture.<br>https://www.nosc.noaa.gov/tpio/main/index.html |
| Value Tree | VT | Value Trees maps the relationship of options (observing systems and databases) to the top of the Value Tree (e.g., MSAs or Goals) through the KPS and KPS Groups. |
| Weather-Ready Nation Goal | WRN | As part of the NOAA Value Tree as defined in the NGSP, the Weather-Ready Nation Goal provides services which enable society to be prepared for, and respond to, weather. |

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