# Independent Cost Estimate of the U.S. Integrated Ocean Observing System (IOOS®)

## Volume I–Summary

Prepared for:

**The National Aeronautics and Space Administration Science Mission Directorate (NASA SMD)**

and

**The Interagency Ocean Observation Committee (IOOC)**

Prepared by

**The Jet Propulsion Laboratory Earth Science and Technology Directorate**

May 4, 2012

# Executive Summary

In response to the Integrated Coastal and Ocean Observation System Act of 2009 (33 U.S.C §3601-3610) call for an independent cost estimate (ICE), the Jet Propulsion Laboratory (JPL) under the sponsorship of National Aeronautics and Space Administration Science Mission Directorate (NASA SMD), assessed the Integrated Ocean Observing System (IOOS®) program from a cost perspective. The ICE team was tasked with assessing the IOOS Central Function and the partnering oceanographic capabilities of 17 Federal agencies and 11 non-Federal Regional Associations. Full cost accounting was employed to include the value of all U.S. oceanographic and Great Lakes observing assets.

The IOOS Central Function, Federal, and Non-Federal contributions were assessed over a 10-year buildout followed by a 5-year sustainment period. All Regional Associations along with 3 Federal agencies provided asset inventories and buildout plans. These inputs, along with an IOOS Cost Analysis Requirements Description (CARD) and supporting documentation, were used to determine the program cost. Central Function cost modeling was based on a grass-roots estimate supplemented by IOOS-provided labor and facility plans. Non-Federal contribution costs were the most certain, as they were based on the Regional buildout plans. Federal cost had the highest uncertainty, as only NOAA, USACE, and EPA supplied input. To account for the higher uncertainty, the Federal cost was modeled by determining the portion of their annual budgets targeted for oceanographic contribution. The resulting budget was sub-allocated into a CARD-prescribed work breakdown structure (WBS).

The program cost for the 15-year period is summarized in the table below. WBS Operations and Sustainment elements whose costs are shown as zeros were due to the limited work breakdown fidelity of the buildout plans obtained. These costs were ultimately accounted for in the Systems Operations element.

| IOOS WBS Element | Central | Federal | Non-Federal | Total |
|---|---|---|---|---|
| **1. Development** | **574** | **15,166** | **4,432** | **20,172** |
| 1.1 Observing subsystems | 13 | 7,843 | 2,926 | 10,782 |
| 1.2 Data management and communication (DMAC) | 337 | 2,289 | 248 | 2,873 |
| 1.3 Modeling and analysis subsystem | 60 | 2,289 | 327 | 2,675 |
| 1.4 Governance and management subsystem | 110 | 1,526 | 643 | 2,279 |
| 1.5 Research and development subsystem | 20 | 763 | 70 | 853 |
| 1.6 Training and education subsystem | 34 | 458 | 217 | 709 |
| **2. Operations and Sustainment** | **412** | **30,047** | **3,575** | **34,035** |
| 2.1 Systems engineering and program management | 21 | 0 | 0 | 21 |
| 2.2 System operations [replication of 1.X functions in sustain mode] | **352** | **15,256** | **3,575** | **19,183** |
| 2.3 Maintenance | 12 | 9,861 | 0 | 9,872 |
| 2.4 Sustaining support/engineering | 0 | 2,465 | 0 | 2,465 |
| 2.5 Indirect continuing support | 0 | 1,233 | 0 | 1,233 |
| 2.6 Continuing system improvements | 27 | 1,233 | 0 | 1,260 |
| **Total (Inflated $M)** | **986** | **45,214** | **8,007** | **54,206** |

# Acknowledgements

This independent cost estimate was commissioned by the Interagency Ocean Observation Committee (IOOC), as called for in section 12309 of the Integrated Coastal and Ocean Observation System Act of 2009 (P.L. 111-11). Completion of the report was made possible by financial contributions from the Marine Mammal Commission; the National Aeronautics and Space Administration (NASA); the National Science Foundation (NSF); the Department of Commerce, the National Oceanic and Atmospheric Administration (NOAA); the Department of Interior, Bureau of Ocean Energy Management (BOEM); and the U.S. Geological Survey (USGS).

This Integrated Ocean Observing System (IOOS®) Independent Cost Estimate (ICE) is the result of work performed by the Jet Propulsion Laboratory's Cost Estimation & Pricing, Information Technology, and Earth-Science & Technology subject area experts. These individuals graciously provided information, comments, and constructive recommendations for the ICE development and results presented herein.

The ICE report was authored by Richard B. Bennett (ICE Task Manager), Milana K. Wood (ICE Team Cost Lead), Cate Heneghan (ICE System Engineer), Douglas Hughes (ICE DMAC System Engineer), Michael J. Fong (ICE Cost Engineer), and Troy J. Schmidt (ICE Cost Engineer).

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- **Cost Support Team:** Sherry A. Stukes; Fred G. Doumani; Edward J. Jorgensen; Jeff H. Smith; Ryan Kramer; Violet Tissot; and Michael DiNicola.
- **JPL Independent Review Team:** Tomas J. Soderstrom; Benjamin M. Holt; Andrew W. Bingham; James L. Hoffman; Daniel J. Crichton; Elizabeth Y. Kay-Im; Chris A. Mattmann; and Thomas Huang.
- **Special Recognition:** A special note of gratitude to Yi Chao for his valuable oceanographic science insight and recommendations.

This work was carried out at the Jet Propulsion Laboratory, California Institute of Technology, under a contract with the National Aeronautics and Space Administration.

# Contents

# Section 1. Scope of the IOOS ICE

In response to the Integrated Coastal and Ocean Observation System Act of 2009 (33 U.S.C §3601-3610) call for an independent cost estimate (ICE), the Jet Propulsion Laboratory (JPL), under the sponsorship of the National Aeronautics and Space Administration Science Mission Directorate (NASA SMD), assessed the IOOS program from a cost perspective. The ICE team was tasked with assessing the Integrated Ocean Observing System (IOOS®) Central Function and the partnering oceanographic capabilities of 17 Federal agencies and 11 Non-Federal Regional Associations. These partnerships are represented by an umbrella organization called U.S. IOOS®. The Central Function is responsible for coordinating and overseeing the development and integration of the capabilities of six IOOS subsystems: observing; data management and communications; modeling and analysis; governance and management; research and development; and training and education. U.S. IOOS partners are comprised of Federal agencies, Regional Associations, and other organizations around the country. The IOOS Program Office is responsible for coordinating these capabilities to maximize partner involvement with U.S. IOOS. The objective is to take maximum advantage of existing capabilities among the partners and to identify opportunities for incorporation and collaboration.

The IOOS Central Function, Federal, and Non-Federal contributions were assessed over a 10-year buildout followed by a 5-year sustainment period. Full cost accounting was employed to include the value of all U.S. oceanographic and Great Lakes-observing assets. The resulting system cost was assessed at confidence levels of both 50% and 80%, as required by the IOOS Cost Analysis Requirements Description (CARD).

## 1.1 The ICE Report—Volumes Overview

The report is divided into two volumes. Volume I contains an Executive Summary and a more detailed summary outlining the approach, cost results, conclusions, and recommendations of the ICE task. Volume II provides a detailed look at the cost breakdown and its associated drivers.

