



December 23, 2011

Dear Dr. Lubchenco:

On behalf of the Science Advisory Board (SAB), I am very pleased to provide you with the attached report, *Towards Open Weather and Climate Services*. The report was developed by the SAB's Environmental Information Services Working Group (EISWG), reviewed and accepted by the Board, and now forwarded to you for consideration for National Oceanic and Atmospheric Administration (NOAA) implementation. The report addresses opportunities for our nation to derive greater value from NOAA's weather and climate information and services. It focuses specifically on a new paradigm that would allow for a significantly richer and deeper engagement of the nation's broad and diverse Weather and Climate Enterprise with NOAA, its data services, and its technology development. The report includes three specific recommendations for action by NOAA that will move the Agency towards the open weather and climate services paradigm envisioned in the report.

The Board received the report and deliberated on its merits at our November 2011 meeting. The SAB was strongly aligned with the intentions and concepts of the report. Formally, the Board has voted to accept the report and transmit it to NOAA for review and response. However, the Board's deliberations recognized many of the challenges identified in the report that NOAA must face in implementing the open weather and climate services paradigm. Therefore, the Board transmits this report to NOAA with the understanding that NOAA will first need to examine the cost, technical, legal, and architectural challenges associated with the implementation of this important concept. This could be done on a case-by-case basis or possibly through pilot projects. The SAB Members also felt strongly that the Academic research community along with the U.S. private sector be considered and engaged in this implementation. The Science Advisory Board is very excited about the prospects and potential of the open weather and climate services paradigm for the Agency and our nation. There appears to be very strong support from within NOAA—and particularly at the National Weather Service—for the report's objectives and an eagerness to identify ways in which the concepts can be implemented. The Board looks forward to the Agency's response and stands ready to provide additional input as may be helpful.

Regards,

A handwritten signature in black ink, appearing to read 'RJB', is positioned above the printed name.

Raymond J. Ban

Chair, NOAA Science Advisory Board

Consultant, Weather Industry & Government Partnerships

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Towards Open Weather and Climate Services

A report from the NOAA Science Advisory Board

December 2011

Executive Summary

Our nation enjoys one of the most robust, modern and accessible weather and climate services in the world through the National Weather Service (NWS) and other line offices of NOAA. However, the Nation has yet to realize the full value of NOAA's weather and climate services for two principal reasons. First, various barriers inhibit the ability of NOAA to distribute or otherwise make available all of its weather and climate information, particularly high-resolution datasets such as numerical weather prediction model output, satellite and radar data. Second, new technology and services are not developed within NOAA in a sufficiently symbiotic manner with the broader community such that optimized value from that new service or technology to society is quickly realized. An Open Weather and Climate Services ("Open WCS") is proposed in which both NOAA and the community share equal and full access to NOAA information and development. Although it may be difficult to achieve a fully Open WCS paradigm, it is recommended that NOAA adopt a core philosophy of instituting this concept whenever and wherever possible. Recognizing that numerous challenges exist (including security, cost, development efficiency, and fair access), it is believed that none of these issues are significant enough or without reasonable solutions to prevent NOAA from moving forward on this concept. NOAA should quickly develop approaches to implementing Open WCS incrementally in areas where the paradigm can quickly and easily be employed such that the Weather and Climate Enterprise can begin to derive value from the paradigm soon. Previous endeavors and actions that have opened information services have proven to be enormously successful and beneficial to society and that is expected to be the case here too.

Introduction

The National Weather Service (NWS) is the world's leader in the creation and distribution of weather data and related information. It sets the global standard for the breadth of the data services offered and relative ease by which the public may access that information. The NWS does not charge users for its weather and climate data in any circumstances, although in some cases nominal charges are levied to cover the costs of communicating the information to the end user. This paradigm of free and easy access to weather information is not uniform in the rest of the world and more often is the exception than the rule. The NWS model clearly establishes the

“gold standard” with regard to open access to weather data. More broadly, the NWS model generally applies to many of the other weather and climate related divisions of NOAA also including the National Environmental Satellite, Data and Information Service (NESDIS) and the Office of Oceanic and Atmospheric Research (OAR). For example, the Climate Prediction Center is partnering with NESDIS and OAR to provide enhanced and free access to retrospective data via a Climate Services Portal.

Despite this leadership relative to the rest of the world, NOAA does not achieve ubiquitous, open access to all of its weather and climate information. In fact, specific to weather, only a tiny fraction of all NOAA information is actually made available by the NWS for use outside of the agency (or even elsewhere within the agency in many cases). Hence, today NOAA does not have universal, open access to all of its weather information. Practical limitations are the most common reason why NOAA does not make all of its data readily available, although this is not the only reason. Regardless of any eventual changes that NOAA might make as a result of this white paper, there is a need for NOAA to develop a data policy that defines access to its information in general, and also provides procedures and guidelines for determining which portions of its data should be made available.

Without universal access to all NOAA weather and climate information, our nation is not realizing the full value of its investment in NOAA. Specific to the NWS, the lack of universal access to NWS information inhibits the NWS from carrying out its core mission of protecting life and property and enhancing the national economy. This is because it is through and in partnership with the broader Weather and Climate Enterprise outside of the NWS (consisting of academic and research institutions, private-sector members of the weather industry including as the media, NWS interagency partners and the general public) where value from NWS information is generally realized and the mission of the NWS is fulfilled. Limiting the amount of weather information made available to the Enterprise necessarily limits the degree of value-added benefits that the Enterprise can provide to society, as well as the ability to use the information in basic and applied research to further enhance the value of the NWS to society. It also prevents the fullest possible prevention of loss of life and property by limiting creativity within the weather Enterprise in developing methods to best use the information to serve that purpose. Enhanced access to NWS information will improve the societal benefits of weather information and therefore help justify further investment in the NWS and NOAA.

