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SYSTEMS ENGINEERING, MANAGEMENT AND SUSTAINMENT AT THE AIR FORCE WEATHER AGENCY (AFWA)- TRANSITION, MIGRATION AND METRICS

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1. INTRODUCTION

Generation and delivery of weather products for military applications and users has taken on ever increasing complexity in light of recent developments in the field of meteorology, and increasingly complex user needs. Operational fine scale numerical weather prediction models, new satellite based sensors, global requirements and operational demands have increased the demands on processing power and bandwidth. This trend will undoubtedly increase with new generation mesoscale modeling systems, and sensor systems and derived products from next generation geostationary and polar orbiting satellites.

The Systems Engineering, Management and Sustainment (SEMS) program provides systems support for the Air Force Weather Agency (AFWA), the strategic center for weather for the U.S. Air Force and supplies all weather-related information to the Air Force, Army, and many federal agencies. AFWA provides meteorological analysis and forecast support to Army and Air Force units worldwide, supports weather forecasting and severe weather prediction by civilian agencies, and participates extensively in the meteorological community's advanced weather research. AFWA is the largest supplier of weather data for military users worldwide in supporting front line combat operations and missions, mission planning, and routine flight operations.

As the prime contractor on the SEMS project, Northrop Grumman Mission Systems (NGMS) has the responsibility for AFWA systems including the Global Theater Weather Analysis and Prediction System (GTWAPS), Satellite Data Handling System (SDHS), the Joint Air Force & Army Weather Information Network (JAAWIN), the Space Weather Analysis and Forecast System (SWAFS) and Cloud Depiction and Forecast System II (CDFS II). The primary goal of SEMS is to support AFWA systems, which provide an integrated depiction of global weather from earth's surface out to space.

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Currently over 32 GB of weather products are generated per day, almost 60 GB of satellite imagery are collected and processed, from over 10 satellites, nearly 10,000 surface and over 3500 upper air observations are assimilated daily and processed into the data base and shared among applications.

This paper describes the current state of support provided to AFWA under SEMS, and an overview of the enterprise. We will describe the advantages of architecture modernization in terms of treating the enterprise as a system of systems, one that SEMS offers. We will present some examples of effective systems engineering and its impacts on operational support and reduction in total ownership costs. We will discuss the transition of current systems, migration processes and metrics used in monitoring component systems in an effort to effectively monitor the health of thee current systems, to reduce operating costs and effect the modernization and enhancement of existing systems to improve mission support. Our staff is actively involved in not only the maintenance of present day AFWA component systems but in the transition from legacy, stove-piped architecture to a more modern, highly integrated, efficient, fault-tolerant enterprise using state-of-the-art systems and information exchange technologies.

2. SEMS OVERVIEW

The primary goal of SEMS is to enable AFWA to achieve more timely, accurate and reliable weather information to the end user. Future improvements introduced and maintained by SEMS will improve spatial and temporal depiction of the weather; characterization of the weather from "mud to sun"; accurate, precise, and highly tailored weather products for combat mission teams and operational weather squadrons; and mission planning and assessment of weather effects (impacts) on component combat systems.

SEMS is a multi-year Northrop Grumman Mission Systems (NGMS) contract at the Air Force Weather Agency (AFWA), Offutt Air Force Base, with a current program value of $119M. With headquarters in

Bellevue, Nebraska, AFWA runs the strategic center for weather for the U.S. Air Force and supplies all weather-related information to the Air Force, Army, and many civilian agencies. AFWA derives information from satellites and other sources and analyzes it to provide predictions used by DoD, government agencies, and military units in the field.

NGMS is the prime on this five-year contract, awarded in September 2002. Approximately 130 personnel currently support the various functions of SEMS on site. It is by far the largest and most wide-reaching support contract in AFWA history.

As the name SEMS implies, our support involves systems engineering, management, and sustainment of major components of the AFWA enterprise. Systems under the SEMS umbrella include the Global Theater Weather Analysis and Prediction System, Satellite Data Handling System, and Joint Air Force & Army Weather Information Network. The Space Weather Analysis and Forecast System and Cloud Depiction and Forecast System II were added to SEMS in September 2003. SEMS is the vehicle through which AFWA expects to obtain an integrated depiction of global weather from earth's surface out to space.

