

An Interagency Collaboration toward the Integrated Ocean Observing System

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Abstract - The National Oceanographic and Atmospheric Administration (NOAA) and the Naval Meteorology and Oceanography Command (NAVMETOCOM) intend to collaborate on software architectures used to enable the processing and dissemination of scientific data and products for their respective missions. This collaboration supports the goals of the U.S. Integrated Ocean Observing System (IOOS). This paper explores some potential areas and approaches for collaboration, enabled by the Service Oriented Architecture model.

I. INTRODUCTION

Addressing data integration from disparate Department of Defense (DoD), Federal and non-federal systems raises many collaboration issues beyond those encountered in typical data integration scenarios. At the OCEANS US Airlie House workshop in 2002 [1], a number of Federal Agencies (the National Oceanographic and Atmospheric Administration (NOAA), Navy, the Environmental Protection Agency (EPA), et al) and academic institutions identified the need for a coordinated network of people and technology that would work together to generate and disseminate continuous data on our coastal waters, Great Lakes, and oceans. This group recognized the need to collect and integrate this data in a manner that would ensure it could be used to better characterize and understand our Nation's oceans and coasts. This vision was formalized in December 2006, when the NOAA Executive Council and NOAA Executive Panel approved the formation of NOAA's Integrated Ocean Observing System (IOOS) Program within the National Ocean Service.

IOOS is a major shift in our approach to ocean observing, drawing together many networks of disparate Federal and non-Federal observing systems into a "system of systems" to produce data, information, and products of common interest at the scales needed to support decision making. Once completed, IOOS will be a nationally important infrastructure enabling many different users to monitor and predict changes in coastal and ocean environments and ecosystems. This infrastructure is critical to understanding, responding, and adapting to the effects of severe weather, global-to-regional climate variability, and natural hazards.

The development of an integrated data management system for rapid access to diverse data from disparate sources is the current highest priority for IOOS implementation. The IOOS interface for most users will be through the Data Management and Communications subsystem (DMAC). The DMAC will knit together the global and coastal components of the IOOS and will link every part of the observing system from the instruments to the users, and will contribute to defining the quality of the end products. The DMAC subsystem is required to transmit multidisciplinary, multi-media observations from a broad range of platforms, and transmit them (in real-time, near- real-time, and delayed modes) directly to users for processing into maps, plots, forecasts, and other useful forms of information. The goal is to link data from buoys, autonomous drifters and vehicles, ships, aircraft, satellites, observatories, and other platforms to models (e.g., GIS, numerical models, statistical models) for rapid analysis and product delivery, while

ensuring data quality and usability. The DMAC subsystem consists of several components including data transport and quality control; data assembly and metadata management; data archeology, discovery, archival, and product development; and associated administrative functions.

This paper represents the collaboration efforts of two agencies that are participants in the IOOS/DMAC program: the Naval Meteorology and Oceanography Command (NAVMETOCCOM) and the National Oceanic and Atmospheric Administration (NOAA) IOOS Program Office. To promote the interagency fielding of the IOOS DMAC, NAVMETOCCOM and NOAA have entered into agreement to collaborate on providing respective system architectures and design, software baselines, and requisite resident expertise to a common DMAC baseline. This paper describes the IOOS/DMAC background, the respective capacities of the agencies, and the activities to be conducted under the terms of the interagency agreement, along with the anticipated results.

II. TECHNICAL SUMMARIES OF EXISTING PROGRAMS

NAVMETOCCOM maintains a software capability that can, in part, satisfy the DMAC baseline requirements, as follows. The NAVY METOC Data Services Framework (NMDSF) provides authoritative Naval meteorological and oceanographic (METOC) data to the Global Information Grid (GIG) through a Jointly defined Community of Interest (COI) interface. The NMDSF was initiated to support the migration of METOC community data integration mechanisms to align with the tenets of the GIG's Net-Centric Data and Services Strategies.