## 1.2 Developing the ICE—Overview of the Approach

Given the importance of properly understanding and modeling U.S. IOOS, coupled with the range and complexity of the system and observational assets, JPL developed a simple database to identify, organize, and categorize the scope, system elements, and system requirements. These data, in conjunction with previously performed cost studies, were utilized to develop cost models for the system elements. A cost estimate was then produced with an uncertainty assessment to provide confidence limits on the cost. The resulting ICE was compared to a Program Cost Estimate (PCE) provided by the sponsor. The ICE was then evaluated and reconciled against the provided cost estimate; this report documents the approach and findings.

JPL performed and delivered the ICE work in five phases on a best-efforts basis:

- **Phase 1:** Received and input IOOS documentation into the ICE Data Library.
- **Phase 2:** Collected, sorted, and categorized the system data.
- **Phase 3:** Developed the Independent Cost Estimate (ICE).
- **Phase 4:** Conducted a Program Cost Estimate review and reconciliation.
- **Phase 5:** Prepared the final report.

## 1.3 Data Management and Communications (DMAC) Architecture

The ICE team made a concerted effort to develop an understanding of the DMAC concept by thorough study of the IOOS Blueprint, DMAC Implementation Plan, and High-Level Functional Requirements documents. The concept embodies a central DMAC function with an overlay of a modeling and analysis capability. The Central Function is to have the capability, through Internet access, to acquire and distribute observational data from up to 20 remote Data Assembly Centers (DACs) (see Figure 1.3-1).

The challenge facing the ICE team was that the DMAC concept, although reasonably clear, did not include a system architecture. The definition of the system architecture, which was necessary to produce a cost estimate, is described in Volume II, Appendix 7.1.

The solution involved developing a representative architecture based on similar working systems. The architecture needed the flexibility to accommodate both an increase in observational data and the number of users accessing it over time. However, the system architecture must be of a nature that allows this increased capability without growing beyond the confines of the facility housing it. The resulting system was envisioned to be server-based, with an architecture that allowed horizontal scaling and load-balancing. To mitigate the need for an ever increasing computing capability, the envisioned architecture would also take advantage of commercial "Cloud" computing services that can be used for modeling and analysis, along with selected data storage. This has the advantage of shifting hardware and labor into service cost at a potentially significant savings.

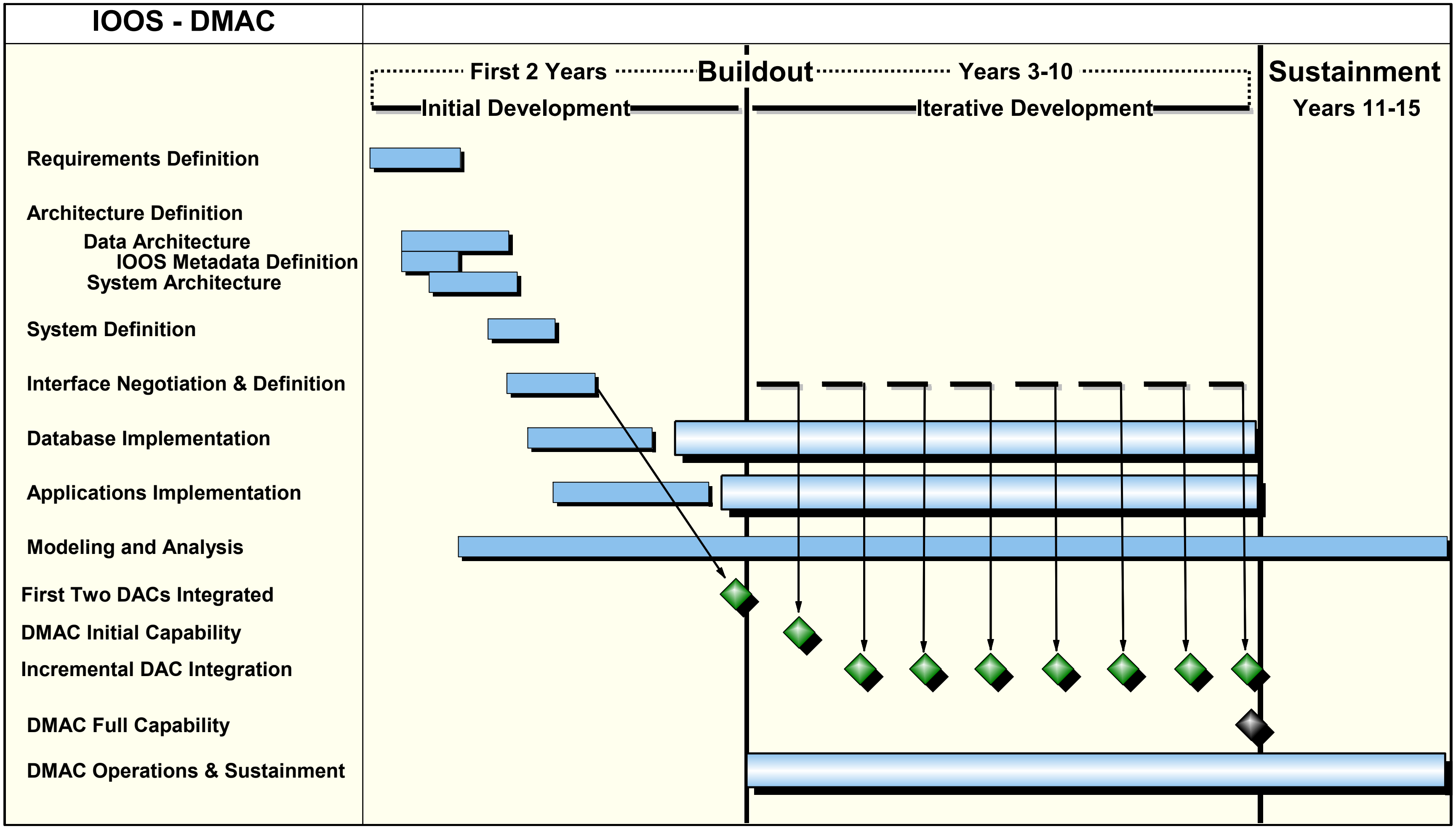


***Figure 1.3-1.*** *The DMAC requires a 10-year buildout incorporating four remote Data Assembly Centers (DACs) by the end of the first 3 years to achieve Initial Capability. This is followed by a 7-year effort to negotiate, define, and integrate the remaining DACs to achieve Full Capability.*

# Section 2. Independent Cost Estimate Summary

## 2.1 Overview

The independent cost estimates were developed by the ICE team in Phase 3 and finalized in Phase 4 of the ICE work plan. The Phase 3 activity developed cost estimates with uncertainty assessments for the Central Function elements and integrated them with the Federal and Non-Federal contribution elements. The Phase 4 activity was a comparison and reconciliation of the independent estimates produced by the JPL and Program Cost Estimate (PCE) teams. This section summarizes the overall results, cost estimating methodology, assumptions, influential drivers, basis of estimates, and the reconciliation process results.

## 2.2 Summary Of Results

The ICE cost estimate spans the Central, Federal, and Non-Federal entities comprising the IOOS. The total cost estimate for all three entities over the IOOS 15-year duration is termed the "Three Component Value (3CV)" in this document. The scope of each entity cost estimate is summarized as follows:

- The Central Function cost reflects the cost for achieving (1) the IOOS Full Capability within 10 years, including the design, implementation, and administration of the IOOS DMAC, followed by (2) ongoing operations and maintenance expenses for a five-year period after deployment.
- The Federal Contribution value reflects the costs associated with operations and maintenance (O&M) of existing federal assets; acquisition and O&M of new assets; operation facilities; observation equipment; modeling and software; data management and communication equipment; and other essential components of the IOOS.
- The Non-Federal Contribution value reflects the costs associated with operations and maintenance (O&M) of existing non-federal assets; acquisition and O&M of new assets; operation facilities; observation equipment; modeling and software; data management and communication equipment; and other essential components of the IOOS. This includes contributions from Non-Federal entities having an existing relationship with IOOS and leveraged assets or data that are accessible to, but not necessarily owned by, these entities.

