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THE CONTINUED EVOLUTION OF NOAA'S OBSERVING SYSTEM INVESTMENT ASSESSMENT PROCESS

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1. INTRODUCTION

The National Oceanic and Atmospheric Administration (NOAA) relies on Earth observations from more than 200 observing systems developed and fielded over many years. In satisfying specific observing requirements, each system contributes to the overall accomplishment of NOAA's mission, which in some cases involves fulfilling international commitments. Breaking from traditional acquisition approaches, in addition to evaluating observing system options based on their ability to satisfy multiple observing requirements, NOAA is evaluating how well observing systems benefit NOAA's mission.

With approximately 50% ($2B) of NOAA's annual budget spent on developing, acquiring, deploying, and maintaining operational and research environmental observing systems, the NOAA Observing Systems Integrated Analysis (NOSIA-II) (Yapur, 2015) is successfully providing an effective observing system portfolio management approach. 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 is still paramount.

Since 2005, NOAA's Technology, Planning, and Integration for Observations (TPIO) Division has been developing, implementing, and improving a methodology to evaluate proposed observing system investments and provide this information to NOAA leadership. TPIO's NOSIA-II is the continued maturation of the NOSIA-I pilot study completed in December 2011, and the first Federal Earth Observations Assessment (EOA 2012) in July 2014. In June 2014, completion of the NOSIA-II effort resulted in a first ever capability to link the impact of single and multiple observing systems and data sources on the key products and services NOAA produces within each of its mission service areas.

Several strategic drivers underpin NOAA's motivation for maturing TPIO's analysis process. These include:

- Managing current observing system lifecycles within NOAA's budget
- Addressing national priorities such as Executive Orders and Congressional Mandates
- Leveraging emerging technologies and commercial sector interest & capabilities to meet observing requirements
- Enabling support to environmental challenges and national disasters
- Supporting priorities for new research and enhanced scientific understanding

The NOSIA-II model is designed to be sensitive to strategic drivers governing investment in observing capabilities.

In a statement from the NOAA Administrator, Dr. Kathryn Sullivan, on NOAA's fiscal year 2016 budget request (Sullivan, 2015), NOAA's Top four priorities are:

1. Provide Information & Services to Make Communities More Resilient
2. Evolve the National Weather Service
3. **Invest in Observational Infrastructure**
4. Achieve Organizational Excellence

In addressing this third priority, TPIO constructed the NOSIA-II model to be a reflection of NOAA's observing system architecture, NOAA's core missions and mission service areas. Within each mission service area the model reflects each line office's business model to deliver product and service outcomes.

The principal purpose of developing this model is to articulate the current NOAA Observing System Architecture and plans to develop an observing enterprise that is flexible, responsive to evolving technologies and economically sustainable in response to an ever-growing demand for environmental information. According to the Observing System Committee of the NOAA Observing System Council (NOSC):

> *"NOSIA-II ignites a broader, NOSC-led effort to pull the many existing, yet disparate, incomplete and highly-technical descriptions of NOAA's observing system portfolio together into a more comprehensive, plain-language architecture to include costs, as well as NOAA's process to sustain, update and retire observing systems."*

The NOAA Administrator is frequently called upon to explain the value of NOAA's systems in order to compete for budget dollars against other Federal programs. We believe NOSIA-II gives her the tools she

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needs to effectively defend NOAA systems in the larger Federal budget environment. Ultimately, we believe NOSIA-II will educate government leaders about the intrinsic value of NOAA systems.

The unprecedented success of the NOSIA-I, EOA 2012 and the NOSIA-II efforts resulted in White House Office of Science and Technology Policy (OSTP) directed use in the second Earth Observations Assessment (EOA 2016). The capability of determining the relative value and impact of observing systems across the enterprise provides NOAA leadership with valuable input to the observing system investment decision process. Here we provide an overview of the enhancements to the NOAA's Observing System Investment Assessment (NOSIA-II) capability since June 2014.

1.1 *NOSIA-II Model Overview*

Intuitively, there are relationships between observing system capabilities, NOAA products and services, and NOAA's key stakeholders, and these relationships are highly complex. TPIO sought to instantiate these relationships in a "Value Tree" model to capture the sequence of cause/effect relationships in order to measure the dependence of stakeholders upon respective foundational observing systems. This dependence is intrinsic to these relationships.