Traditionally, tactical decision aids and other applications have been tightly coupled to METOC data sources through point-to-point interfaces. To better align with the Net-Centric Data & Service Strategies, the METOC community required a process to virtually integrate distributed data stores into a single, METOC Shared Space Environment. METOC Shared Spaces must allow posted data to be discoverable, visible, accessible, and understandable to consumers. Further, applications that access the data should be loosely-coupled with regard to the physical location and identification of the providing node. Three components are needed to achieve these goals: a standard data request/response vocabulary, service endpoints that implement the standard, and an infrastructure that supports routing to distributed provider data stores and synthesis of multiple responses into one for the consumer.

The requirement for a standard data request/response vocabulary was addressed by the Joint METOC Board Data Management Working Group who defined the Joint METOC Broker Language (JMBL). JMBL is implemented in Extensible Markup Language (XML) and consists of a series of DoD registered schema that define a platform neutral Web service for communicating both requests for METOC data and corresponding responses. JMBL provides a uniform request/response message format for Web Services to implement access to METOC data. JMBL supports a service oriented architecture implementation for the METOC enterprise and is now registered in the DoD IT Standards Registry (DISR) and listed there as mandated. The second and third components are enabled by the NMDSF design and implementation. This framework is being used to transform proprietary data access into an open architecture-compliant enterprise level data service consistent with principles of a Service Oriented Architecture.

Establishment of NOAA's IOOS Program provided for a Data Integration Framework (DIF) project with a nominal duration of three years, from February 1, 2007 to February 1, 2010 [2]. The DIF was originally limited in scope and scale to the integration of data from three NOAA sources of five core IOOS variables to address the requirements of four ocean decision-support tools that span multiple NOAA mission goals [3, 4, 5]. Shortly after project inception, the list of core variables to be addressed was expanded to seven; water temperature, salinity, water level, ocean color, water currents, winds and waves. The DIF project objectives are:

- Validate the premise that integrated data has value that can be measured.
- Utilizing the principles of IOOS Data Management and Communications (DMAC), develop a methodology to improve upon existing ocean data integration efforts that will facilitate flexibility and extensibility to other variables, systems and decision-support tools.

- Achieve improved integration of selected data sets by identifying, adopting, and adapting community-developed standards for data content, metadata, quality control, and transport and deploying these standards at selected data sources serving the four decision-support tools.
- Maintain the DIF for a period of three years, from project inception, to conduct adequate performance monitoring and assessment for evaluating and measuring progress.

III. ADOPTION OF NAVMETOCCOM SERVICE ORIENTED ARCHITECTURE STRUCTURES

This section describes the characteristics of Service Oriented Architectures in general, those of the Navy METOC SOA and the proposed adaptation to the IOOS/DIF implementation. [6, 7]

Implementation of a net-centric architecture requires a transformation of IT assets from platform-centric, standalone applications/databases/systems to Web-based applications, net-accessible services, virtual shared data spaces, and a broker to support loosely-coupled integration between collaborating components. A significant enabler of this architectural transformation is the creation of the net-accessible services and integration broker that supports loosely-coupled integration within and across organizational/enterprise boundaries. These mechanisms are the essence of the SOA design pattern.

SOA as a design pattern does not apply to all aspects of IT in an enterprise; only those concerned with creating an agile integration mechanism between capabilities implemented using differing technologies and/or implemented across organizational/enterprise boundaries. In other words, SOA operates at the edge of an organization's IT capabilities by exposing those capabilities and selected associated data most relevant to integration with multiple internal or external entities. SOA can be realized by identifying "major integration points" for internal and external integrations. To wit, the following concepts apply to the common architecture:

- Integration between the Naval METOC Domain, NOAA IOOS and Consumers should use SOA to realize integration requirements. Implementation should provide access to METOC and IOOS capabilities without regard to actual physical location of the capability within respective domains .
- Integration between the physical METOC production centers (FNMOC and NAVO) and IOOS should use SOA to realize integration requirements.
- Integration between Sensor Nodes and applications and databases at a virtual IOOS Production Center node should be done via SOA. Implementation should loosely-couple the actual physical location of the sensor node(s) and the specific physical location of the applications/databases at the physical METOC production centers.