Limitations in the availability of NOAA information to the Weather and Climate Enterprise are largely due to practical considerations and not any systematic censoring policy by the agency. In many cases the sheer enormity of the pace of creation of new information can overwhelm the ability to process, store and communicate that information outside of the various NOAA agencies. In some cases, there not have established mechanisms to propagate the information and this is particularly true for systems and services under development and testing by the NWS. These practical limitations force agencies to make decisions on the priority of the information that it can publish. The necessary filtering process that takes place as a result of that

prioritization is fundamentally the reason why the NOAA supplies only a fraction of the information it creates and/or possesses.

Incomplete access to NOAA information is not restricted solely to real-time weather data from the NWS, but often extends to access to emerging new technology and information systems (e.g. new numerical weather prediction (NWP) models and atmospheric observing systems) that are under development. More specifically, the typical NOAA process for developing and deploying new sources of weather information tends to be serial. That is, while NOAA develops the new technology, access to that technology and the information it creates is largely limited to the developers of the technology. For example, the NWS develops algorithms that will take advantage of the new dual-polarization capabilities of the NEXRAD radars, but the process and any preliminary outputs of those algorithms are generally not available to the Enterprise. Eventually, NOAA typically places new technologies into a semi-operational, beta-testing state in which a subset of the system's information is made available to the Enterprise. The Enterprise is then encouraged to use the testing period to create and adapt their systems to the new technology and evaluate its outputs. However, at this point there is usually very little that the Enterprise can do to influence the technology itself and therefore it largely plays a passive role in the development process. The limited accessibility to the new technology, particularly during the development phase, limits the timeliness by which the Enterprise can create and deliver value-added products to society. It also limits the ability for the Enterprise to drive new research based on the new technology, and to incorporate the new information from the technology in education. Overall, these obstacles reduce the net efficacy that the technology realizes over that achievable if NOAA and the Enterprise were to undertake development and evaluation in a more parallel and symbiotic process.

The purpose of this white paper is to more deeply examine the issues of limited access to NOAA information by the Weather and Climate Enterprise, to propose new concepts and approaches which will allow broader access and use of that information, and to allow the nation to realize a fuller return on its investment in its weather and climate services of NOAA. Although the principal focus of this white paper is on the NWS -- given that it is NOAA's largest supplier of weather and climate information -- the intent is to address issues and proposed solutions that apply across the spectrum of NOAA's weather and climate services, regardless of the specific NOAA line office in which they occur.

Although this white paper discusses a few specific examples where tangible data access improvements can be achieved, it is not attempting to identify a comprehensive set of circumstances that can be improved. Therefore, it is important to recognize that this white paper is proposing a new paradigm that, if implemented ubiquitously throughout the NOAA's weather and climate services, will fully engage the Weather and Climate Enterprise and lead to new ways in which the nation can exploit NOAA's weather and climate information that are not yet envisioned.

NOAA's Weather and Climate Information Model

NOAA weather and climate information has two principal origins: that which it acquires from external sources and that which it creates internally. More specifically to the NWS, outside source information largely consists of weather, climate and related environmental information from foreign governments, other U.S. government agencies and the private sector¹. Internal NWS information largely consists of observations from sensor systems operated by the NWS as well as information derived or created using the complete set of observations in its stores. Forecast data, including output from numerical weather prediction (NWP) systems, is perhaps the most prominent example of the latter. The internal creation of environmental information by the NWS is by far the larger source of total NWS information store.