The expected return on value resulting from investing in NOAA's Observation Architecture is to enable NOAA's stakeholders (investors) to avoid the consequences of poor choices and to exploit opportunities. For example, POES, NOAA Aircraft, NexRAD, MDCRS and ASOS support National Snow Analysis, Winter Storm Warnings, Flood Warnings, and Hurricane Local Statements. These products and services in-turn provide critical guidance to decision makers such as state and local police, FEMA evaluation route planners, building industry, school districts, and emergency managers, and federal and state departments of transportation.

The criticality of an optimal observing system investment strategy can be estimated under the following assumptions:

- U.S. Population: 320 million
- NOAA Observation Architecture: $2.7 billion per year
- NOAA Observation Architecture per Citizen: $8.41 per year
- U.S. Per Capita Income: $18 trillion GNP / 320 million citizens = $56,250 per citizen
- Citizen income exposure to weather (@30% of GNP) = $16,875 per year

The NOSIA-II Methodology report, which explains the model, was just published by NOAA/NESDIS and it can be found online (TPIO, 2015).

1.2 *Mission Service Areas*

The below graphic depicts NOAA's four Goals and their associated core missions, called Mission Service Areas (MSAs). NWS MSAs are listed in bright blue. The NOSIA-II value tree is structured according to these 26 Mission Service Areas, which include OAR's research activities that we have bundled under Science, Services and Stewardship, and Climate Prediction and Projections.

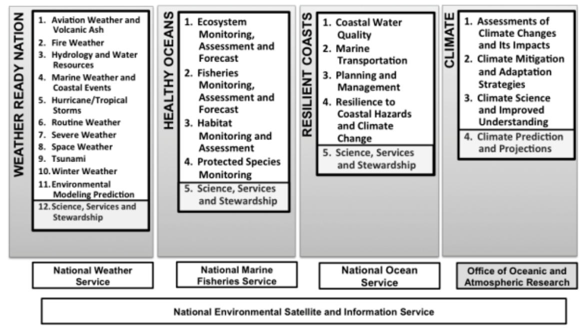

Figure 1

2. NOAA'S OBSERVING SYSTEM PORTFOLIO MANAGEMENT CAPABILITY

NOAA's observing system portfolio management framework includes three levels, consistent with OMB Federal Enterprise Architecture framework: 1) a conceptual level which includes corporate observation requirements, 2) a physical layer which includes built platforms and sensor observing system capabilities, and 3) a logical layer which includes the priorities, relationships and organizational services through which observing system impacts can be assessed (e.g., the value tree). NOAA has developed a suite of tools to effectively manage its observing systems. TPIO's support to the Portfolio Management Framework involves configuration management on three fronts: User's Observation Requirements, Observing Capabilities, and Observing benefits realized through the Value Tree.

2.1 *User's Observation Requirements (COURL)*

NOAA's user observation requirements are mission-based and system independent environmental observation requirements supporting both operations and research. Observation requirements are environmental parameters of a physical, chemical, or biological nature or other data collected to support a product or research.

The NOAA Consolidated Observation User Requirements List (COURL) is a database that houses information about NOAA's environmental observation requirements. COURL provides a comprehensive, standardized mechanism for NOAA organizational units to document their environmental observation requirements.

These units, so-called Line Offices, provide information on their requirements' Priority, Threshold and Objective level needs for attributes such as: geographic coverage, spatial and temporal resolutions and measurement accuracy. They also map these requirements to higher level Program Outcomes and Performance Measures. These requirements are those needed by units to conduct their mission and are not system specific.

TPIO's configuration management responsibilities for user's observing requirements include refreshing user priorities, and environmental parameters, and validating parameter attributes such as geographic coverage, vertical and horizontal resolution, temporal update and latency, and measurement accuracy.

2.2 *Observing Capabilities (NOSA)*

NOAA owns and operates a wide array of observing systems to support its mission. In addition NOAA leverages environmental data from a variety of external sources to supplement its observing assets. These sources may include other US federal agencies, industry and international partners.

The NOAA Observing System Architecture (NOSA) is a key segment in NOAA's Enterprise Architecture (EA). Collectively, the EA supports NOAA's Core Missions (see Figure 1). The NOAA Observing System Architecture (NOSA) is a database that captures the observing capabilities of current, planned and conceptual observing systems used, or with potential, to address NOAA environmental observational requirements.