SOA allows creation of new capabilities by composing reusable functionality hosted at various nodes on the enterprise/domain network and/or other accessible networks. This reusable functionality is made available via published "service" interface descriptions that any interested and authorized consumer can discover and access. Three key architectural components are required in an SOA implementation to enable service providers to effectively interact with a broad and diverse collection of consumers: the Service Integration Layer, the Enterprise Service Bus, and the Service Endpoint Infrastructure.

Service Integration Layer (SIL)

A SOA assures that any consumer can talk to any provider through service interfaces, even in cases where their IT infrastructures are based upon different computing servers, operating systems, or programming languages. This capability is provided by the critical design characteristic of SOA referred to as "loose-coupling". In this case, providers and consumers are loosely-coupled with respect to their implementation technologies. SOA provides this by requiring that service interface descriptions are based upon well known, published standards that are broadly implemented by most if not all IT vendors. The SOA architectural component called the SIL is intended to provide a coherent, mutually supportive, set of open service interface descriptions that represent the "major integration points" to an organization's capabilities. A major integration point is one where the underlying functionality or data has significant use (and/or reuse

potential) across the internal METOC or IOOS Domains. This layer, specified for the Navy METOC Domain's portfolio of METOC COI services is referred to as the METOC Enterprise Service Integration Layer (MESIL).

Service interface designs shall be influenced not only by the functionality to be provided by the service but also by the structure of the MESIL itself. The MESIL structure shall reflect the requirement that service interfaces should be reusable in multiple contexts and should provide a degree of abstraction and loose-coupling between operational process logic and technology specific application logic. This indicates that it may be appropriate to partition the MESIL into multiple service layers. For example, one such layering is reflected in the following service taxonomy:

- **Orchestration Services:** These contain workflow logic for specific processes and sub-processes. These should link directly to process specifications of the customer and/or METOC/IOOS production processes.
- **Business Task/Entity Services:** These encapsulate a coherent, specific, but significant single business task or entity that is best accessed via a SOA service interface. These services will not contain workflow logic so that it will be reusable across multiple processes.
- **Application Utility Services:** These map fairly directly to reusable infrastructure capability that is common to many needs.

Enterprise Service Bus (ESB)

In order to achieve the stated goals of SOA and net-centricity in general, the design characteristic of loose-coupling has to be extended to other facets of provider/consumer interactions. For example, by providing an architectural component that handles data format conversions between the consumer and provider, SOA can support "loose-coupling" with regard to data formats. This sort of negotiation/translation can also be extended to other facets of provider/consumer interactions such as security and network access protocols. Together, these types of brokering services are referred to as mediation services.

In a net-centric environment, consumers should not be tightly coupled to a provider's specific location, or even identity. This gives great flexibility in where to deploy a capability on the network and supports access to alternate service providers based upon enhanced performance needs. Providing a message broker capability between consumers and providers extends the trait of loose-coupling to location and provider identity transparency.

Finally, enabling a level of comfort for Program Managers to use services provided by other programs and organizations requires very clear service contracts, called Service Level Agreements (SLAs), and mechanisms to monitor compliance and mitigate degradation of performance. This suite of services is called Enterprise Services Management (ESM).

The SOA architectural component that hosts the capabilities is referred to as an ESB. This architectural component is called METOC community of interest Service Bus (MCSB).

Service Endpoint Infrastructure

The third enabling element of an SOA consists of those things required to actually implement the service interfaces described in the SIL. These components are attached to SOA architectural components called Service Endpoints; locations on the network where the SIL interfaces are implemented with scalable software components, middleware infrastructure (application servers w/ XML and web service toolsets), and server infrastructure. In the METOC Domain this is referred to as Node Integration Infrastructure (NII). The Naval METOC Domain will deploy such integration infrastructure at each physical node that must integrate with the DoD's Global Information Grid (GIG) and host Naval METOC services. In addition, while the Naval METOC Domain will physically host NCES type services, additional hosting infrastructure will be provided at METOC Production Center nodes for these core services. Core Services integration infrastructure will federate across multiple nodes to support the realization of a single virtual node for the Domain.

