# 14.2 NOAA FY08 OBSERVING SYSTEMS INVESTMENT ANALYSIS

**Eric J. Miller***

**NOAA/NESDIS. Silver Spring, MD; and**

**T. C. Adang[1], R. C. Reining[2], P. P. Salamone[2] and L. E. Key[3]**

## 1. INTRODUCTION

Making decisions about investments in NOAA's observing systems is a daunting challenge. NOAA has a broad and diverse mission that extends far beyond weather forecasting and includes global climate observations and forecasting, assessing fish stocks and setting fishing quotas, managing marine sanctuaries, managing the Nation's geodetic reference system, and hydrographic surveying. To accomplish this mission, NOAA invests in the acquisition, operations, and maintenance of a broad array of observing systems—more than 80 different observing systems based in space, on land, in the oceans, in the air, and in the cryosphere. These systems contribute to satisfying about 800 mission-critical observing requirements across 21 NOAA programs. In the context of this complexity, NOAA leadership needs to be able to determine which investments would best support and advance NOAA's mission in a cost-constrained environment--whether to invest in sustaining existing systems, improving existing systems, or in acquiring new systems. In January 2005, the NOAA Observing Systems Council directed the NOAA Observing Systems Architect and supporting team to establish a NOAA-wide observing system investment analysis capability.

## 2. OBJECTIVE OF THE FY08 OBSERVING SYSTEM INVESTMENT ANALYSIS

The purpose of the FY08 investment analysis is to develop recommendations to NOAA leadership on a NOAA-wide portfolio of observing system investments for the FY08 budget cycle. An optimal portfolio is defined as the combination of observing system investments that provides the greatest benefit within a given budget, recognizing legal and other constraints.

"Benefit," in this analysis, refers to the extent to which NOAA's mission critical observing requirements are satisfied, using the hierarchical "value tree" described below.

The intent was to develop a process to support the programming component of NOAA's planning, programming, budgeting, and execution system (PPBES) cycle for FY08 and beyond. The portfolio model also provides the capability to conduct "what-if" exercises and to do sensitivity analyses.

## 3. CONSTRUCTING A NOAA-WIDE VALUE TREE

The investment analysis (IA) team worked closely with three NOAA programs to develop and refine this process, and then expanded it to include all NOAA programs that have defined mission-critical observing requirements. The observing systems portfolio model is based on a hierarchical mission goal-to-requirements model, or value tree. Elements from NOAA's structure, strategic plan, and program documentation were used to build a tree that represents how NOAA is organized to obtain and use environmental observations to achieve its mission. This tree provides explicit linkages that can be traced from observing systems through observing requirements, program outcomes, programs, and mission goals. Figure 1 shows a partial representation of the NOAA value tree, breaking out the Marine Transportation Systems program within the Commerce and Transportation mission goal. The model was created using the Portfolio Analysis Machine (PALMA) software developed by The MITRE Corporation with Government funding.[4]

## 4. DATA COLLECTION

Data collection at the program level was by far the biggest component of the effort. The program level data collection steps are as follows:

- Programs define their mission-critical environmental observing requirements. (Only programs that identified mission-critical observing requirements are included in this year's analysis.)

* Corresponding author address: Eric J. Miller, NOAA/NESDIS, 1335 East-West Highway, SSMC-1, 5th Floor, Silver Spring, MD 20910; e-mail: eric.miller@noaa.gov