The 3CV is estimated to be $54.2B. The percent of each component's contribution to the IOOS total cost is provided in Figure 2.2-1.

The total 15-year 3CV split by Central, Federal, and Non-Federal entity is summarized in Table 2.2-1, which shows the distribution of costs organized by the IOOS WBS presented in the CARD. A time-based profile of the 3CV is displayed in Figure 2.2-2, which shows the IOOS expenditure profile by year.

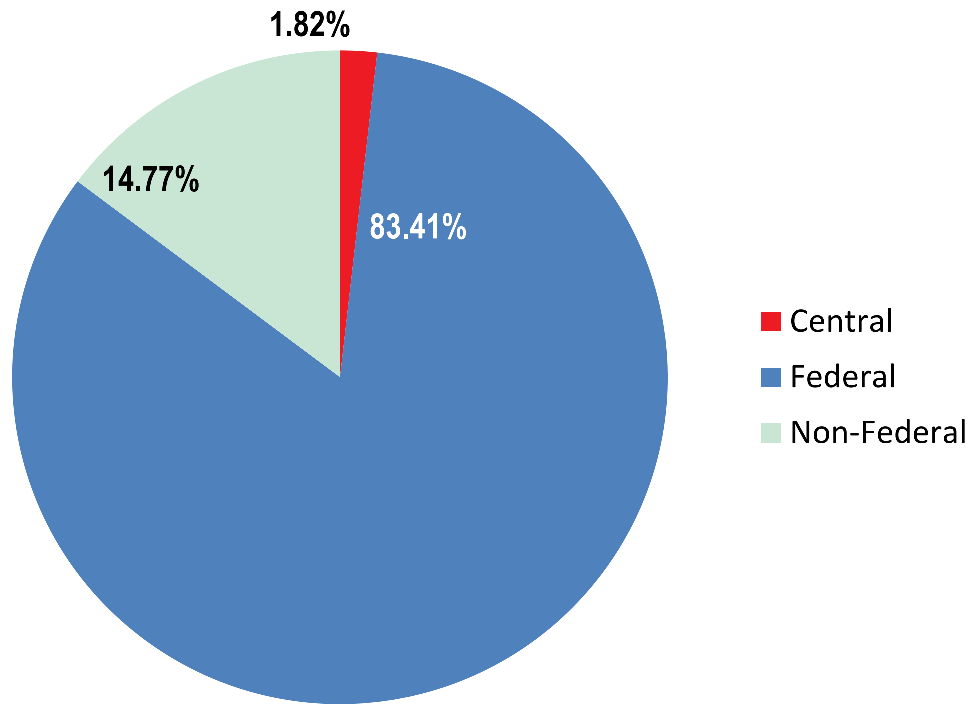


***Figure 2.2-1.*** *The Central Function role of design, implementation, and administration is estimated at $986M and is equal to less than 2% of the total 15-year 3CV cost estimate.*

**Table 2.2-1.** 3CV cost estimate by entity and work breakdown element (costs are inflated $M).

| IOOS WBS Element | | Central | Federal | Non-Federal | Total 3CV |
|---|---|---|---|---|---|
| **1.** | **Development** | **574** | **15,166** | **4,432** | **20,172** |
| 1.1 | Observing subsystems | 13 | 7,843 | 2,926 | 10,782 |
| 1.2 | Data management and communication (DMAC) | 337 | 2,289 | 248 | 2,873 |
| 1.3 | Modeling and analysis subsystem | 60 | 2,289 | 327 | 2,675 |
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| 1.5 | Research and development subsystem | 20 | 763 | 70 | 853 |
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| **2.** | **Operations and Sustainment** | **412** | **30,047** | **3,575** | **34,035** |
| 2.1 | Systems engineering and program management | 21 | 0 | 0 | 21 |
| 2.2 | System operations<br>[replication of 1.X functions in sustain mode] | **352** | **15,256** | **3,575** | **19,183** |
| 2.3 | Maintenance | 12 | 9,861 | 0 | 9,872 |
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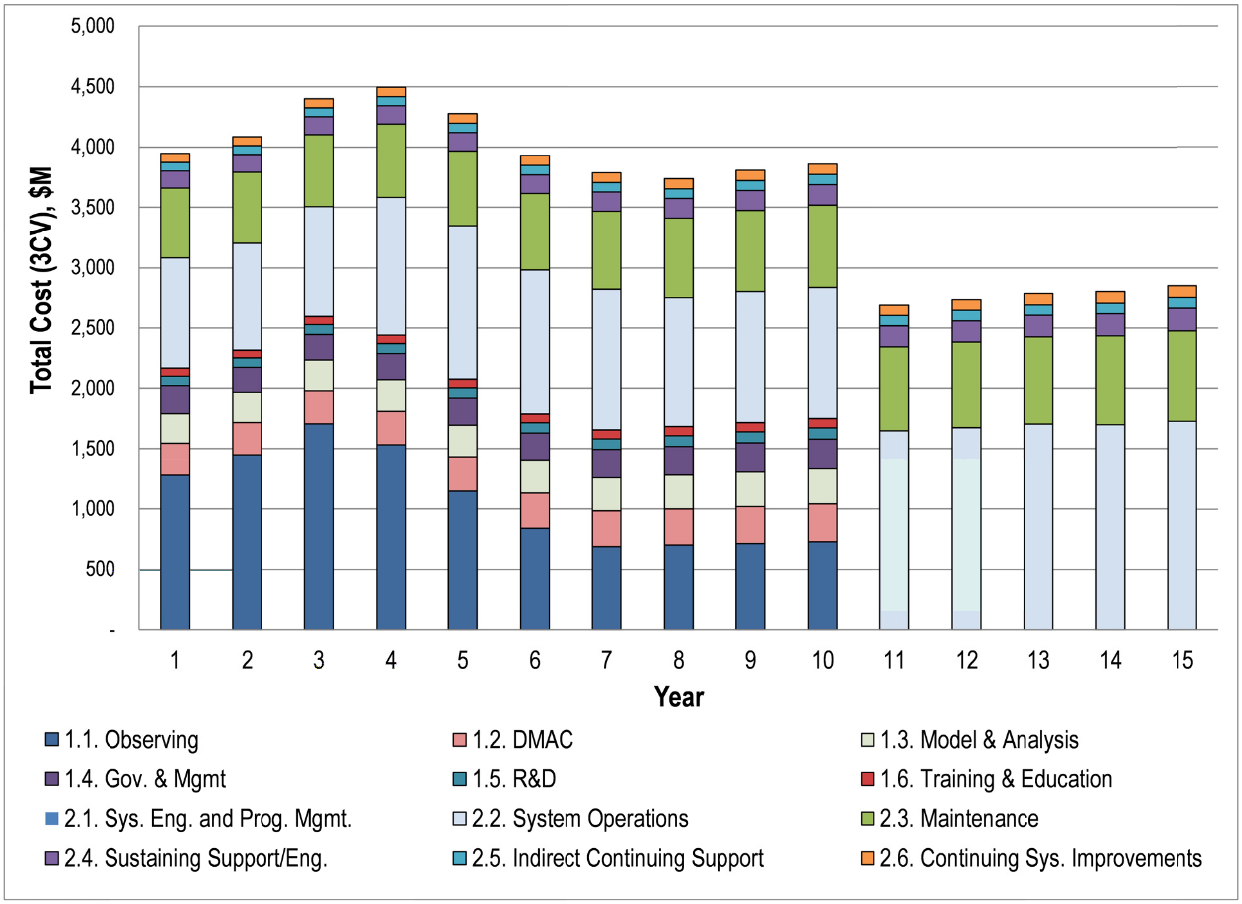
| 2.6 | Continuing system improvements | 27 | 1,233 | 0 | 1,260 |
| | **Total Inflated ($M)** | **986** | **45,214** | **8,007** | **54,206** |