To connect nodes together in a METOC SOA, the following concepts apply:

- Naval METOC will provide content to a Department of Navy and/or DoD Enterprise Portal via “Remote Portlets” hosted at NAVMETOCCOM nodes –or– code will be hosted directly at a DON/DoD Portal Site.
- Discoverable COI Service Interfaces will expose METOC capability to providers/consumers.
- A collection of common core services will support reliable, loose-coupled, secure interactions between service providers and consumers. These will be accessible at a single, virtual access point for machine-to-machine (M2M) interactions. It is expected that DoD will provide the bulk of these capabilities, but Naval METOC (like other enterprises or domains) will be required to host some of these capabilities. Without an ESB, a SOA environment can repeat the problem of a plethora of P2P interfaces that make for the brittle, less agile IT environment that exists today
- The emergence of DoD Core Services and Naval METOC Core Services must be coordinated, both in a strategic and technical sense. The ESB Bridge represents both of these needs.

The implementation of the principles cited above in the NAVMETOCCOM architecture is shown in Figure 1.

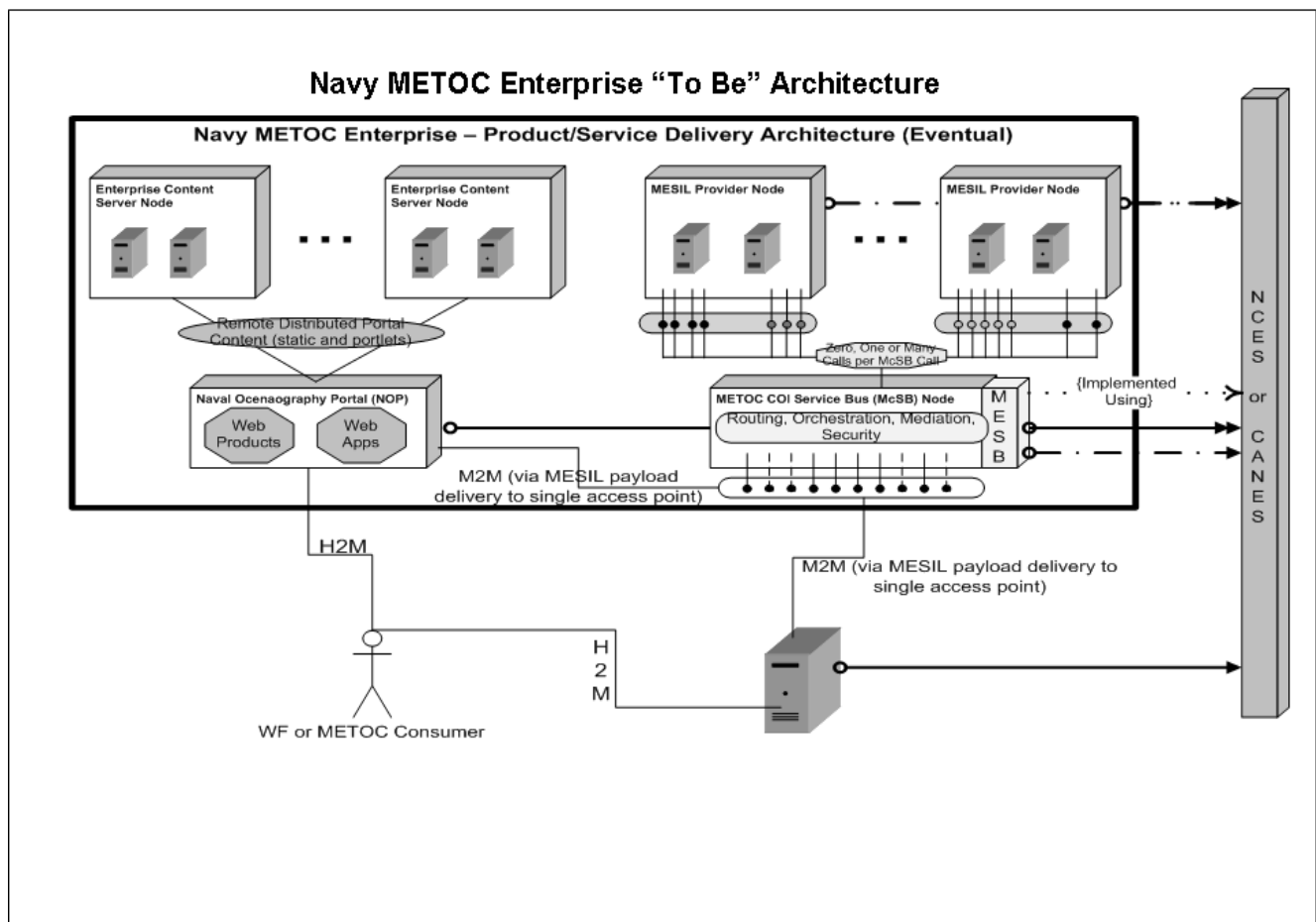


Figure 1. Navy METOC Enterprise “To Be” Architecture

IV. ADAPTATION OF NAVY METOC CONSTRUCTS TO IOOS/DIF

Referencing the SOA principles cited above, the following observations are tendered concerning NOAA IOOS DMAC:

- DIF is largely focused as an ingest engine to ingest parameters of varying complexity (point, image, map coverage) from external sensors and servers.
- The integration from Sensor Nodes to aggregation points is currently apparent in the DIF through the experimental use of the Sensor Observation Services, an open source interface standard developed within the OGC community that provides an API for managing deployed sensors and retrieving sensor observations
- DIF provides means to integrate multiples of instances of information objects into stratified data bases that are further parsed into the seven core variables.
- DIF is a subset of a larger architectural strategy for DMAC, to include SOA implementation.