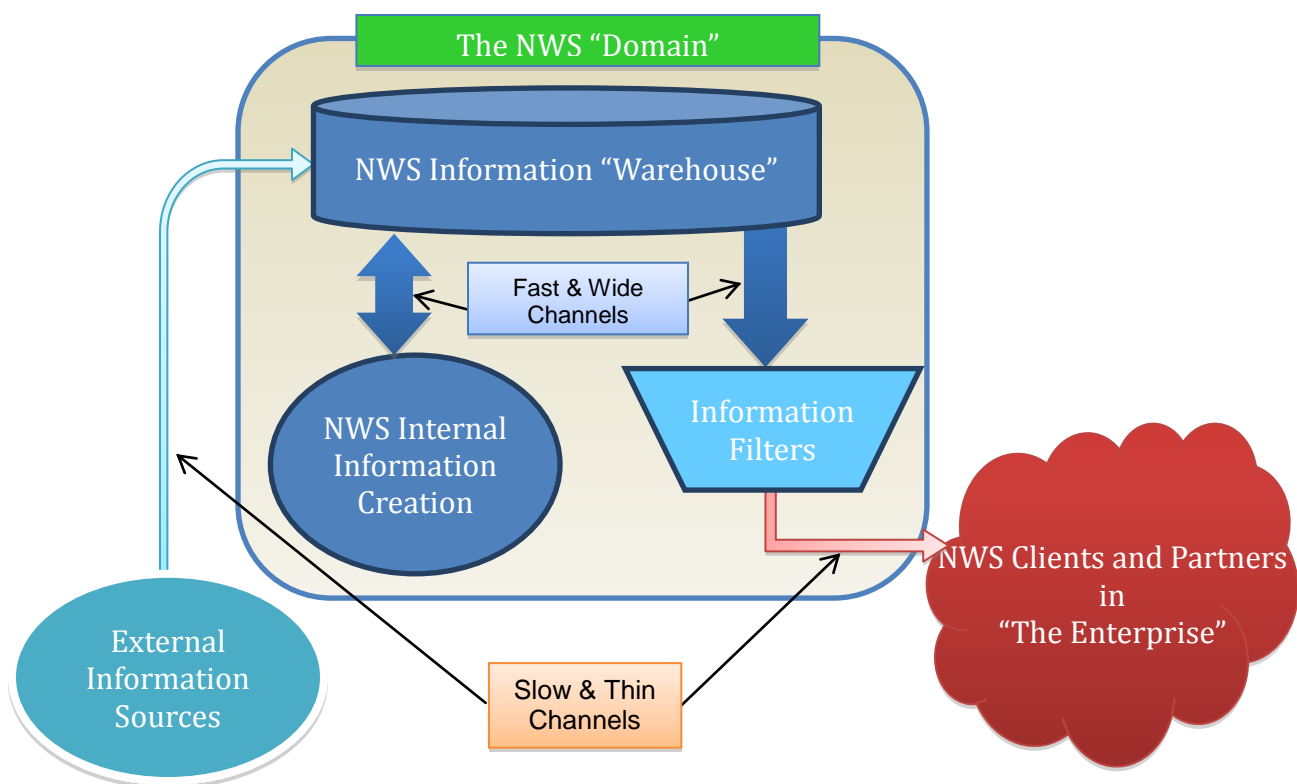


Figure 1. A high-level schematic diagram of the NWS information flow model. The volume of information collected and created by the NWS, together with limited ability to communicate that volume of information to the broader enterprise necessitates the need for information filters to be placed on the data before being made available to the Enterprise.

The flow of information through the NWS is illustrated at the highest level by Fig 1. Inside of the generic NWS “domain” is a virtual “warehouse” that holds all of the information that the NWS collects and creates. Here, the NWS domain and warehouse do not represent any single

¹ In some cases, the information that the NWS collects and maintains from sources outside of the agency is available only for internal use by the NWS by agreement. This white paper addresses just that information that can be freely distributed by the NWS.

physical location or information store, but rather the collection of locations and data stores across all types of weather and climate information. In reality, the data warehouse consists of a tremendous variety of different information, in different formats, in various media (disks and databases, computer memory, paper) and in a plethora of locations distributed throughout the NWS. The rate at which new data are added to this warehouse depends on the source, but in general, internal sources have fewer physical constraints and can add new information much faster than external sources. For example, a NWS-internal NWP model can write its output to a local disk much faster than the ECMWF can transfer output from its model to the NWS. Similarly, the rate at which content can be physically transferred from the warehouse to the external clients in the Enterprise is also generally much slower than the rate at which some information can be created. In the case of a NWS NWP model, the rate (and hence volume) of information that the NWS can store from a forecast run is much larger than the rate that the information can be communicated via its common distribution channels such as NOAAPort and the internet. NOAA's NOMADS initiative is intended to partly address this issue, but only from an archives perspective and not a real-time information access perspective.

Information Filtering

To deal with the inconsistency between the rates of information creation and external communication, the NWS places filters on the data before making the information available to the Enterprise. This makes communication of the information to these external clients more practical given the bandwidth limitations of our communication systems.

Nearly every type of NWS weather information data source is filtered before publication to Enterprise clients. Some common examples include:

- NWP forecast data is filtered, particularly in time. Forecast models produce forecasts in time increments of several minutes, but only a small subset (about 1 in 100 typically) of those time samples are actually published. Depending on the model and publication portal, spatial filtering of the model data may also take place.
- NWP ensemble forecast data is further filtered by parameters, with typically a very small subset of the model's parameters published in the ensemble suite.
- Satellite imagery is cropped and sub-sampled before broadcast on NOAAPort. Full resolution satellite data is available to the Enterprise through direct readout equipment, but this requires relatively expensive satellite receiving and processing equipment by each client wishing to receive the information. Unfortunately, the NWS does not publish real-time satellite data via the internet unlike much of the rest of its weather information.

- ASOS surface weather observing sites take observations every minute. Only hourly samples of the data are available², unless a significant change in the weather occurs, in which case an observation at the time of change is also published. Here, “significant” is largely defined based on aviation interests, which of course does not serve all interests. Data from the NWS NEXRAD Doppler data is first distilled into Level 2 moments (reflectivity, velocity, etc.) before publishing. The raw (Level 1) data is not published.

This is by no means a comprehensive list, but represents a flavor of the types of data filtering done today.

Despite no specific policy governing procedures on how the NWS should design and implement the filters it applies to its data, the methods employed by the NWS are generally reasonable and often created with input from the Enterprise. This ensures that the Enterprise will be able to use the filtered data for a majority of the most common purposes. For example, by publishing the most commonly requested parameters (e.g. geopotential heights, temperatures, humidity, winds and precipitation) from a NWP model, the NWS ensures that that more common uses of the information can be conducted by a large percentage of users.