The NOSA provides a comprehensive, standardized mechanism for documenting the environmental parameters measured by an observing system providing associated data on attributes such as: geographic coverage, spatial and temporal resolutions and measurement accuracy.

TPIO's configuration management responsibilities for observing capabilities include routinely examining the functionality of existing capabilities in terms of those same requirement attributes, and cataloging system cost information to include acquisition cost, and maintenance and operations cost, and owner information. TPIO also continues to refine and develop practices, policies, standards, and protocols to manage NOAA's observing systems. A summary of NOSA is given in the table below.

Total NOAA Observation Requirements = 1515

Observing System Owner	Location of Observing Systems				
	Terrestrial	Marine	Atmosphere	Space	Total
NOAA	42	50	12	7	111
U.S. Federal	36	6	13	21	76
State and Local	11	10	0	0	21
Academia	7	1	0	0	8
Commercial	1	3	0	3	7
International	10	9	3	12	34

Table 1

2.3 *Observing Benefits (NOSIA-II)*

NOSIA-II is 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.

NOSIA-II is a highly complex model of NOAA's business practices used to affect outcomes. It took one year to complete initial data collection. The number of connecting nodes in the model exceeds 27,000 with more than 125,000 active connections among the nodes with a unique impact function for each connection. Among these nodes, there were more than 1100 surveyed products from 72 survey sites (see Figure 2) and these products decomposed into 565 unique options.

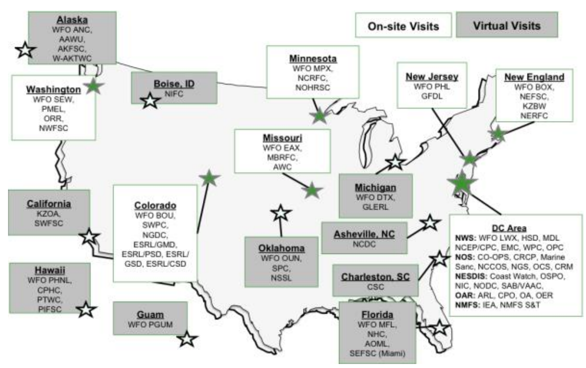

Figure 2

An individual option can influence as many as 370 surveyed products. Product and option performance scores varied nearly over the entire range of possible scores less than 99. The number of data sources cited for each product varied from 1 to 80. Subject Matter Expert (SME) names for the various product and option data sources often exceeded a dozen unique names for the same product or option. The value tree hierarchy is illustrated below.

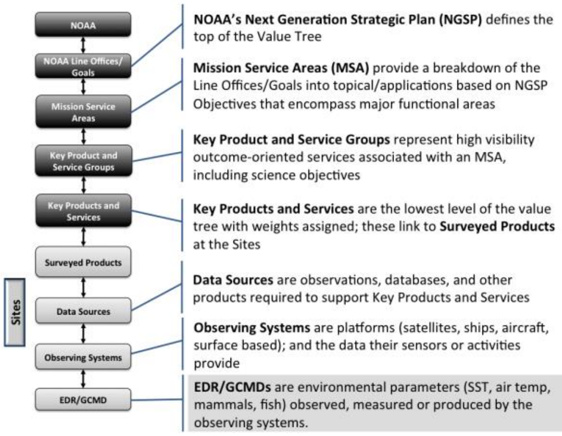

Figure 3

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 surveyed products as key to their Mission Service Areas. The Line Offices also meticulously reviewed each product to select those that are key and then grouped and prioritized them into three tiers to reflect their business models.

NOSIA's complexity wasn't restricted to only the data; there was also a great deal in the management of the model. This included managing the diversity of information derived from the SME's, the Line Offices. Project management included the creation of project teams for data SME elicitation, model construction, information management systems development, and data integrity using TPIO's available manpower, time, computing and software development environment, which was very challenging to say the least. Formality in TPIO's management process was absolutely essential to building a credible, decision-quality model. This included crafting and scheduling elicitations, following a detailed work breakdown structure, model configuration management, assembling teams with the right mix of expertise, and maintaining open and frequent communication with NOAA's Line Offices.

