Towards Open Weather and Climate Services

A white paper prepared by the

Environmental Information Services Working Group (EISWG)

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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 agencies of NOAA. However, the Nation has yet to realize the full value of NOAA's weather and climate services for two principal reasons. First, numerous 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 predication model output, satellite and radar data. Second, new technology and services are not developed in a sufficiently symbiotic manner with the broader community such that optimized net value of that new service or technology to society is 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. It is recognized that numerous challenges exist including security, cost, development efficiency and fair access. However, none of these issues are considered significant enough or without reasonable solutions to prevent NOAA from moving forward on the concept. NOAA should develop Open WCS policies and procedures incrementally in areas where the paradigm can be exploited first such that the Weather and Climate Enterprise can begin to exploit the value of the paradigm quickly in key arenas. Previous endeavors and actions that have opened information services have proven to be enormously successful and beneficial to society; there is no reason to believe that this would not be the case here too.

Introduction

The U.S. 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 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.

Despite this leadership relative to the rest of the world, the NWS does not achieve ubiquitous, open access to all of its weather information. In fact, a tiny fraction of all NWS weather 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 the NWS does not have universal, open access to all of its weather information. The NWS could benefit from a specific data access policy that provides for open access to its information, and/or a policy that defines procedures and guidelines for determining which information it makes available.

Without universal access to all NWS information, our nation is not realizing the full value of its investment in the NWS. More broadly, it inhibits the NWS in its ability to carry out its core mission of protecting life and property and enhancing the national economy. It is through the broader Weather and Climate Enterprise outside of the NWS (consisting of academic interests, private-sector enterprises, NWS interagency partners and the general public) where value from NWS information is realized. 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 by the weather Enterprise in methods to best exploit the information to serve that purpose. Improving 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 NWS 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 NWS information can overwhelm the ability to process, store and communicate that information outside of the NWS. In some cases, the NWS does 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 the NWS 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 NWS supplies only a fraction of the information it possesses.

Lack of complete access to NWS information is not limited to just real-time weather data but extends to other information and services including new technology (e.g. NWP models and observing systems) that are under development. More specifically, the typical NWS process for developing and deploying new sources of weather information tends to be serial. That is, while the NWS develops the new technology, access to that technology and the information it creates is largely limited to the developers of the technology. For example, while the NWS develops

algorithms that will take advantage of the new dual-polarization capabilities of the NEXRAD radars, the process and any preliminary outputs of those algorithms are generally not available to the Enterprise. However, at some point, the NWS will typically place 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 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, it reduces the net efficacy that the technology realizes over that achievable if the NWS and 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 NWS weather data by the Weather and Climate Enterprise and to propose new concepts and policies which will allow broader access and use of NWS information and hence allow the nation to realize a fuller return on its investment in the NWS. Although the focus of this white paper is on the NWS, the intent is to address issues and proposed solutions that apply to all of NOAA's weather and climate services, regardless of which specific part of NOAA they arise from.

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 sector[1]. Internal NWS information largely consists of observations from sensor systems operated by the NWS as

[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 which can be freely distributed by the NWS.

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.

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 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 is 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