- Much of the functionality of the Navy METOC Data Services Framework (NMDSF) is directly applicable to the Utility Services layer of the IOOS architecture, specifically for “Service Gateway” and “Data Integration.”
- The SOA attribute of composability will allow the integration and loose coupling of NAVMETOCCOM SOA components with the DIF framework.
- The Service Gateway of the DIF architecture equates to the Service Integration Layer.

Our approach for integrating the planned Naval METOC SOA constructs is not unique to NAVMETOCCOM. This approach has applicability to a broader range of programs, in particular to the IOOS DMAC. Therefore, the following general approaches are proposed for this collaboration:

1. Application of SOA practices to DIF.
2. Implementation of NAVMETOCCOM-like data services framework.
3. Instantiation of publicly releasable NAVMETOCCOM data in DIF.

The overall consolidation of these points is reflected in the Figure 2. Figure 2 shows a representation of several service layers that would comprise a hypothetical IOOS. The far right of the diagram depicts actual instances of working functional capabilities in use by NAVMETOCCOM that can be used to instantiate the components to which they are connected by a single line. For example, NMDSF is a multi-faceted component that meets part or all of the requirements for Service Gateway, Data Integration, Enterprise Service Integration Layer, and Enterprise Service Bus. The dashed lines represent an example data flow. In this case, data from the Wave Watch 3 model, operated by Fleet Numerical Meteorology and Oceanography Center, passes in the form of regular grids via NMDSF, to support the Coastal Inundation Model. This approach will allow NOAA to make use of various types of publicly-releasable information produced by NAVMETOCCOM.

Much of the specificity for this sharing of services is yet to be defined, but the generality that is enabled through the use of SOA allows these services to be combined in a way that can satisfy many of the IOOS requirements through re-use of existing software. The general SOA principles of encapsulation, abstraction, loose coupling, composability, and reusability will provide economies that will enhance the abilities of NOAA and NAVMETOCCOM to deliver mutual IOOS capabilities.