TPIO's configuration management responsibilities include refining the identification of key products and services and the line office's business model, which includes groups of products to represent outcomes, and assigning outcome priorities. TPIO also works to refine individual product assessments including updates to product performance, product interdependence, product data source relevance, and data source performance.

3. OBSERVING REQUIREMENTS, CAPABILITIES, AND BENEFITS ANALYSIS TOOLS

NOAA's goal is to achieve an Efficient and Cost Effective Architecture through implementation of defined management principles that maximize mission outcomes within available resource.

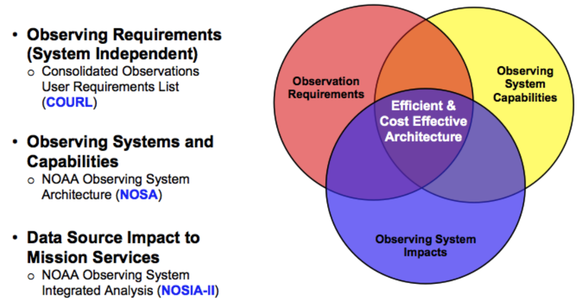

Figure 4

Evidence of progress associated with a mature architecture:

1. Observing system architecture is the "best value", as judged by all available trades, and
2. Fills gaps in all operationally significant mission information needs (this is subjective, mostly a policy judgment), where mature technological solutions can fill information gaps

Using these tools collectively, NOSA portfolio managers assess the consistency between expected performance from requirements satisfaction and actual performance to identify gaps in capabilities which are limiting service performance, requirements which may defined by not impactful, requirements which may need to be defined, and capabilities for which there is limited or no impact and/or requirements satisfaction.

3.1 *Observable Parameters (GCMD)*

TPIO's COURL, NOSA and NOSIA-II databases use standardized names for observable environmental parameters following the well-established NASA Global Change Master Directory (GCMD) science keyword structure to the fullest extent possible to characterize each environmental requirement at topic, term and variable levels.

To analyze observation requirements, observing capabilities, and observing capability benefits together, the information in NOSIA-II must evolve to include GCMD variables as the focus of comparison. TPIO's general approach to do this is to map NOSA's listing of observed GCMDs for each observing capability to the observing capabilities surveyed for each product in NOSIA-II. This is in lieu of explicitly re-surveying GCMDs required for each of NOAA's 1200+ surveyed products.

Before we could accomplish this, it was necessary to harmonize the GCMD information between COURL and NOSA while adhering to NASA's nomenclature as much as possible. Some departure from NASA's taxonomy was necessary because NASA's GCMD listing was much more granular than that found in COURL, and some of NOAA's GCMDs were simply not present in NASA's GCMD list. Once TPIO harmonized NOSA and COURL's GCMD topic, term, and variables, we harmonized the NOSA, OSC System of Record (SoR), and NOSIA-II options.

The various granularities of observing options in NOSIA-II complicated the NOSA-to-NOSIA-II harmonization effort. NOSA and OSC SoR were well harmonized at the funding program level, but NOSIA-II often gave observing options at the sensor level. This required the development of NOSIA-II options sets that were grouped by funding program to serve as equivalent objects to NOSA and OSC SoR capabilities.

The resulting harmonization effort produced a map of GCMDs between NOSA and NOSIA-II that TPIO can now use to analyze CORUL's GCMD requirements. Further review of this map helped to identify GCMDs that were not present in NOSA. These additional GCMD's came from NOSIA-II options that were not originally part of NOSA.

NOAA maintains a suite of tools that test and validate the consistency and efficacy among requirements (COURL), capabilities (NOSA) and benefits (NOSIA-II). Principal among these are tools for requirements gap assessment, value tree construction, benefit assessment, and observing portfolio information services.

3.2 *CASRT*

The legacy system housing COURL and NOSA is called CasaNOSA. TPIO users browse and manage the database, generate reports, and conduct requirements gap assessments with a software tool called the CasaNOSA Analysis Systems Requirement Tool (CAS-RT). This tool provides a Relative Gap Assessment (RGA) of the current observing system capabilities satisfaction of validated requirements.