However, it does not ensure that all potential value-adding purposes can be accommodated and this is the fundamental issue being addressed here. For example, consider the potential use of ensemble NWP information for developing experimental or operational probabilistic turbulence forecasts that could be used to plan airline routes more effectively. One method to create such a forecast would be to compute turbulence estimates from each ensemble member and then estimate the turbulence probability based on resulting turbulence variations across the members. However, implementing this technique outside the NWS is not possible with only the filtered ensemble data published today. This is because a common method for estimating turbulence requires the full, unfiltered 4-D fields from a NWP model. Therefore, a probabilistic turbulence forecast, which could have significant value to the airline industry, could not be computed using this technique by anyone outside the NWS. The general theme of this example illustrates how creative and innovative development of new ideas for exploiting weather and climate services by academic or private-sector researchers and developers can be inhibited by the current limited information services.

² One-minute ASOS data is available in hindsight from the archives at NCDC.

Serial Development and Deployment of New Weather and Climate Technologies and Services

There is a second way in which NOAA limits access to its information that reduces the ability of society to derive value from its technologies and services. NOAA typically employs a “block” change process when releasing new technologies into service such as new NWP models, databases (e.g. 4D Weather Data Cube), tools (e.g. AWIPS II) and products (e.g. from the upcoming GOES-R and just-launched NPP satellites). A block change process means that NOAA typically develops the technology in semi-isolation and then releases the technology into service. Although NOAA often makes reasonable efforts to inform the Enterprise regarding its development goals, architecture, functionality and schedule, barriers exist during the development process that limit the value that the Enterprise can derive from these new technologies. In particular, without more substantial advanced visibility and hands-on insight into the details and working of new technology, the Enterprise is not able to fully prepare to accommodate and exploit the technology, hence limiting the nation’s return on this new investment.

Fig. 2 illustrates the return on investment (ROI) that results from the current block release process used by NOAA and the potential increased return if a different paradigm was followed. The left panel shows the ROI as a function of the life of the technology after the block release. The area below the curve represents the return while the area above the curve represents unrealized value due to the time it takes society to exploit the technology. The right panel illustrates the gain in ROI that society could expect if the NOAA used a more open paradigm in the development and release of new technologies that allowed the Enterprise to capitalize more effectively when the technology was first released.

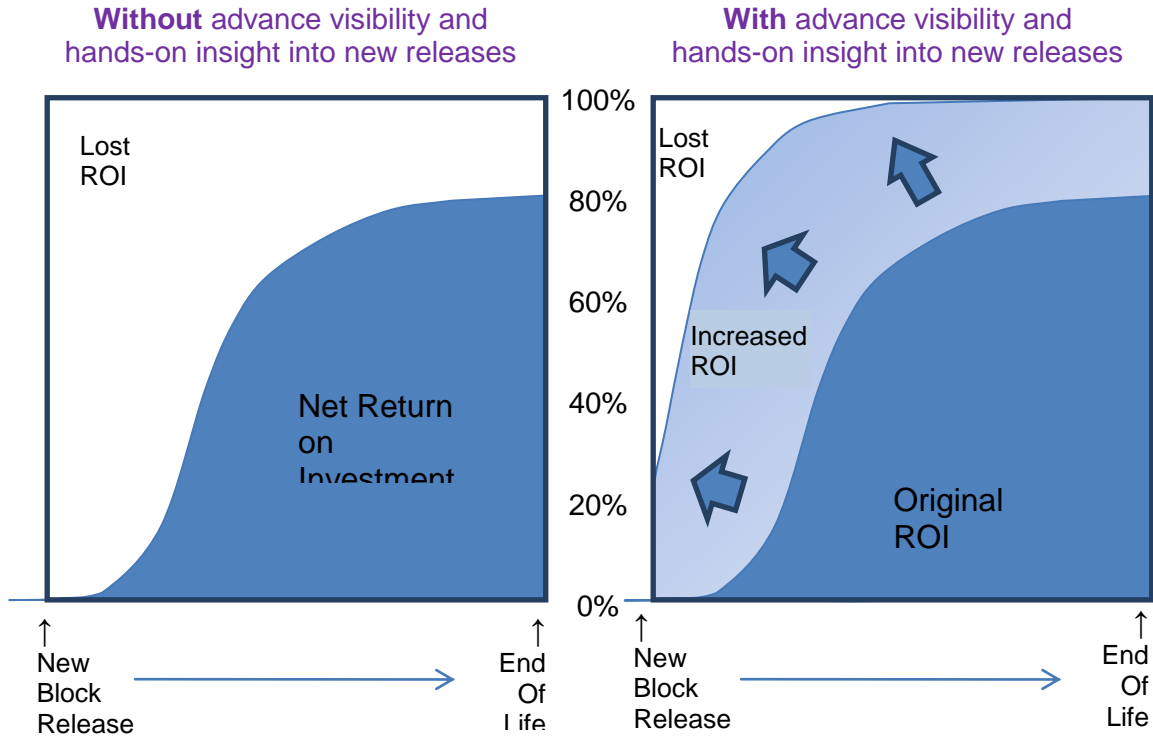


Figure 2. Schematic diagram illustrating the return on investment (ROI) over the life cycle of a certain technology under the existing NWS block release paradigm (left panel) and a new paradigm that allows society to exploit the technology earlier and more fully. Adopted from “*The Tail Wagging the Dog: A User Focus on End-to-End Environmental Sensing and Data Utilization*”, by Philip Ardanuy, Jimmy Jensen, Thomas Vonder Haar, Randolph Ashby, Gary Gray, Ron McHenry, and Adrian Ritchie, SPIE Optics and Photonics, 2004.