*Footnote: WBS element 2.2 includes sustainment of 1.x functions. 1.x functions level of effort costs are carried through sustainment but have been re-allocated here per customer requirement.*

***Figure 2.2-2.*** *IOOS annual 3CV cost profile by WBS (units in inflated $M).*

## 2.3 Overall Risk Assessment

To meet the objectives stated in the CARD, a probabilistic S-curve (Sigmoid-curve) analysis was performed on the 3CV cost estimate. The S-curve provided a measure of variability present in the cost estimates, given uncertainties inherent in any cost assessment approach. A probabilistic simulation was used to capture the best- and worst-case scenarios for each cost element and the uncertainties of the IOOS pertaining to technical design, estimation approach, variability among cost inputs, and other external factors that could augment the overall uncertainty of the cost estimate. The intent of the S-curve was to provide a probabilistic cost assessment of the program. Primary inputs for the simulation were the minimum, maximum, and most likely costs for each WBS element.

The resulting S-curve is a blend of all probabilistic cost model estimates into a single common S-curve. As required by the CARD, cost estimates are to be provided at both 50th and 80th percentile confidence levels. Figure 2.3-1 displays the cumulative percentiles for the 3CV cost versus confidence level showing the median value at the 50th percentile. Based on the probabilistic distribution, the cost-confidence in the ICE estimate of $54.2B falls at the 55th percentile on the S-curve; the 50th percentile is at $52.9B and the 80th percentile is at $60.4B.

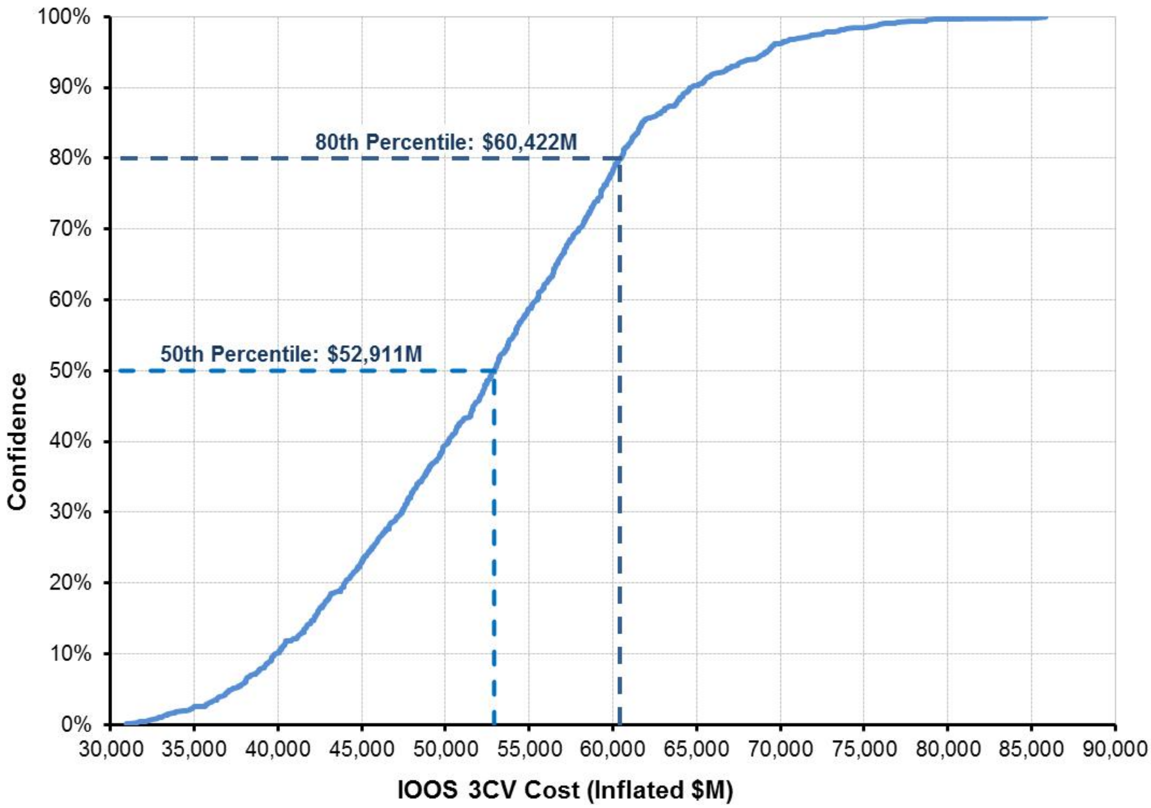



***Figure 2.3-1.*** *IOOS Probabilistic Distribution (S-curve) displaying the 50th and 80th percentile estimates.*

## 2.4 Summary of the Cost Estimating Methodology

The 3CV estimate was developed using a process tailored to the early design maturity of the IOOS and information available to the ICE team and drawing from JPL's experience in designing and implementing large data management systems (e.g., the Planetary Data System, PDS and the Physical Oceanography Distributed Active Archive Center, PO.DAAC). The cost estimate was organized according to the Work Breakdown Structure (WBS) presented in the CARD and reflected in Volume II, Section 7.2. The overall cost estimating process is depicted in Figure 2.4-1.

The cost process was initiated by reviewing all available documentation provided by the IOOS Program Office, which defined the system requirements, technical concept, and overall goals of the IOOS Program. Several iterations of the cost estimate were generated to assure a credible estimate for each WBS level 3 element.

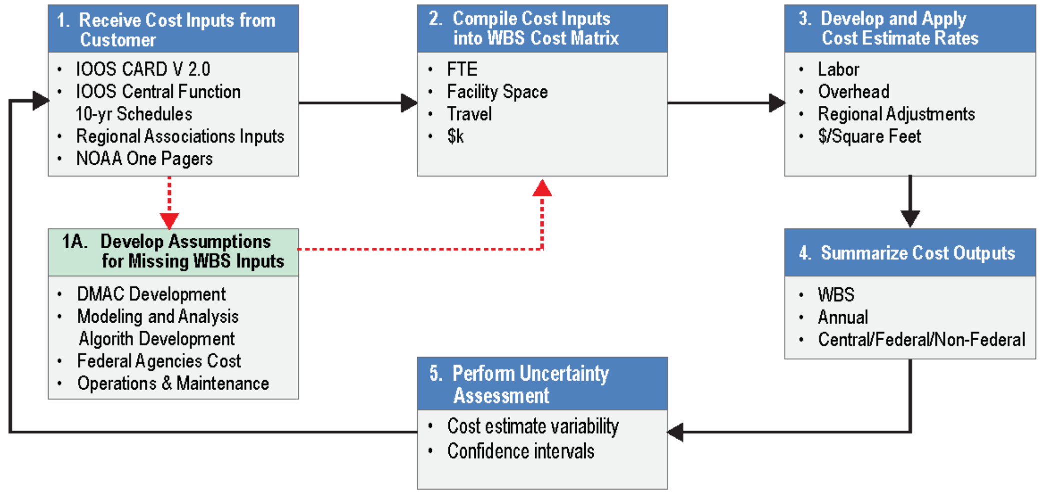



***Figure 2.4-1.*** *The 3CV estimate was developed using processes tailored to the information available for each WBS element.*

Building credible estimates required a series of cost reviews at progressive milestones to ensure completeness and accuracy as the estimate evolved. Functional and senior management assessed the 3CV estimate based on the technical and programmatic requirements set forth in the CARD. The reviews also addressed the feasibility and resulting cost realism of the estimate against the CARD requirements.