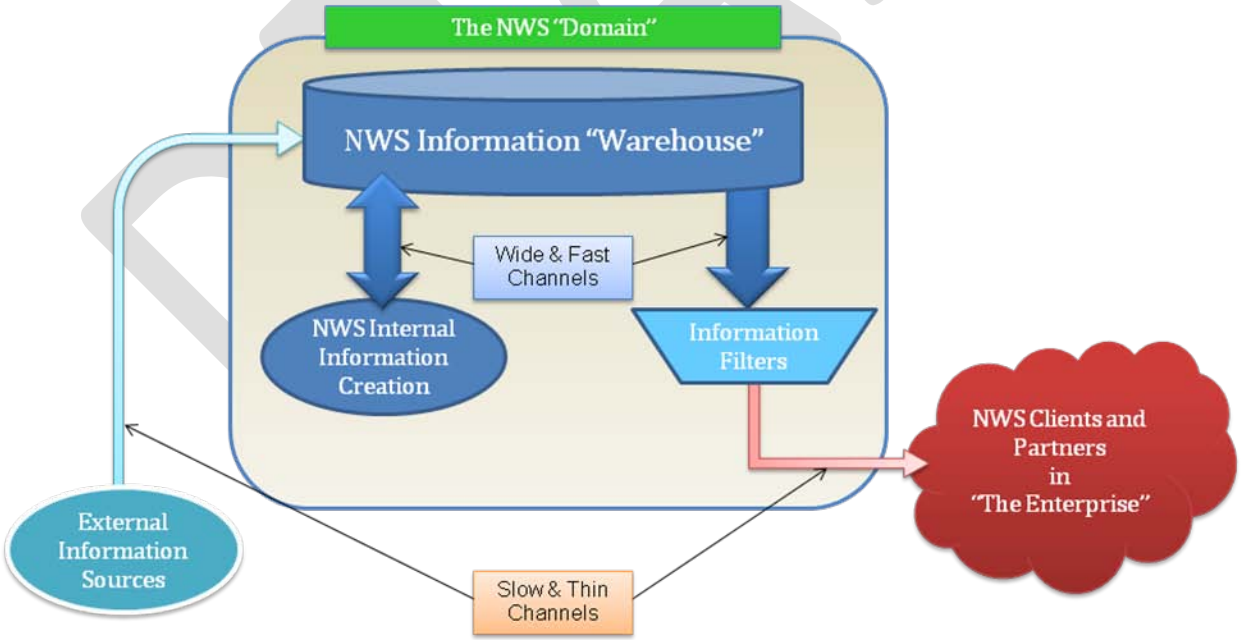

Figure 1. A high-level schematic diagram of the NWS information flow model. The volume of information collected and created by the NWS, together with limited ability to communicate that volume of information to the broader enterprise necessitates the need for information filters to be placed on the data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

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) 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 models parameters available in the model 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 satellite data via the internet unlike much of the rest of its real-time weather information.
- ASOS surface weather observing sites take observations every minute. Only hourly samples of the data are available, 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 data filters, the filtering employed by the NWS is generally reasonable and many times done 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. By publishing the most commonly requested

parameters (e.g. geopotential heights, temperatures, humidity, winds and precipitation), 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 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 efficiently. One method to create such a forecast would be to compute turbulence estimates from each ensemble member and then estimate the 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, which are not made available today. 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.

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

There is a second way in which the NWS limits access to its information that reduces the ability of society to derive value from its technologies and services. The NWS 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. the upcoming GOES-R). A block change process means that the NWS typically develops the technology in semi-isolation and then releases the technology into service. Although the NWS 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 the NWS 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 NWS 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.

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, allowing value-adding mechanisms to be deployed coincident with the block release and allows for the immediate incorporation for 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 the NWS 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.