There are two ways in which a more open development paradigm can bring increased value to society. First, by allowing increased visibility and hands-on experience during development, mechanisms to exploit the value of the technology can be developed in parallel with the technology. Value-adding mechanisms can then be deployed coincident with the block release enabling the immediate incorporation of the technologies and their outputs in scientific research and education. This is illustrated by the ROI curve in the right panel of Fig. 2 to be steeper and beginning materially above zero upon release. Second, a more open interaction between NOAA and the Enterprise during the design and implementation phase can lead to fundamental alterations in the design that allow the technology to be more fully exploited once operational. It also helps ensure that the technologies are suitable to address pressing and wide-ranging scientific questions. In turn, the improved design leads to a larger peak ROI and hence society achieves a higher net value over its lifetime.

Developing the skills, decision support tools and demand for new products takes time, and capacity building requires a sustained period of communication. Instead of gathering science requirements and then designing and implementing the capability, science, engineering, and

systems engineering stakeholders can be engaged in parallel throughout the entire development period. By understanding the requirements, their relative priorities, and the consequence of designing to satisfy the requirements, engineers are better able to push back or push forward if incremental requirements drive (or limit) a design in cost or risk (or opportunity). Adopting such a productive and iterative development process can help NOAA yield more optimized weather and climate services.

Part of the rationale in the current NOAA development process is to try to establish an optimal balance between minimizing the time and cost of development while achieving a reasonable solution. Readers should not conclude that NOAA undertakes its new technology development programs in a vacuum free from any exposure to the Enterprise. In reality, NOAA reasonably communicates with the Enterprise and often solicits guidance and feedback on its plans. The point raised in this white paper is that there may be alternative and deeper ways for NOAA and the Enterprise to interact during technology development that will lead to improved solutions for society, without significantly impacting the time or cost to develop the technology.

“Therefore, the basic position advocated in this white paper is that NOAA should adopt the Open WCS paradigm as part of its core philosophy and work to implement it whenever and wherever possible.”

Summary of the Issue

The basic issue addressed in this white paper is that our nation is not fully realizing the potential value of the weather and climate services of NOAA because various technical, practical and procedural barriers exist that limit the availability of NOAA information and technology to society. The two primary causes of this limitation are:

1. NOAA collects and creates valuable weather and climate information more rapidly than can be practically communicated outside of its domain;
2. Exchanges between NOAA and the Enterprise during the development and deployment of new information technologies are not optimized to realize maximum value of that new technology once deployed.

Towards an Open Weather and Climate Services

The barriers that inhibit the flow of information outside of NOAA exist because the fundamental concept of being “inside” and “outside” of the NOAA exists. Therefore, one path towards improving the exchange of information is to eliminate the institutions that create the notion of

“inside” and “outside”. An idealized state, one in which the Enterprise and NOAA conduct the nation’s weather and climate business in a side-by-side symbiotic fashion, is the concept of Open Weather and Climate Services (“Open WCS”). In this idealized paradigm, the need to filter information transmitted by NOAA is eliminated because there is no longer a need to transmit the information. Enterprise value-adding services, including research and education, exist within the same “domain” as the NWS itself. Development of new technologies does not require communication and consultation with the Enterprise because the Enterprise is fundamentally taking part in the design and development of that technology. Although such an ideal sounds enticing, in practice it may not be fully achievable as there will always be some distinction between the NWS and the Enterprise. Therefore, the basic position advocated in this white paper is that NOAA should adopt the Open WCS paradigm as part of its core philosophy and work to implement it whenever and wherever possible.

Fig. 3 illustrates the NWS information model under the Open WCS paradigm. In this schematic, the “NWS Domain” is replaced by the “Enterprise Domain”. Value-adding services provided by commercial and academic Enterprise partners share equal access (and may contribute) to a common Enterprise Information Warehouse. Information filters may still exist to support those clients of the information that cannot participate within the Enterprise Domain, or for which filtered information is required. In this case, filtering could become a form of value-added services by the Enterprise.