3.3 *PALMA*

NOSIA-II information is encoded into a specially formatted document called a Model Building Workbook (MBW). MITRE's Portfolio Analysis Machine (PALMA^{TM}) software suite compiles the model building workbook into a "Tree" file that displays NOAA's value tree information. It is capable of mathematically modeling the value tree and its inter-nodal relationships in order to compute the benefit of the observing capabilities surveyed. TPIO uses PALMA as the analytic engine to assess the impact of observing system capabilities on products.

One of the results TPIO obtains from PALMA is a listing of benefit scores the observing systems have on the various nodes and branches of the value tree. NOSIA-II does not currently contain information on the benefit of a particular environmental parameter, i.e., GCMD variable. PALMA provides comprehensive and robust analysis tool that can interactively answer leadership's questions to help inform their decision-making process in terms of current observing system impacts and future observing system investments.

3.4 *EORES*

The jointly developed NOAA/USGS system called Earth Observation Requirements Evaluation System (EORES) is a collaborative effort between the National Oceanic and Atmospheric Administration (NOAA) Technology, Planning and Integration for Observations (TPIO) Program and the United States Geological Survey (USGS) Requirements, Capabilities and Analysis for Earth Observations (RCA-EO) Office.

The joint team is developing EORES for Observing Systems Architecture and earth observing requirements & analysis. Both TPIO and RCA-EO support their parent agencies in understanding and managing their Earth observing portfolios. EORES is a critical tool in performing this task. In addition, EORES will be used as the repository of information collected in support of the second Earth Observation Assessment being conducted by the White House Office of Science and Technology Policy (OSTP).

EORES is a web-based application designed and built to store, manage, and analyze information about Earth observing capabilities, system-independent user requirements, and agency mission value trees. The application consists of a spatially-enabled relational database and a web-based graphical user interface for browsing, editing, and querying information. EORES is also being designed to export information to several external analytical and visualization tools. NOAA's version of EORES is hosted by NOAA/National Environmental Satellite, Data, and Information Service (NESDIS).

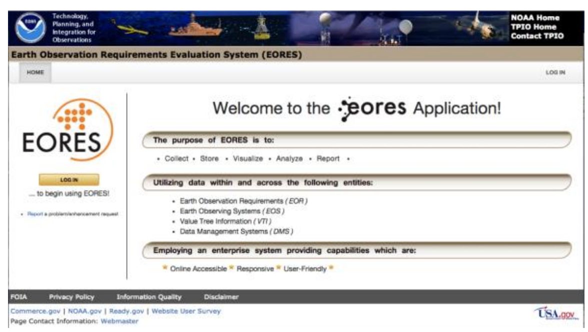

Figure 5

EORES contains the NOSIA-II Value Tree of NOAA's products and services. COURL, NOSA, and CAS-RT functionality are now being porting into EORES. Because EORES is still in development, it is currently assessable only to NOAA users registered in NOAA's Lightweight Directory Access Protocol server.

This capability is foundational for the model applications described below, and it was presented at the 20th Conference on Integrated Observing and

Assimilation Systems for the Atmosphere, Oceans, and Land Surface (IOAS-AOLS) by TPIO's Eric Miller, Lewis McCulloch, and Scott Smith.

4. NOSIA-II PERFORMANCE SUMMARY

The NOSIA-II Performance Summary in the figure below illustrates our preliminary findings.

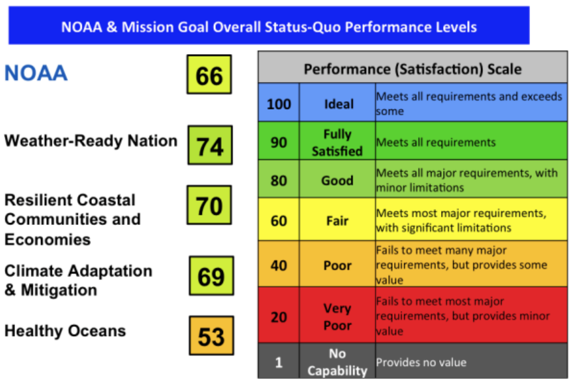

Figure 6

The Goal and NOAA "Status Quo" scores represented in the figure above are determined from the integration of Subject Matter Expert (SME) self-appraisal of performance of the NOSIA-II surveyed products associated with each core mission goal. Each goal includes a representative sample of products, which are produced for that goal and its stakeholders.