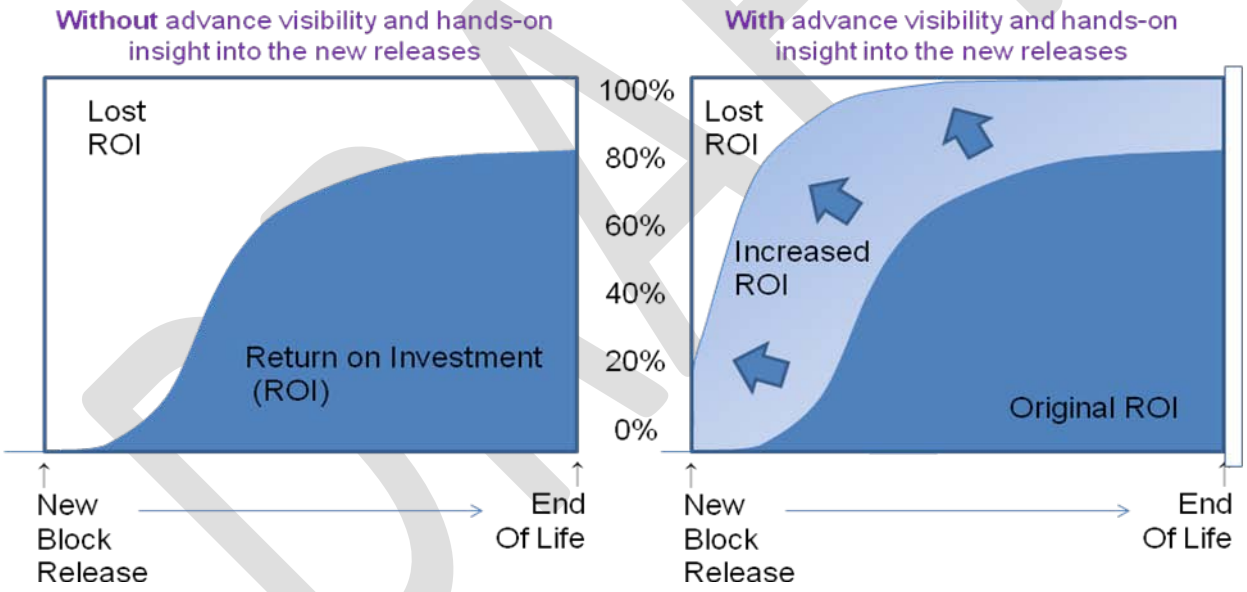

Figure 2. Schematic diagram illustrating the return on investment (ROI) over the life cycle of a certain technology under the existing NWS block release paradigm (left panel) and a new paradigm that allows society to exploit the technology earlier and more fully.

Part of the rationale in the current NWS 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 the NWS undertakes its new technology development programs in a vacuum free from any exposure to the Enterprise. In reality, the NWS often 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 ways for the NWS 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.

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 NWS because various technical, practical and procedural barriers exist that limit the availability of NWS information and technology to society. The two primary causes of this limitation are:

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

Towards an Open Weather and Climate Services

The barriers that inhibit the flow of information outside of the NWS exist because the fundamental concept of being "inside" and "outside" of the NWS exists. Therefore, one path towards improving the exchange of information is to eliminate the institutions that create the notion of "inside" and "outside". The ideal state, in which the Enterprise and the NWS 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 the NWS 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.

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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.