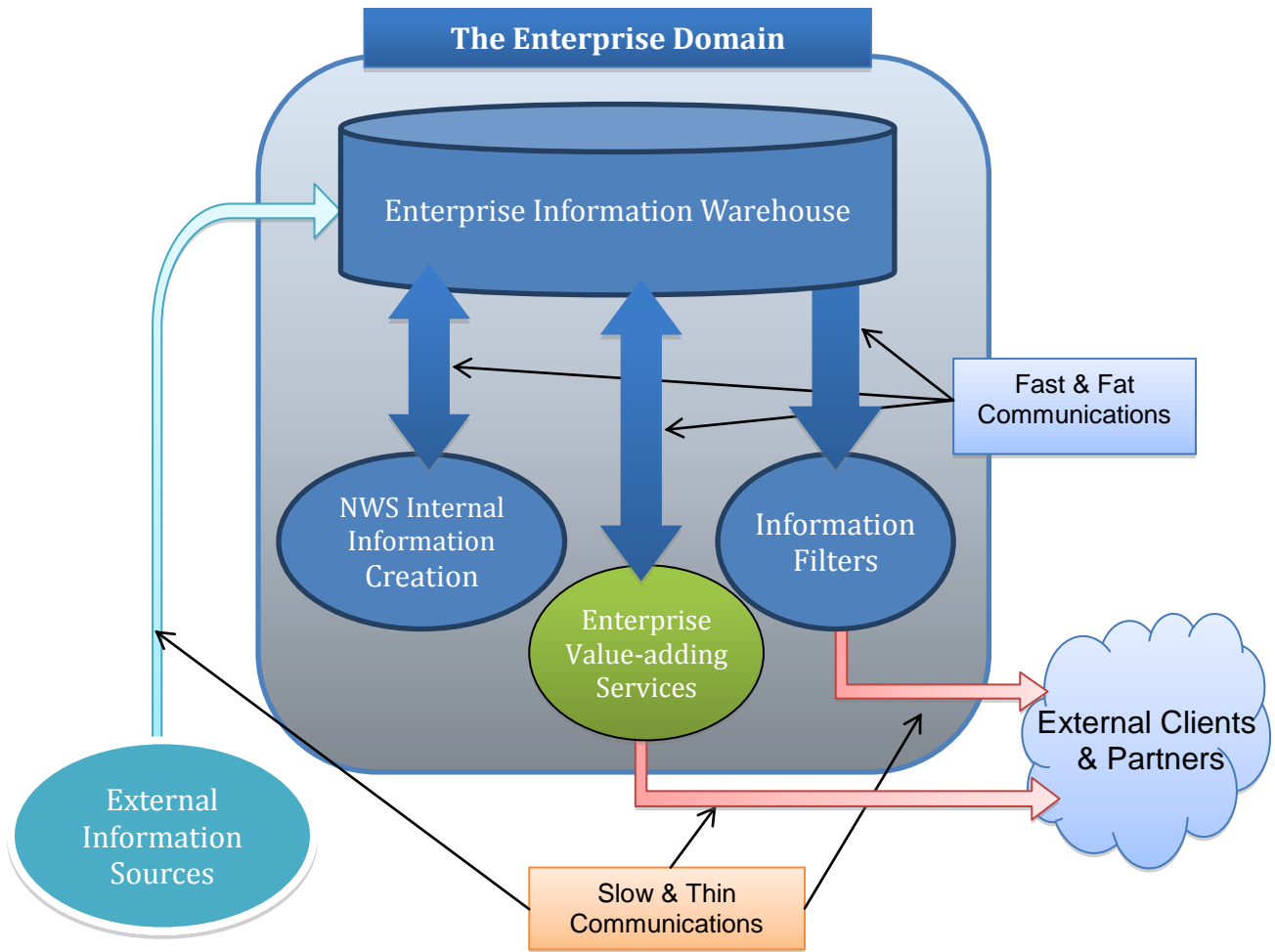


Figure 3. A high-level flow diagram of NOAA information under the Open WCS paradigm.

Again, consider the potential probabilistic turbulence forecast discussed earlier. Under the Open WCS paradigm, the algorithm that computes turbulence estimates from each of the ensemble members would be run on a server that resides within the Enterprise Domain and have direct and complete access to the full, unfiltered ensemble data. Probabilistic turbulence forecasts would then be created from the suite of turbulence forecasts, and then communicated to external clients outside of the Enterprise Domain. This could be achieved if, for example, the Enterprise servers were hosted at the National Center for Environmental Prediction (NCEP) facility and connected to the model’s data “bus” or main model-storage devices.

The Open WCS paradigm also supports improved communication between NOAA and the broader Enterprise during the development and deployment of new weather and climate technologies. To illustrate, consider the High-Resolution, Rapid-Refresh (HRRR) NWP model currently under development in NOAA’s Earth System Research Laboratory (ESRL). The HRRR model is intended to be the NWS’s first routine, national-scale forecast model that explicitly

resolves (rather than parameterizes) convection. As such, the character of the precipitation forecasts issued by the model has the potential to be significantly different than those from existing NWS models. Therefore, existing methods, practices and products that have been developed by the Enterprise based on the parameterized models may need revamping in order to continue to provide value to society. For example, a simple legacy algorithm that characterizes the type of precipitation as being either steady or showery based on the partitioning of precipitation between the resolved and parameterized scales would not function with the HRRR model output, since no precipitation-scale partitioning exists. Under the Open WCS paradigm, Enterprise developers would have access to digital output from prototype and test versions of the model from inception. The Enterprise developers would create new methods to determine the precipitation character (steady vs. showery) and perhaps recommend alternative implementations of the model that would support these new methods. As a hypothetical solution, an Enterprise partner may conclude that one way to ascertain the precipitation character requires examination of a high-resolution time series of precipitation rate from the model. To accommodate such, NOAA model developers could then implement such a time-series analysis as part of the core model, and include an “intermittency” parameter as part of its standard model output. This entire interaction could, for example, be facilitated in a development test bed environment such as that created by the National Center for Atmospheric Research in Boulder.

Derivative Benefits of an Open WCS

The primary purpose of the Open WCS paradigm is to maximize the value to society of NOAA information. Implementing the concept will have numerous secondary benefits that will further advance the value of that information. These include:

- *Encouraging broader and creative new uses of NOAA information to serve the nation’s interests.* The direct benefit of the Open WCS paradigm is to implement ideas that currently exist but are not possible because of the limitations of information availability. With less inhibited access to NWS information, academic and commercial Enterprise members will be able to conceive of new ways in which the information can create value but are not anticipated at this time.
- *Catalyzing more bilateral interactions between the NOAA and the Enterprise.* A criticism of the current NOAA product technology development process is that it does not fully leverage the talents and expertise available in the broader Enterprise community. The Open WCS paradigm will create a sandbox for development in which partners from all corners of the Enterprise can participate and more freely interact. This will ultimately lead to more effective product development by both NOAA and the Enterprise and thus further increase the value NOAA information by facilitating both Research to Operations (R2O) and Operations to Research (O2R) activities.