SMEs assessed the "Status Quo" performance of individual survey products based on all limiting factors, including access to observing system data sources. In addition to availability of observations, limiting factors also include understanding of the physical process, information technology, training, etc. Once a status quo performance was established, it was used as a reference to assess the impact resulting from availability (loss) of observations.

Status Quo Background: The Goal and NOAA "Status Quo" scores represented are determined from the integration of Subject Matter Expert (SME) self-appraisal of performance of the NOSIA-II surveyed products associated with each core mission goal. Each goal includes a representative sample of products that are produced for that goal and its stakeholders.

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5. EARTH OBSERVATION ASSESSMENT

The U.S. Group on Earth Observations (USGEO) is chartered as a subcommittee under the National Science and Technology Council (NSTC), which is under the direction of the White House Office of Science and Technology Policy. In 2014, OSTP published the National Plan for Civil Earth Observations (OSTP, 2014) with the help of the USGEO.

TPIO was instrumental in data collection and in laying the technical foundation of the analysis used to develop this plan. That effort was reflected in the plan's Annex I: 2012 Earth Observation Assessment Results (OSTP, 2014). The next step is the 2016 National Earth Observation Assessment (EOA 2016), which will build on its 2012 predecessor to evaluate the U.S. portfolio of Earth observations and consider how it benefits society in various areas of concern, including climate.

"Led by USGEO, with US Global Change Research Program (USGCRP) contributions through agency expertise and shared working group membership, EOA 2016 will assess existing systems and provide insight into future research and data needs. The ultimate goal of this effort is to inform policy and budget decisions across the Federal Government for a robust, cost-effective national Earth-observing capacity." -- Global Change Research Program (USGCRP, 2015).

There is a deep relationship between NOSIA-II and the Federal Earth Observation Assessment (EOA) efforts (EOA 2012 and 2016) chartered under the National Science and Technology Council, Committee on Environment, Natural Resources, and Sustainability, co-chaired by the White House Office of Science and Technology Policy, NASA, NOAA, and USGS.

NOSIA-I, which was conducted with a limited scope internal to NOAA in 2010, developed the methodology and toolset that was adopted for EOA 2012, and NOAA staffed the team that conducted the data collection, modeling, and analysis effort for EOA 2012. NOAA conducted NOSIA-II starting in 2012 to extend the NOSIA-II methodology across all of NOAA's Mission Service Areas, covering a representative sample (over 1000) of NOAA's products and services.

EOA 2012 was the first-ever integrated analysis of the relative impact of 379 observing systems and data sources contributing to the key objectives identified for 13 Societal Benefit Areas (SBA) including Weather, Climate, Disasters, Oceans and Coastal Resources, and Water Resources. This effort culminated in the first National Plan for Civil Earth Observations.

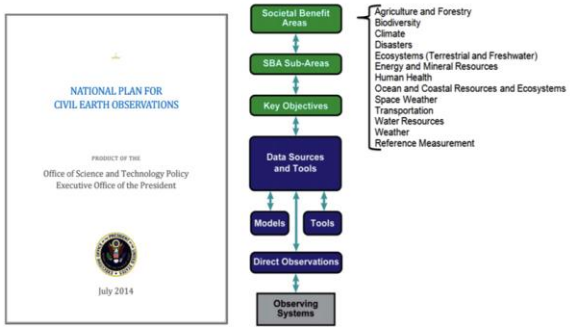

Figure 7

The detailed information from NOSIA-II is being integrated into EOA 2016 to underpin a broad array of Key Products, Services, and (science) Objectives (KPSO) identified by the inter-agency SBA teams. EOA 2016 is expected to provide substantially greater insight into the cross-agency impacts of observing systems contributing to a wide array of KPSOs, and by extension, to societal benefits flowing from these public-facing products.

6. INVESTMENT DECISION SUPPORT

NOSIA-II provides NOAA an analytic capability to represent the relationships, dependencies and complexity that exist among NOAA service outcomes, products, and observing systems. The NOSIA-II capability incorporates organizational priorities within missions, observing system cost and capabilities, and the impact of information on the quality of NOAA's products and services.

The Value Tree framework is based on Decision Analysis theory, which is used to support complex value assessments. Value Trees provide a logic process, which documents the strength of relationships between fundamental objectives underpinned by a hierarchy of intermediate "means" objectives and their data sources (Keeney, 1992). The Value Tree enables observing system assessments to link NOAA missions, their required activities, products and objectives to the specific impacts and costs of each observing system.