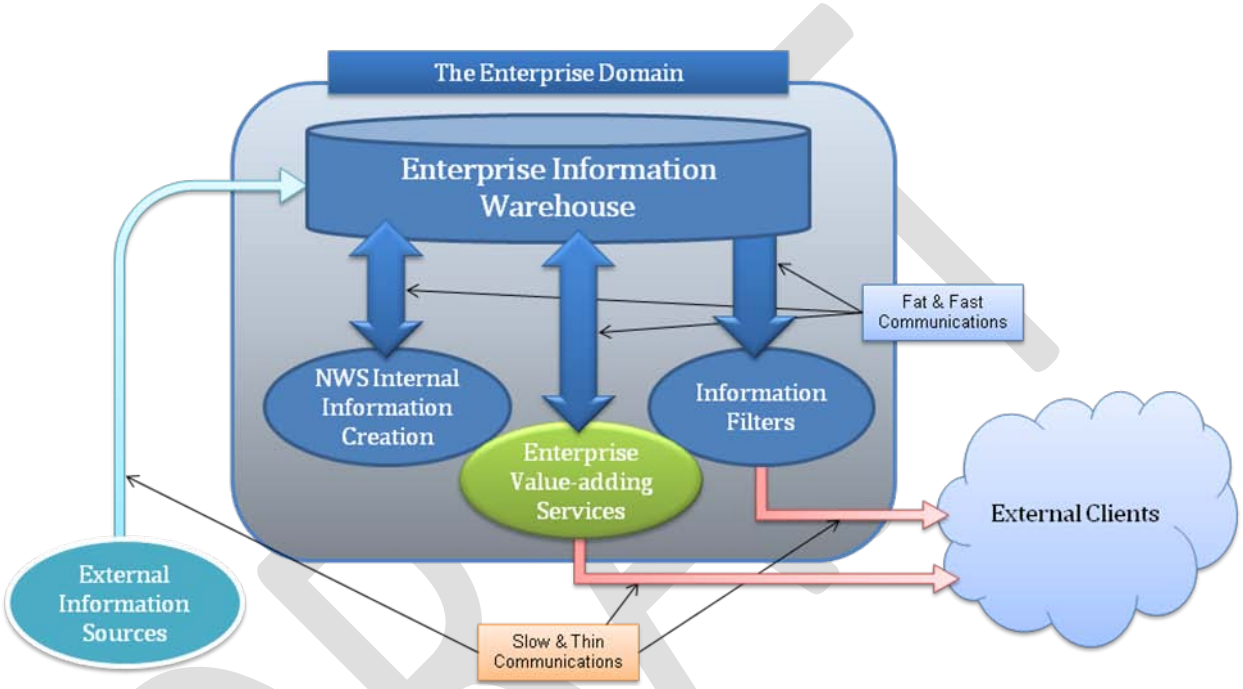

Figure 3. A high-level information flow diagram under the open WCS paradigm.

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 storage devices.

The Open WCS paradigm also supports improved communication between the NWS and the broader Enterprise during the development and deployment of new weather and climate technologies. To illustrate, consider the High-Resolution, Rapid-Refresh (HRRR) model

currently under development[2]. 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 alternative 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, the NWS 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 NWS 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 NWS 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 NWS and the Enterprise*. A criticism of the current NWS product development process is that is 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

[2] Technically, the development of the HRRR model is largely taking place within NOAA's Earth System Research Laboratory in the Office of Atmospheric Research. The Open WCS concepts discussed in this white paper are intended to apply to all of NOAA's weather-related institutions.

Enterprise can participate and more freely interact. This will ultimately lead to more effective product development by both the NWS and the Enterprise and thus further increase the value of NWS information by facilitating both Research to Operations (R2O) and Operations to Research (O2R) activities.

- *Accelerating retirement of legacy NWS services.* The NWS has procedures to retire and eliminate services from its repertoire; however in practice these are not exploited often. 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 eliminated. 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.

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A Path Forward

The concept presented in this white paper is rather simple when considered from afar. However, in practice its implementation would 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 the NWS. 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 NWS and NOAA leaders and the development of policies and procedures that support it. A tentative initial endorsement by the NWS stating that the basic concept has merits and should be considered further is critical to the success of this initiative. This initial

endorsement would then be followed by the development of effective policies and procedures that would guide the actual implementation of the paradigm. In order to develop those policies, the following approaches could be considered:

1. Policy and Procedure First. Comprehensive policies and procedures are developed and then implemented by the agency. This serial approach would require a very careful, detailed policy development phase in order to ensure that the policy was exhaustive and effective. It would likely take a long time to determine all of the circumstances, nuances and issues with the new policies. The lengthy period before the nation would realize benefits of the Open WCS paradigm, combined with risks that the policies developed may not have sufficient omniscience argues against this approach.
2. Proposals First. An alternative approach would be for the NWS to solicit from the Enterprise proposals for how it would exploit an Open WCS paradigm to meet its business and academic needs, and then use these proposals to develop more comprehensive policy to implement those and subsequent proposals. This approach would allow for a more informed set of policies to implement the paradigm but probably does little to accelerate deriving benefits for the nation.
3. Concurrent Policy and Prototypes. In this approach, the NWS first creates minimal policy and procedure to seek, support *and implement* a limited number of functional prototypes that exploit the Open WCS paradigm. These prototypes are operated while concurrent efforts are undertaken to develop the long-term policies. Periodically during the policy development process, the ongoing prototypes are examined and those results are used to refine and improve the policies. This approach has the benefits of a much more informed and thus enduring policy. It also results in some benefits of the paradigm are being realized by early adopters that participate in the prototype phase.
4. Incremental Policy. In this approach, comprehensive policy is not developed initially, but rather a sequence of narrower policies that support the Open WCS paradigm are incrementally developed and implemented. Each incremental policy is intended to support a specific realization of the Open WCS paradigm. In this approach, the benefits of the paradigm are realized quickly as the time to implement each narrower policy would likely be relatively short. This is analogous to the "build a little, test a little" approach often adopted in systems engineering and implementation.