“...it is reasonable to expect that select implementations of the Open WCS paradigm may make significant improvements in meteorological services to our nation without incurring substantial cost.”

- *Accelerating retirement of legacy NWS services.* The NWS has procedures to retire and eliminate services from its repertoire; however in practice these are not often used. As such, the NWS is often bogged down in supporting numerous, seldom-used older services and therefore operates at less than optimal efficiency. Clients of NWS systems develop dependency on the services and this often inhibits the pace by which legacy services can be retired. Under the Open WCS paradigm, Enterprise members can work more closely with NWS developers to develop methods to replace the legacy dependencies using new NWS services. The HRRR precipitation characterization example discussed earlier illustrates how the Open WCS concept could accelerate the retirement of an

older non-convective resolving model after the HRRR is implemented.

- *Strengthening the partnership.* The Open WCS concept will lead to strengthened relationships between NOAA and its private-sector and academic partnerships. This will inevitably lead to improved weather services to society and therefore help justify continued investment and modernization of NOAA.

A Path Forward

The concept presented in this white paper is rather simple when considered from afar. However, in practice its implementation could be complex with far reaching implications. Therefore, a careful, thoughtful and prudent approach must be adopted while implementing the concept. However, the potential benefits of the paradigm are significant enough that its implementation should be given reasonable priority within NOAA. Although a more thorough cost-analysis of the Open WCS paradigm has not been performed, it is reasonable to expect that select implementations of the Open WCS paradigm may make significant improvements in meteorological services to our nation without incurring substantial cost.

The first step in implementing the paradigm must begin with tentative endorsement of the concept by senior NOAA and NWS leaders and the development of tactics that support it. The current director of the NWS, Dr. Jack Hayes, has endorsed the Open WCS paradigm in his public remarks on the topic to the American Meteorological Society's 2011 Summer Community Meeting in Boulder. His remarks, made after consultation with work force representatives, were very much welcomed by EISWG. However, it is now important that this endorsement be echoed by other senior leaders at NOAA and be followed by actions that begin the implementation of the

concept throughout the agency. In particular, the development of effective approaches that would guide the actual implementation of the paradigm across the agency needs to begin in earnest..

Although there are numerous approaches that NOAA could undertake in implementing Open WCS, it is believed that first developing comprehensive policies and procedures will not be effective. Such a process would be lengthy and likely not well informed regarding the numerous nuances and challenges faced by the paradigm. Rather, it is recommended that NOAA undertake an incremental approach to implementing the Open WCS. In this approach, targeted implementations of the Open WCS paradigm in specific sectors of the agency should be identified, with each implementation having substantial benefit and challenges that are limited in scope. Each incremental implementation or prototype is intended to support a specific realization of the Open WCS paradigm. In this approach, the benefits of the paradigm are realized quickly in areas where Open WCS can realize immediate benefits to society. This is analogous to the “build a little, test a little, deploy a little” approach often adopted in systems engineering and implementation. NOAA should work with the broader Enterprise to identify where targeted Open WCS instances can be implemented quickly and will yield substantial benefits to the Enterprise, while also informing NOAA on a more comprehensive Open WCS approach.

Challenges

There are numerous challenges that will be faced in adopting the Open WCS paradigm. Many of these are substantial and will require creative thought and planning in order to minimize their effects on accomplishing the goals of this concept. However, none of these challenges are considered to be substantial enough in their own right to prevent moving forward with this initiative. Some of the more material challenges include:

- *Cyber Security.* The NWS infrastructure is part of the critical U.S. infrastructures, which also includes power grids, emergency communications systems, financial systems, and air traffic control networks, etc. As new vulnerabilities are continually discovered and exploited, approaches ensuring the operational stability and security against penetration and cyber-attack of the NWS systems is vital to U.S. national, homeland, and economic security interests.³ Therefore, cyber security and information assurance must remain an integral part of the Open WCS implementation. Determining methods by which the Enterprise and NOAA can coexist within the same information domain, while maintaining security of the NOAA infrastructure will be necessary in order to implement the concept.
- *Cost.* The net cost to NOAA of implementing the Open WCS paradigm is not clear. On one hand, NOAA may incur costs in order to implement the concepts, open its facilities to the Enterprise and participate in more open collaborative development. On the other hand,

³ http://www.nitrd.gov/pubs/csia/csia_federal_plan.pdf

NOAA could realize substantial cost savings through lower costs to deliver services to the Enterprise, more effective technology development and fewer legacy services supported. Clearly, a more thorough cost analysis of the Open WCS paradigm would be beneficial in guiding approaches of its implementation. However, where there are clearly identified costs to servicing a specific Enterprise need within the Open WCS paradigm, those costs could be borne by the partner(s) and not NOAA. Furthermore, costs of implementation could easily be less than realized societal and economic benefits, but our ability to adequately predict these benefits is not well developed.