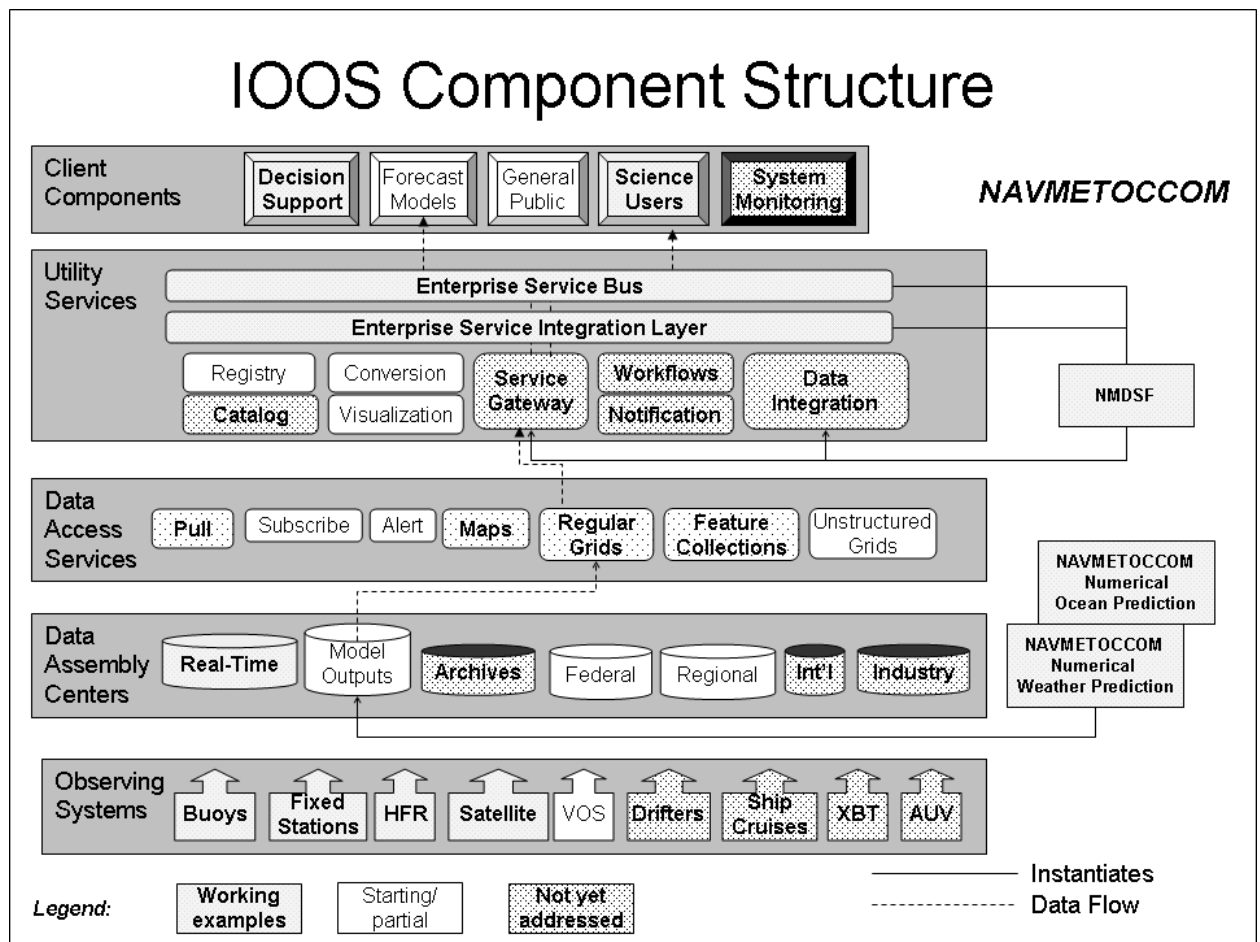


Figure 2. IOOS Component Structure with NAVMETOCCOM analogues

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