The ICE team's 3CV cost estimate was compared and reconciled with the Program Cost Estimate (PCE) in meetings that occurred during the week of March 26, 2012.

## 2.5 KEY COSTS AND DRIVERS

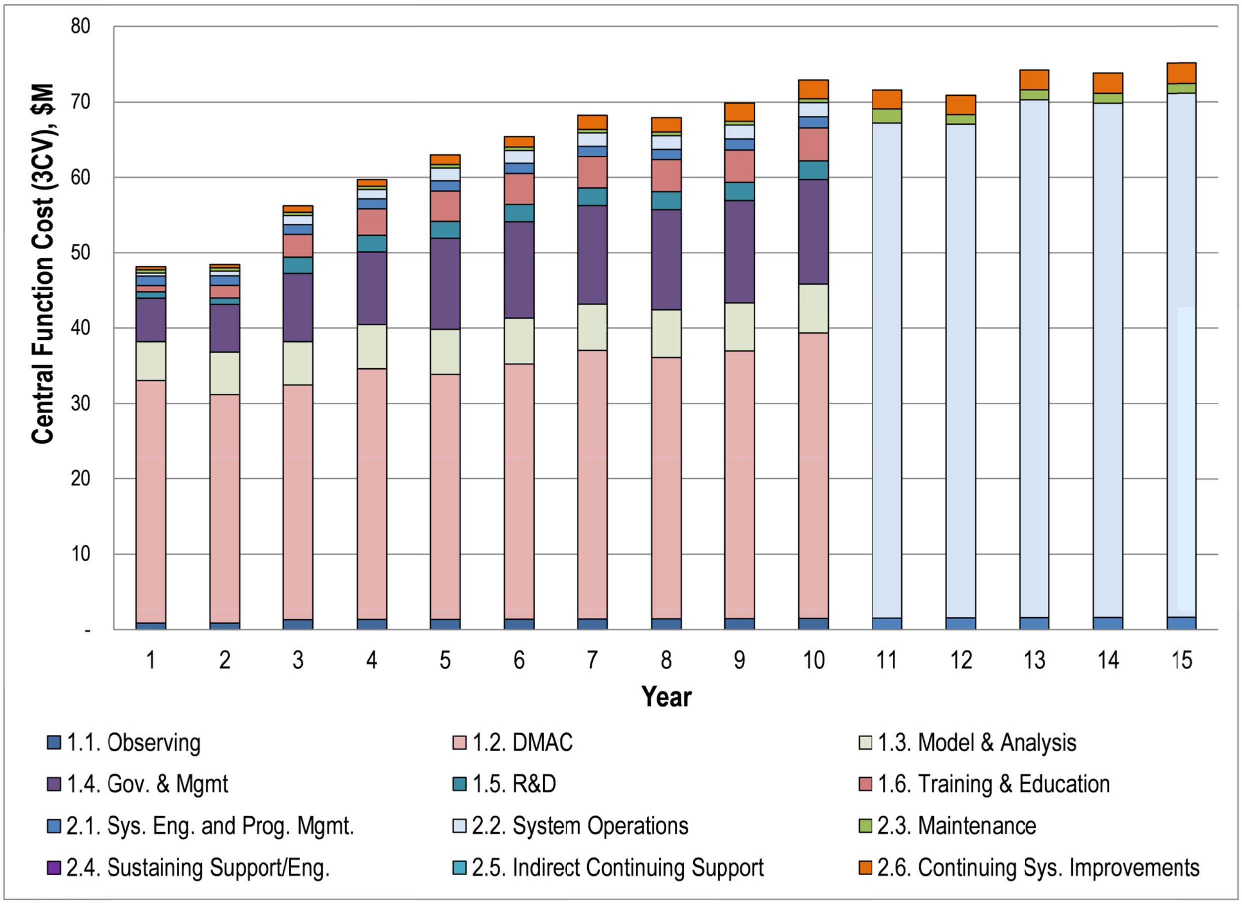
The key costs and drivers for the Central Function, and Federal and Non-Federal contributions are summarized below.

### 2.5.1 Key Costs and Drivers for the Central Function

The Central Function role of design, implementation, and administration of the IOOS is estimated at $986M and is equal to less than 2% of the total 15-year 3CV cost estimate. Figure 2.5.1-1 displays the annual cost profile plot of the Central Function. Year 1 cost is estimated at $48M, with the annual cost increasing to $75M by Year 15.

#### 2.5.1.1 Key Costs and Drivers for the Central DMAC Function

The DMAC buildout and sustainment cost comprises more than half of the Central Function estimate (53%) or $526M. Figure 2.5.1-2 presents the distribution of the Central Function costs between DMAC and Other costs associated with administration of IOOS. During buildout, years 1-10, the DMAC WBS functions were estimated to comprise approximately 59% of the Central Function's cost or $337M. During sustainment, years 11-15, the DMAC estimate is allocated under WBS 2.2 (System Operations). The DMAC estimate for sustainment is approximately $35M per year or about 46% of the WBS 2.2 estimated annual cost of $190M.




*Footnote: WBS element 2.2 includes sustainment of 1.x functions. 1.x functions level of effort costs are carried through sustainment but have been re-allocated here per customer requirement.*