NOAA is adopting NOSIA-II as a corporate decision-analysis and support capability to inform leadership decisions on its integrated observing systems portfolio. Application examples include assessing the agency-wide impacts of planned decommissioning of ships and aircraft in NOAA's fleet, and the relative cost-effectiveness of alternative space-based architectures in the post-GOES-R and JPSS era. Like EOA, NOSIA-II is not limited to NOAA observing systems, and takes the contribution of observing systems from other agencies, the public sector, and international partnerships into account. NOSIA-II users include NOAA Leadership, Line Office Portfolio Managers, Program Managers and architecture planners.

TPIO constructed NOSIA-II to support the analysis of observing system architecture impacts and return-on-investment to current product and services with the primary focus on outcomes. TPIO also continues to evolve, assess, and calibrate model performance and to answer a wide range of specific business questions in these three categories.

1. Sustainment trades among current/planned observing programs under a constrained budget
2. Fly-in/fly-out or implementation /retirement schedules for observing systems
3. Investment trades among proposed observing architectures

6.1 *Efficient Frontier*

Harry Markowitz, a 1990 winner of the Nobel Prize in Economics developed the modern portfolio theory, which included a cost-benefit equation he developed called the Efficient Frontier (EF). An example of NOAA's EF is pictured below. The purpose of this EF is to identify the portfolio of observing systems that maximizes benefit NOAA-wide while minimizing NOAA's investment.

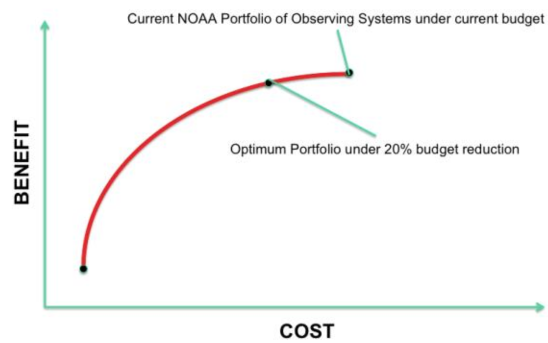

Figure 8

6.2 *Multi-Period Investment Analysis*

NOSIA-II supports the assessment of planned changes to NOAA's observing portfolio. This type of analysis can examine how satellite fly-in or fly-out; aircraft or ship commissioning or decommissioning; or planned technical enhancements, replacements, or maintenance attrition can impact mission services area performance. Proposed observing platforms must be integrated into current and planned products in NOSIA-II.

Some examples of these changes include assessing mission service area, goal, and agency-wide impacts of planned (Murphy, 2014):

- Decommissioning of ships and aircraft in NOAA's fleet;
- Fly-ins for spacecraft; e.g., DSCOVR, GOES-R, JPSS, COSMIC-II, JASON3, Sentinal, and MetOp spacecraft;

- Fly-outs for spacecraft; e.g., GOES-N/O/P, ACE, POES, A-Train (Aqua, CloudSat, and Aura), TERRA, DMSP, and SNPP spacecraft
- Changes for the FAA and NOAA radar observing networks; e.g., TDWR, MPAR, and NEXRAD.
- Changes for collaborative ocean observing; e.g., OceanSITES, and Chlorophyll Global Integrated Network (ChloroGIN).
- New space weather support models: Whole Atmosphere Model, University of Michigan Space Weather models

6.3 *Observing Architecture Trades*

NOSIA-II supports the analysis of investment trades among proposed observing architectures. For example the Office of Marine and Aviation Operations Aircraft Operations Center is conducting an Analysis of Alternatives for hurricane research platform replacement. This activity compares alternative solutions to replace NOAA's capability that will be lost when existing WP-3D aircraft reach the end of their services lives in 2030. Early phases of this activity seek to identify the services to be delivered by the platforms, the priority of those services, and the observing capabilities required for those services.

NOSIA-II supports assessments of the relative cost-effectiveness of alternative space-based architectures in the post-GOES-R and JPSS era. TPIO is supporting a program we call the NOAA Space-based Observing System Architecture (NSOSA). TPIO is working with the Office of Satellite Architecture and Advanced Planning (OSAAP) Architecture Development Team (ADT) under NESDIS and with the Space Platform Requirements Working Group (SPRWG) to identify the optimum future space-based observing portfolio achievable within planned budget constraints.