1 NOAA/NESDIS, Silver Spring, MD
2 The MITRE Corporation, Bedford, MA
3 General Dynamics, Falls Church, VA

4 PALMA is a trademark of The MITRE Corporation

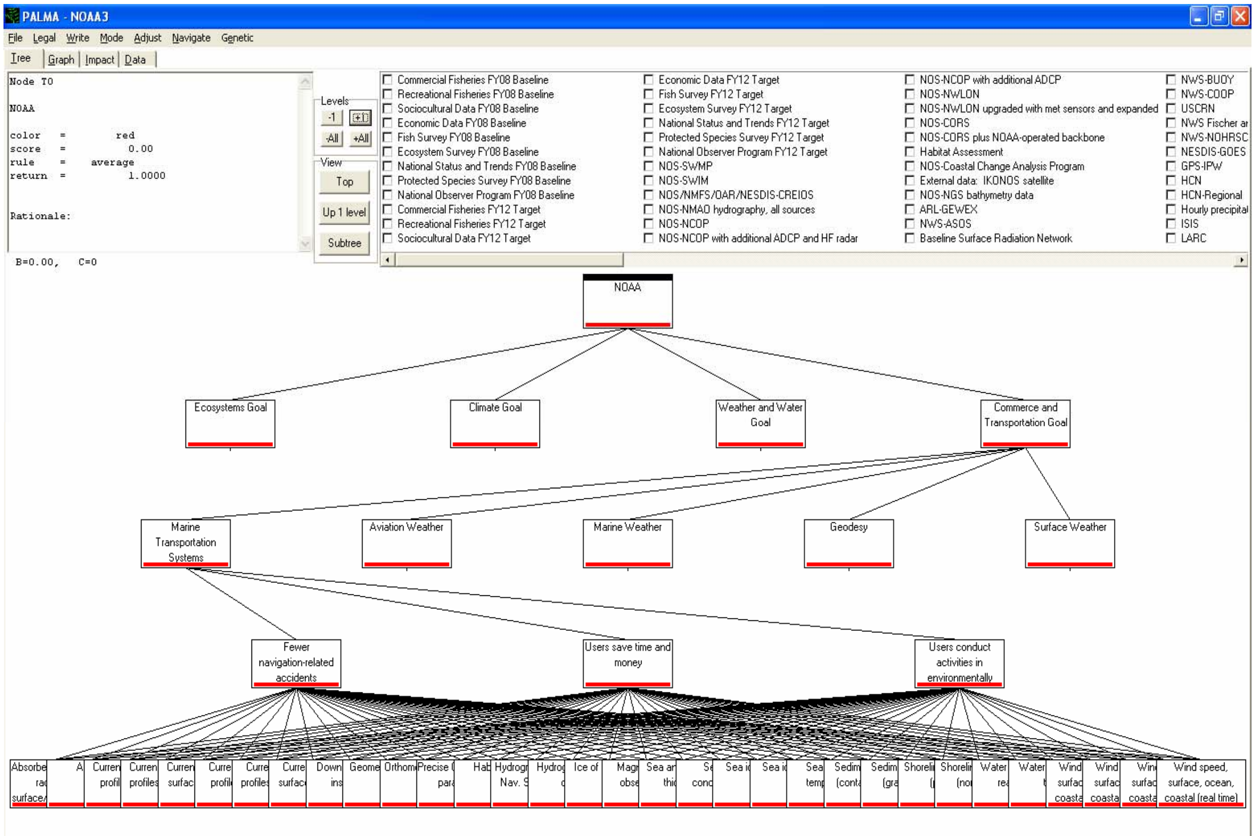


**Figure 1: Partial NOAA Value Tree—Breakout of Marine Transportation Systems Program within the Commerce and Transportation Goal**