***Figure 2.5.1-1:** Estimated annual cost profile for the Central Function (units in inflated $M).*

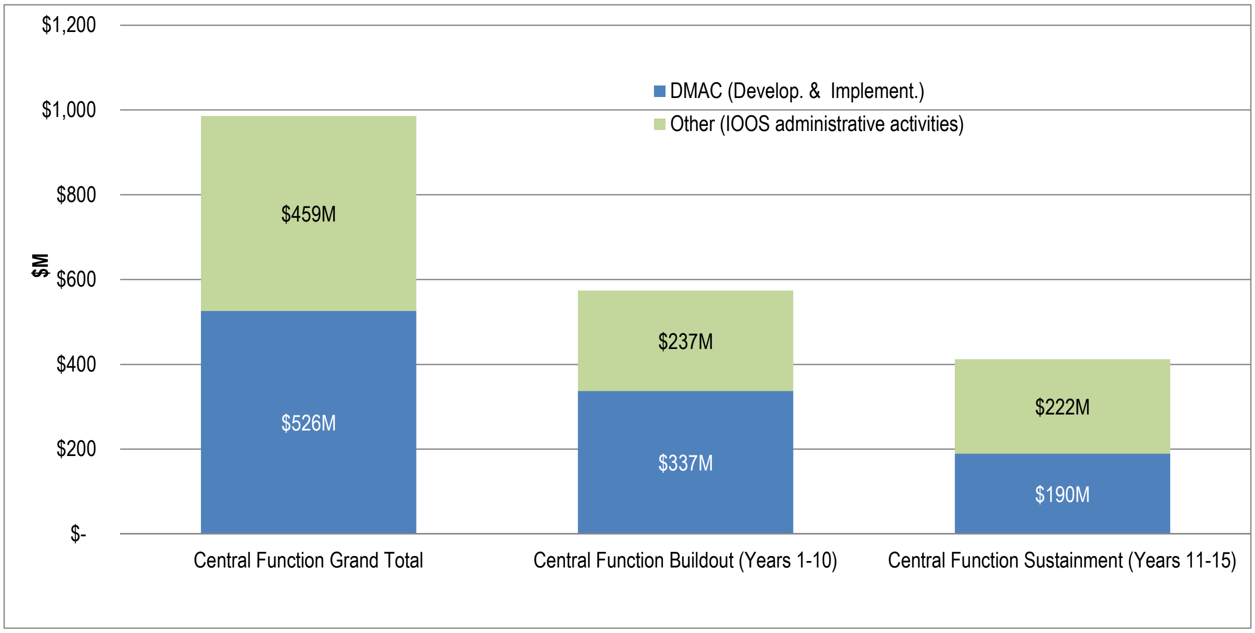



***Figure 2.5.1-2:** The largest component of the Central Function is the DMAC.*

### 2.5.1.2 Risk Assessment for the Central Function

The Central Function cost estimate is believed to be of low risk and low uncertainty because:

1 Estimated workforce detail for the central activities was provided in the CARD and Central Function 10-year schedule.

2 The DMAC estimate was based on existing architectures such as the Planetary Data System (PDS) and the Physical Oceanography Distributed Active Archive Center (PO.DAAC).

## 2.5.2 Key Costs and Drivers for Federal Contributions

As shown in Figure 2.2-1, the Federal contribution makes up 83% of the 3CV estimate, or $45B. The Federal contribution was modeled using an expert based approach built on an assessment of each agency's annual budget and a determination of that portion allocated for oceanographic contribution. The resulting estimate indicates that 98% of the Federal contribution is attributed to NOAA, NSF, NASA and ONR. The remaining Federal entities contribute the balance of IOOS assets and activities.

A base cost was identified for each Federal contributor. This base cost was then distributed into the IOOS WBS level 2 using the percentages summarized in Volume II, Table 6-4. The first percentage in the matrix of Table 6-4 identifies the cost split between the buildout (WBS 1.0) and sustainment (WBS 2.0) activities. The second percentage identifies the cost split within WBS 1.0 and 2.0 to the next lower WBS level.

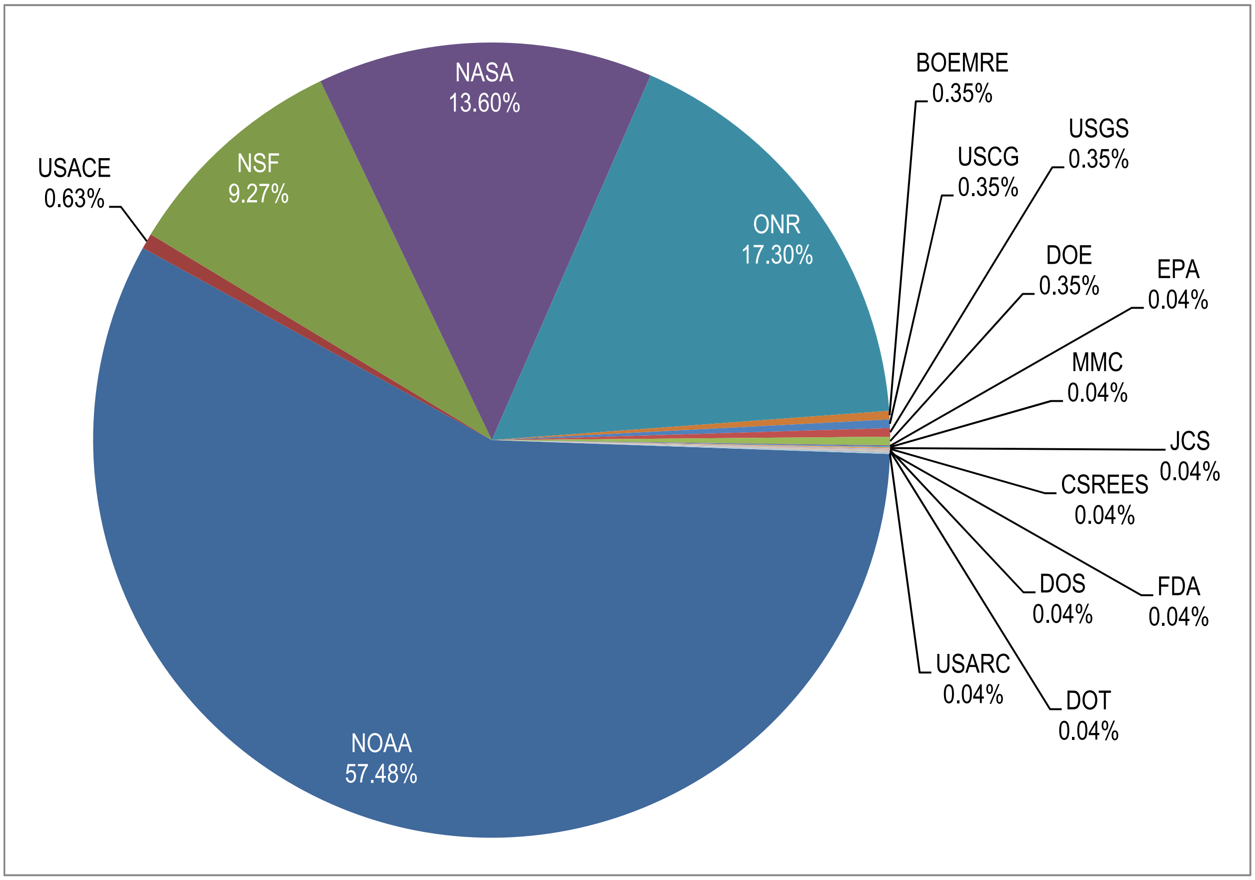



***Figure 2.5.2-1:*** *Estimated percentages of Federal contributions*

## 2.5.3 Key Costs and Drivers for the Non-Federal Contribution

The Non-Federal contribution is comprised of 11 Non-Federal Regional Associations plus the Alliance for Coastal Technologies (ACT). As shown in Figure 2.2-1, the Non-Federal contribution comprises approximately 15% of the 3CV estimate, equivalent to $8B. The Non-Federal cost estimate was derived from direct inputs provided in buildout plans submitted by each Regional Association to the IOOS Program Office. The buildout plans identified the priority products, information requirements, and the services required by their stakeholders. The cost inputs provided in the buildout documents were translated into the IOOS WBS. The Full-Time-Equivalents (FTE's) and direct dollars were provided as inputs. The ICE team used these inputs to estimate each Regional Association's contribution. The inputs were priced using rates and factors developed by the ICE team as described in Volume II, Section 3, Rate Development. The Non-Federal contributions are shown in Figure 2.5.3-1.