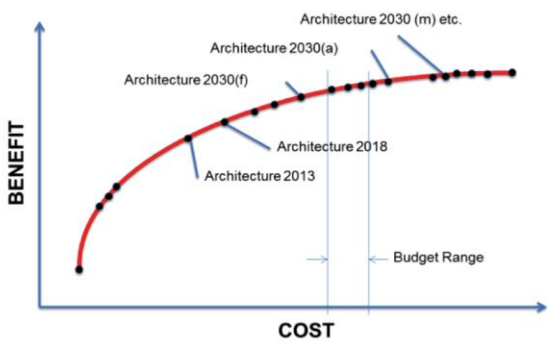

Figure 9

In support of NSOSA, TPIO has begun to transform the model to assess observing requirements instead of observing systems, and to provide the ADT the product relevant observing requirements that we need from the proposed space-based observing architectures.

The primary function of the ADT is to identify future observing capabilities and assess how well various architectures of those capabilities meet observing requirements. The primary function of the SPRWG will be to determine mission priorities to meet user needs in the 2030 epoch. The TPIO team then assesses how much benefit an investment in such architectures will be realized in the value tree. Observing systems surveyed in NOSIA-II are instantiations of observing capabilities funded to address observation requirements, so it is intuitive that observing system nodes in the NOSIA-II model can be transformed to observing requirements.

6.4 *Calibration To GPRA Indicators*

Expectations for performance management in the federal government were codified in the Government Performance and Results Act (GPRA) enacted in 1993. In NOAA, There are several GPRA Indicators (DoC, 2014) that may be tied to NOSIA-II product performance assessments. TPIO is working with the Line Offices' performance measurement divisions to establish a correlation between product performance and NWS's GPRA metrics (see Table 2) and to estimate how observing system performance and portfolio investment may affect GPRA metrics.

Government Performance And Results Act (GPRA) Indicators for NWS
Number of days of forecast accuracy and warning lead time – Agency Priority Goal
American Customer Service Index
U.S. temperature forecasts (cumulative skill score computed over regions where predictions are made)
Lead time for tornadoes/storm based (Minutes and Accuracy in %)
Lead time False Alarm Rate for tornadoes - storm based (%)
Severe weather warnings for flash floods – storm based - Lead time (Minutes and Accuracy in %)
Hurricane forecast track error (48 hour) (nautical miles)
Hurricane forecast Intensity error (48 hour) (difference in knots)
Accuracy (%) threat score of Day 1 precipitation forecasts
Winter storm warnings – Lead time (hours and accuracy)
Marine wind speed and wave height accuracy (%)
Aviation forecast accuracy and FAR for ceiling/visibility (3 mile/1,000 feet or less) (%)
Geomagnetic Storm Forecast Accuracy (%)

Table 2

6.5 *Calibration To OSEs*

Observing system experiments (OSEs) are important in determining the impact of various earth observing systems on a numerical weather prediction (NWP) model. Observing system simulation experiments (OSSEs) are critical in examining future observing system impacts or changes in configuration on an NWP system. While an OSE or OSSE provides a quantitative analysis of current or future observing system impacts for a single model, the effects on products that rely on that model can only be estimated qualitatively. Additionally, the observational impacts due to observing system configuration changes cannot be gauged concurrently across a suite of NWP models (such as those at the NCEP Environmental Modeling Center).

TPIO and the Quantitative Observing System Assessment Program (QOSAP) in NESDIS are collaborating on calibrating NOSIA-II with relevant studies from QOSAP. Specifically, we are calibrating GFS performance in NOSIA-II with QOSAP's satellite data denial studies. TPIO's objective is to estimate product sensitivity to observing system performance in order to recommend more focused studies.

7. CONCLUSION

NOAA has developed the methodologies and tools that allow it to effectively manage a large, complex suite of observing systems from space to bottom of the ocean.

The NOSIA-II and EORES toolsets comprise the backbone of a portfolio management framework to develop an observing enterprise that strategically addresses mission priorities, that is flexible and responsive to evolving technologies, and that is economically sustainable.

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