Both the Concurrent Policy and Prototype and the Incremental Policy approaches have substantial benefits and a hybrid of these options is considered the path that will ultimately lead to the most effective and timely implementation of the Open WCS paradigm.

Adoption of the Open WCS paradigm will also require activities on the part of the broader Enterprise. Most important, the Enterprise will need to actively engage with NOAA in helping to define where the benefits of the paradigm will be most effective and immediate and hence areas where incremental policy creation and program implementation should focus. Since the Open WCS can represent a materially different way in which the Enterprise acquires and uses

information, the Enterprise will need to think carefully and creatively about areas where this concept would be most beneficial. NOAA interagency partners should also consider the Open WCS paradigm and how it may affect their relationship with NOAA.

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 affects 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, policy and procedures 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 NWS can coexist within the same information domain, while maintaining security of the NWS infrastructure will be necessary in order to implement the concept.
- *Cost.* The net cost to the NWS of implementing the Open WCS paradigm is not clear. On one hand, the NWS 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, the NWS 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 policy and procedures 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 the NWS.
- *Development Burden.* As mentioned earlier, the current NWS 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 policy and finding a more optimal balance between the need to have open vs. timely development will be a challenge.

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

- *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 a 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 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 policy is formed. 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 NWS 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. Policy and practices that minimize this potential segregation will need to be considered.

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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 as the first phase towards adopting the Open WCS paradigm. They are intended to be near-term actions that can move the agency in the direction of the Open WCS.

It is recommended that:

- The NWS leadership agree that the Open WCS concept as generally described herein is potentially beneficial to the nation and that the agency should further study how the concept might be implemented. This should occur within the first 90 days. The endorsement of the concept and recognition of the need to engage further on the topic from the highest levels of the NWS are critical to make substantial progress towards the paradigm.
- The NWS work closely with the SAB, its relevant working groups (EISWG and DAARWG) and perhaps other partners to develop an action plan that will create specific recommendations and follow-on actions on how the Open WCS can be adopted as the

policy of the NWS. The action plan should be completed and adopted within 6-9 months of the completion of this white paper.

- The action plan developed by NWS, SAB and its committees should,
    - Recommend a concurrent incremental policy and prototype approach to developing the more comprehensive Open WCS policy.
    - Consider 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 policy.
    - Consider mechanisms that catalyze better interactions between NWS development centers and the broader Enterprise such as open access to development datasets and use of open Development Testbed Centers.
    - Address various challenges of the Open WCS policy including security, costs, fair access and effective internal development.

Summary

This white paper has discussed the general nature of the way the NWS 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 the NWS. 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 coincidental with gains in the ability of 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 NWS 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 NWS "domain" are dismantled and the NWS and Enterprise work side-by-side with equal access to the information. Further, in an Open WCS, the Enterprise openly participates along side of the NWS 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 the Open WCS cannot be fully achieved. This white paper recognizes that limitation, but encourages that NWS to create policy and procedure that will take the agency towards the Open WCS paradigm. Specific recommendations on the development of those policies and the process and issues that should be considered were provided.