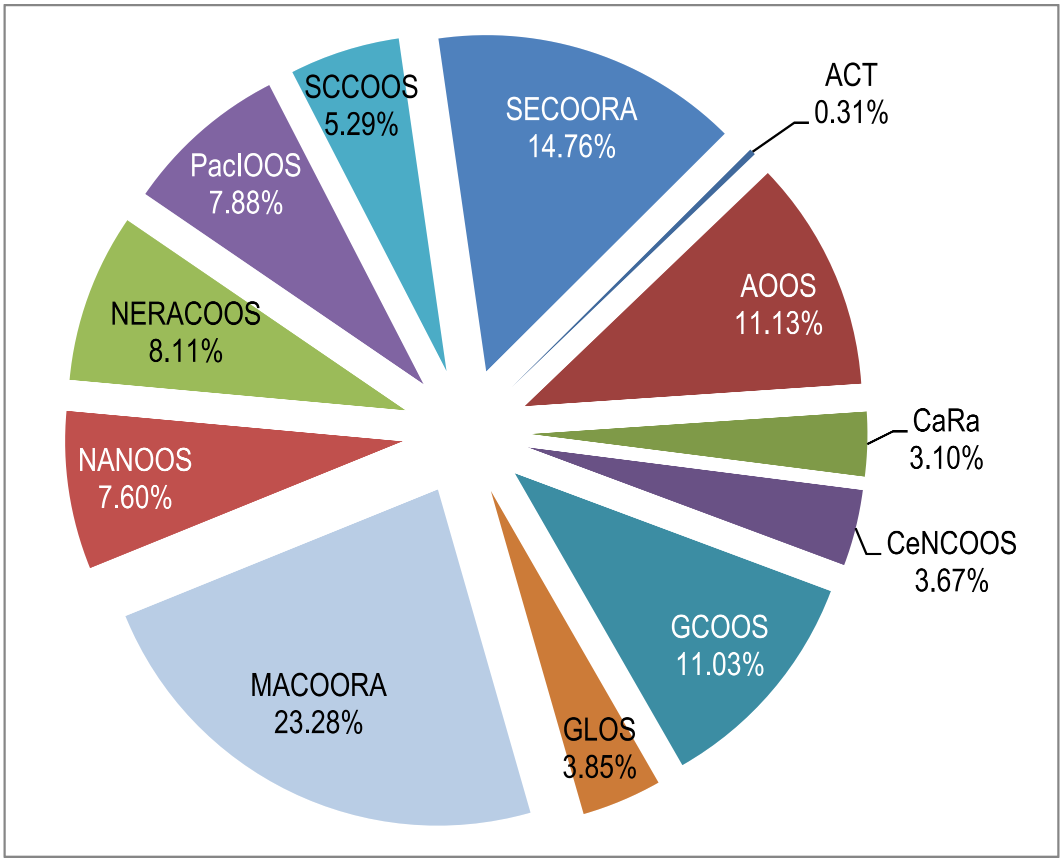



***Figure 2.5.3-1:*** *Estimated percentages of Non-Federal contributions.*

## 2.6 Summary Basis of Estimate

This section presents a basis of estimate summary broken down by major WBS category and contributor. For the Federal and Non-Federal contributions, a standard process was applied across all WBS elements based on the availability of data and the type of information that had to be processed. The standard processes are defined as follows:

- **Federal Standard BOE Process**: Expert assessment was used to categorize federal agency oceanographic contributions into major, average and minor groups. Total funding for agencies within each group was identified along with the portion allocated to oceanography. Each agency's allocated funding was then subdivided into the WBS structure by percentage. Refer to Volume II, Table 6-4. Parametric assumptions used to derive Federal contribution value by WBS, for more details.
- **Non-Federal Standard BOE Process**: The regions supplied summaries in the form of 11 plans. Costs include workforce, facilities, computing H/W, along with operations and maintenance (O&M). The O&M inputs were used for years 11 to 15 as sustainment cost.

The summary BOE for each WBS element is presented in Table 2.6-1 and captures any unique assumptions beyond the standard process.

**Table 2.6-1:** Summary Basis of Estimate for each WBS.

| WBS | Summary BOE |
|---|---|
| **1.1 Observing subsystems** | The observing system subsystem will serve as the source of U.S. IOOS-provided data. |
| ***Central*** | Workforce for the first 10 years of development was provided by IOOS in the form of an Excel file labeled "Central Functions_10 Year Sched_2011-0805.xlsx." Workforce staffing for years 11 to 15 were assumed to be a continuation of the workforce in year 10 of the development period. The Central Function facilities definition was supplied in the Card Report file "NOA72C10_00 IOOS CARD REPORT V2.0.pdf." Facilities were broken down into units of square feet and then priced by type and location including annual inflation factors. |
| ***Federal*** | Direct Input from NOAA and USACE. This was followed by the "Federal Standard BOE Process." |
| ***Non-Federal*** | Used the "Non-Federal Standard BOE Process". |
| **1.2 Data management and communication (DMAC)** | The DMAC subsystem will manage data provider and sponsored model participation and create, manage, and deliver IOOS DMAC-compliant data and utility services. |
| ***Central*** | JPL Estimate of DMAC buildout costs. The estimate cost drivers are as follows:<br>1. Major percentage of senior personnel required to meet delivery commitments within allotted timeframe.<br>2. Each DAC interface is estimated on a worst case basis with no commonality or code re-use.<br>3. Staffing level support incremental delivery on DAC integrations and resultant enhancements in the applications. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | Used the "Non-Federal Standard BOE Process." |
| **1.3 Modeling and analysis subsystem** | All users of U.S. IOOS receive their data/utility services through the processes defined in the Modeling and Analysis subsystem and use these processes to make their requirements known. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. Augmentation of costs with JPL Estimate of Algorithm Development costs.<br>1. Project Scientist required to support modeling and analysis.<br>2. M&A staff increases after development ends.<br>3. Sponsored models will require some rework to run in common environment.<br>4. Central model development requirements are unknown and not present in the requirements document. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | Used the "Non-Federal Standard BOE Process." |
| **1.4 Governance and management subsystem** | The governance and management subsystem will support U.S. IOOS in terms of guidance, resources, process, tools, and infrastructure. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | Used the "Non-Federal Standard BOE Process." |
| **1.5 Research and development subsystem** | The R&D subsystem will create R&D requirements, coordinate R&D programs, create processes, manage pilot projects and develop technology enhancements. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | Used the "Non-Federal Standard BOE Process." |

**Table 2.6-1:** Summary Basis of Estimate for each WBS.

| WBS | Summary BOE |
|---|---|
| **1.6 Training and education subsystem** | The training and education subsystem will manage development of U.S. IOOS specific training and educational materials to support the needs of training and education providers. These processes include development of training and education strategy, plans, and curriculum. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | Regional Association Subsystem Inputs. |
| **2.1 Systems engineering and program management** | The technical and management efforts of directing and controlling an integrated engineering effort for the project. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. Augmented with JPL Estimate for DMAC and Model & analysis S/s. |
| ***Federal*** | N/A |
| ***Non-Federal*** | N/A |
| **2.2 System operations** | Replication of 1.X functions in sustaining mode. Operational aspects of WBS 1.0. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. Augmented with JPL Estimate for DMAC and Model & analysis S/s. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | Regional Association Subsystem Inputs. Replication of 1.X Function in sustaining mode. Includes replication of all 1.X functions in sustainment mode. |
| **2.3 Maintenance** | Maintain current assets thru repairs and HW/SW replacement/refresh. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. Augmented with JPL Estimate for DMAC and Model & analysis S/s. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | N/A |
| **2.4 Sustaining support/engineering** | Respond to changes in operating environment and accommodate future growth, does not include new functionality or improvements. |
| ***Central*** | N/A |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | N/A |
| **2.5 Indirect continuing support** | Maintain a workforce pipeline, support training and education, and support follow on user training. |
| ***Central*** | N/A |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | N/A |
| **2.6 Continuing system improvements** | Improvements and new development to the operational system after initial system deployment. |
| ***Central*** | FTE inputs collected from Central Functions_10 Year Sched_2011-0805.xlsx. |
| ***Federal*** | Used the "Federal Standard BOE Process." |
| ***Non-Federal*** | N/A |