- *Development Burden.* As mentioned earlier, the current NOAA development practice is to provide a reasonably isolated environment for its key technology developers in order to achieve efficient and timely product development. However, the isolated nature of that development is counter to the Open WCS concept and finding a more optimal balance between the need to have open vs. timely development will be a challenge.
- *Fair Access.* As with all information services provided by NOAA, it is important that access to those services be equitable to all potential clients. Under the Open WCS paradigm this may present some practical challenges wherever access may not easily scale to a large number of participants. For example, it may be impractical to have numerous developers with interest in the next-generation NWS NWP model have access to the NWS model development team without overwhelming that team with the burden of managing such a large group of participants. (In this particular case, expanded use of Development Test Center(s) may be part of a solution.) Similarly, the costs of information access may need to be addressed as Open WCS ideas are implemented. Currently, users of NOAA information must bear the cost of information access whether that be as simple as purchasing a computer and internet connection to access NOAA information on the web, or more involved such as installing dedicated equipment to receive high-volume data (e.g. ground receivers to receive raw GOES satellite data). Since higher-volume data services generally come with more expensive access costs for the client, and since much of the information made available under an Open WCS may be high-volume, the gap between those that can and cannot afford to participate may widen. Approaches and practices that minimize this potential segregation will need to be considered.
- *NOAA Partnerships:* NOAA and the NWS have numerous partnerships and dependencies with other governmental agencies (such as the Navy and Air Force) and it is important that implementation of an Open WCS is sensitive to the needs and histories of those partnerships.

Although these challenges are real and may appear daunting, it is noted that there have been programs implemented within NOAA and the Weather Enterprise that are consistent with the Open WCS concepts. Each was faced with a specific set of challenges, but mechanisms to work within and around those challenges were identified in each case. The CRAFT program to distribute NEXRAD Level II radar data to the community is a notable example.

Specific Recommendations

The Open WCS paradigm has potentially far reaching implications. A thoughtful approach in adopting the paradigm must be undertaken as discussed above. The following recommendations are considered the first steps towards a general adoption of the Open WCS paradigm. They are intended to be near-term actions that can move the agency towards an Open WCS model.

It is recommended that:

- NOAA leadership should agree that the Open WCS concept as described herein would be beneficial to the nation and that the agency should immediately begin to develop internal programs to implement the paradigm in targeted parts of the organization that will be most effective in delivering the benefits of Open WCS to society. The established endorsement of the concept and commitment to its principles by NWS Director Dr. Jack Hayes is recognized and welcome.
- NOAA should work closely with the SAB, its relevant working groups (e.g. EISWG, CWG and DAARWG) and perhaps other partners to develop an implementation action plan that will create specific recommendations and follow-on activities to implement the Open WCS approach across the agency. This action plan should be developed quickly and target short-term actions that will lead to prototype and targeted Open WCS implementations whose experiences can be used to develop a more comprehensive NOAA Open WCS strategy.
- As a general framework, this recommended action plan should:
 - Recommend that NOAA implement Open WCS incrementally using targeted programs and prototypes rather than developing broad Open WCS policy and implementation concepts.
 - Quickly identify short-term actions that can target accelerated implementation of the Open WCS in specific areas that have limited risk or cost and can be achieved without a more comprehensive approach.
 - Consider mechanisms that catalyze better interactions between NOAA's development laboratories and the broader Enterprise such as open access to development datasets and use of open Development Test Centers.
 - Address various challenges of the Open WCS paradigm including security, costs, fair access and effective internal development in the context of the incremental and targeted implementation approach

“NOAA leadership should ... develop internal programs to implement the paradigm in targeted areas of the agency that will be most effective in delivering the benefits of Open WCS to society.”

Summary

This white paper has discussed the general nature of the way NOAA shares information with the Enterprise, and has pointed out a shortcoming that limits the effectiveness and value that the nation derives from its investment in NOAA. In particular, limited access by the broader Enterprise to the vast volumes of weather and climate information collected and created by the NWS leads to suboptimal use of that information by society. The limitations largely arise from practical constraints on the ability to cost-effectively publish and communicate this environmental information to the Enterprise. It is unlikely that technology advancements will eventually lead to a solution to this issue since gains in the ability to communicate information are likely coincident with gains in the ability of NOAA (and in particular the NWS) to acquire and create additional information. Therefore, a new paradigm is required in order to optimize the value that the Enterprise can realize from NOAA information. An open weather and climate services (“Open WCS”) paradigm is proposed in this white paper as a solution to the issue. In an Open WCS, the bounds of the NOAA “domain” are dismantled and NOAA and Enterprise work side-by-side with equal access to the information. Further, in an Open WCS, the Enterprise openly participates alongside of NOAA in the development of new information technologies and has free and secure access to development and test datasets and contributes to the betterment of the technology and to innovative uses of the technology.

Practically, the utopia of an Open WCS cannot be fully achieved. This white paper recognizes that limitation, but encourages NOAA to create implementation approaches that will take the agency towards the Open WCS paradigm. Specific recommendations on a process that creates narrow but effective implementations of the paradigm were provided.

Ample experience from many other realms teaches us that openness, transparency, increased choice and diversity of connections, though sometimes a source of temporary inconvenience, are ultimately the primary driver of increased economic benefit and social good. The concepts advanced herein appeal to the creative forces that have long driven this country forward, invoke tested entrepreneurial approaches to stoke the engine of innovation, and position the United States to be a global leader in development of an effective, robust, comprehensive, and responsive provision of weather and climate services.