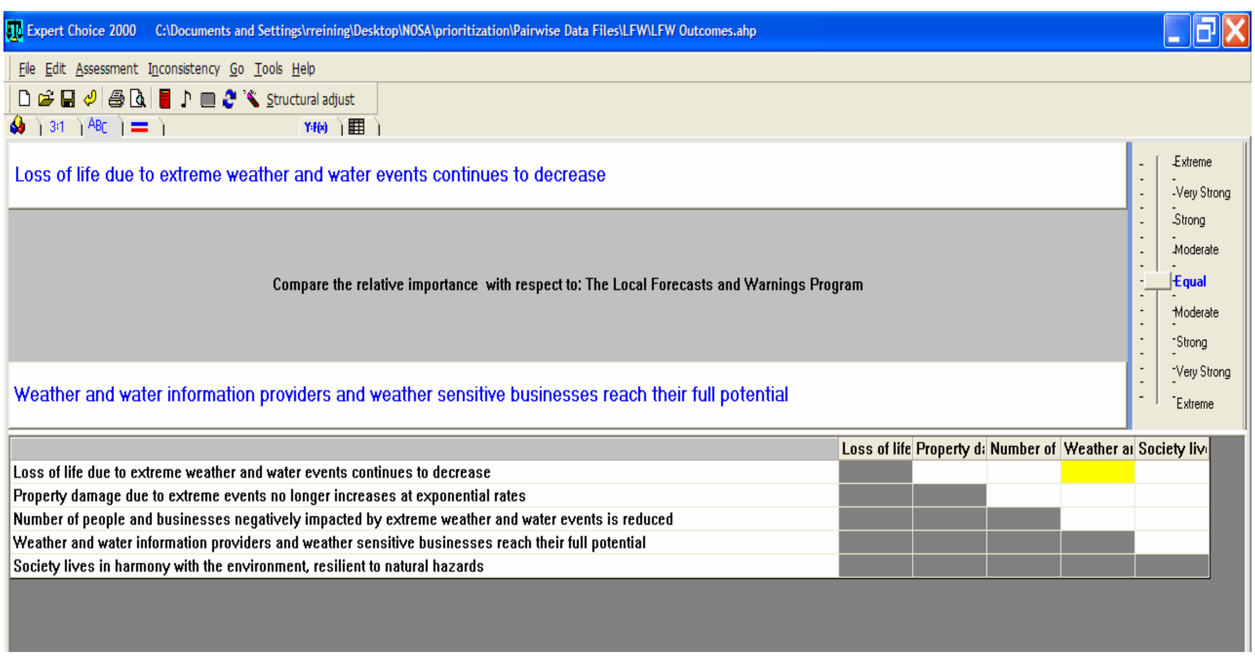


**Figure 2: Example of Expert Choice Pair-wise Comparison Input Screen**

- Weight factors for the PALMA value tree are elicited using a commercial software package called Expert Choice® which employs an analytic hierarchy process to facilitate pair-wise comparisons.[5] The IA team used Expert Choice to facilitate assessment of the contribution of long-term program outcomes to each program and of mission-critical observing requirements to the program outcomes. Figure 2 shows an example of an Expert Choice® input pair-wise comparison screen used to elicit inputs as to the relative importance of program outcomes.
- Programs identify current observing systems that contribute value to meeting mission-critical requirements.
- Programs determine future observing system investment options (e.g., expansions of or upgrades to current systems, new systems) for meeting mission-critical requirements
- Assess benefit and cost
    - Programs evaluate the contribution these investment options make to meeting mission-critical requirements (expressed as percent satisfaction). NOAA program managers and subject matter experts make quantitative assessments of how well the defined observing system options meet mission-critical observing requirements.
    - Costs for observing systems that are part of the NOSA baseline architecture were derived from NOAA's observing systems database. Programs that proposed enhancements of current observing systems or new observing systems were asked to provide the cost data for those options. In either case, average annual costs for FY08-12 were used.

The IA team also worked with the NOAA Mission Goal Team leadership to derive weight factors for programs relative to the four Mission Goals (Ecosystems, Climate, Commerce and Transportation, and Weather and Water).

## 5. PORTFOLIO ANALYSIS

PALMA is designed to search the space of all possible portfolios (collections of observing system options), calculating the benefit and cost of possible portfolios and identifying optimal portfolios over a range of budget constraints—the so-called "efficient frontier." For the NOAA portfolio model, "benefit" is defined as the total satisfaction of NOAA's priority 1 observing requirements by a given portfolio of systems, taking the program, program outcome, requirement weight factors and impact of systems on individual requirements into account. In addition, synergies between NOAA observing options were defined and modeled in PALMA. For example, if system A is needed to make system B work effectively, a dependency was created to ensure that if system B is selected, system A will also be selected. For relatively small numbers of options (less than 30), an exhaustive search of all possible portfolios can be carried out. For larger numbers of options, PALMA searches the portfolio space using a genetic algorithm. The genetic algorithm used in PALMA is inspired by the processes of evolution and natural selection and—for this analysis—was typically run over 10,000 "generations" to find optimal portfolios for as many as 1000 cost intervals. Figure 3 shows a notional representation of the NOAA-wide efficient frontier from a PALMA run. The "example portfolio" indicated on Figure 3 is selected from the list of observing systems on the right-hand side of the figure and is comprised of the systems that are "checked". No other combination of notional systems would provide greater benefit at that particular budget point.

[5] Expert Choice® is commercially available software.