## 2.7 PROGRAM COST ESTIMATE RECONCILIATION

The requirement for reconciliation with the Program Cost Estimate (PCE) was part of the Statement of Work for the ICE development. The requirements of the reconciliation were:

1. The federal agencies involved in ocean observing will provide a Program Cost Estimate of the System to the Independent Cost Estimate team.
2. Provide an assessment of the alignment of the two cost estimates.

The PCE team and the ICE team delivered their initial estimates to the customer on March 15, 2012. At that time, the two estimates for the 3CV cost over the 15-year project duration were within 30% of each other, the PCE estimate was at $40.6B and the ICE estimate was at $54.6B.

During the reconciliation process each team presented their respective methodology and cost development process that raised a number of important differences in assumptions. The differences in assumptions were summarized with their cost impacts and, where appropriate, updates to the estimates were incorporated. The IOOS Program Office concurred with these adjustments based on clarifications or modifications of the cost assumptions. The main areas where differences arose included labor and facilities costs, regional asset costs, federal agency contributions, and cost growth profiles over time.

The differences due to labor and facilities were traced to the ICE assumption of a senior level engineering team (more expensive than a mixture of levels) with the cost of occupancy (facilities) included in the corporate overhead applied to all labor. The PCE team assumed a mixture of junior, mid-range and high pay staff with facilities accounted separately.

The differences in regional asset costs were traced to the fact that PCE did not receive any of the 11 regional buildout plans and had to synthesize regional costs from less detailed sources. The ICE team did have the 11 buildout plans and used the detailed data found in those documents.

The primary difference between the teams for federal agency contributions was the ICE team usage of a parametric approach leveraged with data from NOAA and USACE. The PCE team gathered cost data from publicly available sources and direct inputs from federal and non-federal components resulting in the biggest deviations between teams. After modification of some assumptions, the parametric approach was updated and then used by both teams.

The differences in cost-growth by the teams was mirrored by whether the team used data from the regional buildout plans or had to estimate the growth profile from a synthesis of the plans. The ICE team used the plans to quantify the assets for years 1-10 whereas the PCE team used the year 1 and year 10 values to interpolate a linear ramp-up over the interim years.

As a result of the reconciliation, the resulting PCE and the ICE estimates are within 5% agreement (as of April 23, 2012 the PCE estimate is at $56.4B while the ICE team estimate is at $54.2B).

# Section 3. Conclusions/Recommendations

The process of developing the ICE involved detailed review of the goals, plans and requirements of the core Central Function. It also compared the IOOS system design and functionality against comparable, highly distributed, functioning architectures. The review revealed opportunities and lessons learned from existing systems that could feed forward to improve the approach.

## 3.1 Conclusions of ICE

### 3.1.1 The Need for System Engineering

A key challenge for IOOS is the implementation of sufficient systems engineering discipline to perform technical oversight and interface definition and to ensure proper acquisition and utilization of the observational data. The key tasks and challenges include:

1. Merging the systems engineering and IOOS system architect functions in order to construct an IOOS Central Function consistent with program objectives while maintaining technical leadership.
2. Developing a comprehensive requirements hierarchy that captures the envisioned system concept and traces to specified data and operational needs.
3. Negotiating and establishing interface control documentation with each of the remote data acquisition systems and their organizations.
4. Envisioning, specifying and overseeing development of the Central Function DMAC software system architecture.

It is essential that the aforementioned tasks and challenges be managed under the cognizance of the Central Function system engineering office to maintain a focused development toward IOOS program goals. This approach benefits IOOS by establishing a well-defined, documented and internally consistent system design.

### 3.1.2 Requirements Definition and Breakdown

The IOOS is defined by a set of high-level functional requirements that provide a vision for the system. However, they must be refined and allocated to obtain a more detailed definition of the actual architecture to be implemented. IOOS should balance these requirements so they fully define the conceptual architecture without overly constraining or locking out feasible alternatives. Development of the requirements will involve important system tradeoffs. These trades include:

1. Interface versus metadata standardization implementation.
2. Full data ingestion by the Central Function versus relying on remote data acquisition storage.
3. Determination of the extent of modeling and data analyses tasks at the Central Function versus at the remote data acquisition centers.

4. Cost-benefit analysis comparing commercial "Cloud" computing resources versus developing and maintaining equivalent capability within the Central Function architecture.

### 3.1.3 Project Planning, Development and the WBS

An important aspect of the IOOS system design and buildout will be the development of an integrated management plan. The plan must contain a well-defined work breakdown structure (WBS) that captures the development work and follows it through operations and maintenance. To maximize cost effectiveness, the WBS and associated cost should be integrated with the development schedule. The integrated management plan will enable IOOS leads and decision-makers to have sufficient insight and project resource control to develop the Central Function on schedule and within cost.

## 3.2 Recommendations for Future Work

As the core Central Function DMAC comes online, it has the potential of becoming the "go to" source for oceanography and Great Lakes data as viewed by both government and commercial enterprises. Technology and observational assets will continue to evolve generating more sophisticated data sets and the need for the remote data acquisition centers to be upgraded. It will require an ongoing relationship between the Central Function and the DACs to accommodate these changes. It is highly recommended that the Central Function maximize the use of metadata "standards" for the remote data acquisition centers. A fundamental challenge for the Central Function is the need to interoperate with systems that have not adopted uniform standards. However, future systems should be designed based on core standards that allow for adaptations and interoperations with the IOOS. Given the 10-year buildout horizon, it is very likely that data acquisition centers will perform numerous upgrades providing repeated opportunities to evolve toward uniform data standards.

# Section 4. Definition of Terms Used in this Report

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|---|---|
| Buildout: | Years 1-10, the development period. |
| Sustainment: | Years 11-15, the operations and maintenance period. |
| DAC: | Data Assembly Center. Collective term for all data assembly centers, archives, sponsored models, national backbone data systems, regional data centers, data archive centers, data acquisition centers, data repositories that will be connected via the IOOS DMAC. |
| Customer: | The IOOS and the IOOC, with direction provided by the Deputy Director of IOOS. |
| Central Function: | The IOOS central organization, IOOS central offices. |
| DMAC: | Data Management and Communication Function. |
| Federal Contributor: | Collective term for participating federal agencies, federal assets, federal partners. |
| Federal Contribution: | Collective term for costs associated with Federal Contributors. |
| Non-Federal Contributor: | Collective term for participating non-federal entities, regional associations, regional partners, regional assets. |
| Non-Federal Contribution: | Collective term for costs associated with Non-Federal Contributors. |
| Three Component Value (3CV): | Combined value of Central Function costs, Federal Contributions, and Non-Federal Contributions. |