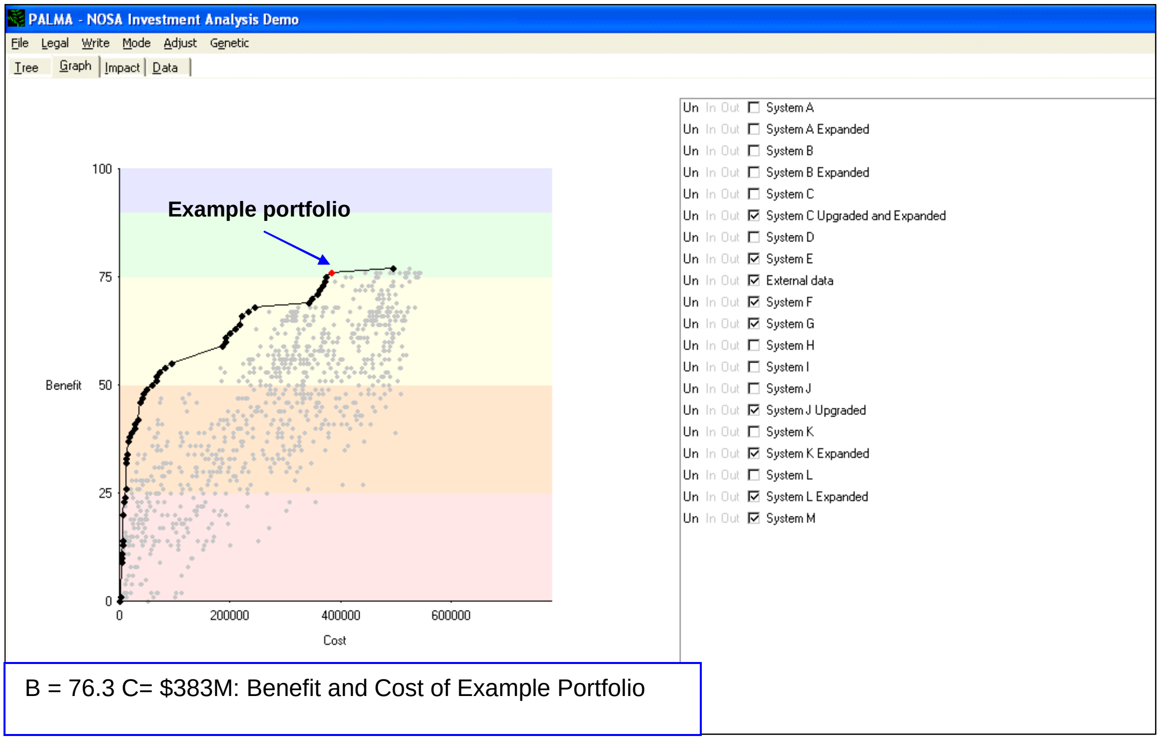


**Figure 3: Notional NOAA-wide Efficient Frontier (PALMA screen shot)**

## 6. LIMITATIONS OF THE CURRENT NOAA PORTFOLIO ANALYSIS CAPABILITY

While the current capability represents a substantial breakthrough in terms of quantity and consistency of data from across NOAA and employs a very powerful optimization technique, there are several limitations that should be kept in mind:

- Portfolio analysis should be considered only one of several inputs to funding decisions—it is not the final answer. It serves to focus attention on certain key tradeoffs, but additional analysis is needed to arrive at funding recommendations. For example, the current portfolio analysis also does not generate estimates of societal impacts or economic benefits from proposed investments.
- The current portfolio model addresses observing system investments, which are only one component of the investments needed to achieve NOAA's program outcomes. NOAA also invests in information management, research, outreach and education, and other activities to achieve its outcomes.
- The current portfolio analysis is not designed to be an analysis of NOAA's total requirements satisfaction. For example, it does not account for the additive effect of multiple systems that contribute to satisfying a particular observing requirement. This means that the total satisfaction of NOAA's requirements is probably higher than the analysis results indicate. This factor may or may not affect the choice of optimal portfolios in the higher cost range, but does obscure the added benefit derived from these higher cost portfolios, since the "efficient frontier" curve flattens out at higher costs. This effect is being investigated further.
- The value tree is based on a quantification of expert judgment concerning the degree to which individual observing systems satisfy requirements. Simulation- or science-based studies could improve the accuracy of estimated contributions of current or proposed of observing systems towards satisfying observing requirements.
- In the current portfolio analysis, each program assessed the relative importance of its program outcomes. Inputs on the importance of program outcomes were not sought from parties external to the programs.
- The assessments of proposed enhancements to existing systems and of new systems were incomplete. For example, some programs

proposed certain enhancements or expansions of existing systems, but other programs were typically not aware of these proposals and therefore did not assess them. Also, several of NOAA's research oriented programs did not participate in the analysis, so analysis of the nature and potential impact of research-oriented systems was incomplete.

- The current portfolio model does not explicitly address risk. For example, NOAA depends on a wide variety of free or low cost external sources of data, but the risk that some of these data will not be available in the future has not been assessed.

## 7. FUTURE DIRECTIONS

To address the limitations described above, the NOSC support team believes that several extensions or refinements of the portfolio analysis should be considered:

- Investments in data and information management should be included in the investment portfolio and analysis.
- NOAA's science and research communities should be involved in the definition and assessment of investment options.
- More complete evaluation of proposed options should be obtained from programs that could benefit from them.
- The value tree should be revised to be more fully task oriented—e.g. focusing on program outcomes or performance measures—and NOAA-wide inputs obtained as to the relative importance of these tasks.
- Use of more sophisticated roll-up rules and more complex options to better model the interactions between investments—such as the additive or synergistic effect of different options or the interaction between observations and data management—should be investigated.
- The risks inherent in certain options should be addressed and modeled.

## 8. ADDITIONAL INFORMATION

For additional information about NOAA's observing system architecture and its inventory of observing systems see:

www.nosa.noaa.gov