AFWA is the largest supplier of weather data for military users worldwide in supporting front line combat operations, mission planning, and routine flight operations. Weather data, including surface and upper air observations, satellite data, aircraft observations, ship data, radar data, and space weather data are collected within the AFWA component systems and distributed to DoD and other various government users. The same data are used as input to numerical weather prediction models to provide custom fine-scale weather forecasts worldwide. Aside from sustainment of these component systems, NGMS is responsible for the consolidation of Air Force weather systems in an effort to reduce operating costs and effect the modernization and enhancement of existing systems to improve mission support.

NGMS provided IT services include programming, testing and evaluation of software components, system maintenance and administration, logistics support, computer system and site security support, database management, and technical documentation. Our staff is actively involved in not only the maintenance of present day AFWA component systems but in the transition from legacy, stove piped architecture to a more modern, highly integrated, non-redundant enterprise using state-of-the-art data structure and data exchange technologies. The primary goal is more timely, accurate and reliable weather information supplied to the end user. Other goals include improved spatial and temporal depiction of the weather; characterization of the weather from "mud to sun"; accurate, precise, and highly tailored weather products for combat mission teams and operational weather squadrons; and for mission planning and assessment of weather effects (impacts) on component combat systems. The modernization effort also benefits Department of Defense civilians and National Intelligence Community agencies by providing improved tropical cyclone direction and intensity tracking, analyses of high-level winds, and severe storm aircraft alerts.

3. GTWAPS

Northrop Grumman Mission Systems (NGMS) is responsible for the entire life-cycle engineering of the Air Force Weather Agency's (AFWA) GTWAPS program. GTWAPS, which is known as Air Force Weather's premier system, acquires data from a variety of sources internal to AFWA and externally from other agencies, and produces fine scale atmospheric modeling worldwide to support DoD missions. NGMS's successes include supporting the war in Bosnia and the Kosovo conflict and, support for both the Gulf War and Operation Iraqi Freedom. We have obtained excellent feedback for our efforts to maintain a system capable of producing timely, accurate high-resolution forecasts supporting combat operations and mission planning. This system of systems houses no less than six 'applications', which are models designed for very specific purposes meeting DoD, DOT, and other federal agency's needs.

GTWAPS has been supported by the NGMS team since the late 1990's, and the specifics of the system were described in earlier papers by Starr et al. (2000, 2001). The conglomerate system consists of two IBM massively parallel production systems, an applications server, data server, development system, and a High Performance Gateway Node.

In 1995 the hardware/modeling system was conceptualized to use IBM scalable parallel architecture running the Penn State University developed Mesoscale Model 5 (MM5). Over the last 8 years this system has typically had two large production systems and was re-architected to house the smaller models on an applications server, while serving incoming and outgoing data via its data server.

GTWAPS takes data from a variety of sources internal to AFWA and externally from other agencies, including the Fleet Numeric Meteorology and Oceanographic Center (FNMOC), the National Center for Environmental Prediction (NCEP) and the World Meteorological Organization (WMO), and produces fine scale atmospheric modeling worldwide to support DoD missions. This model is run 4 times a day operationally over most of the globe.

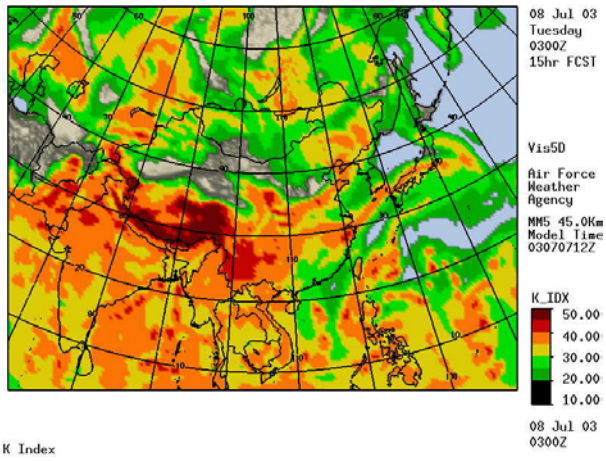

Figure 1: GTWAPS is operationally run over most of the earth's land surface. The current operational model is the Penn State/NCAR Mesoscale model, version 3.5. Shown is 15 hour forecast K-index for Asia.

Aside from MM5, a number of specialized models support and comprise GTWAPS. Satellite data are integrated to better depict the snow cover with the Snow Depth (SNODEP) module and surface moisture and vegetative characteristics via the Agriculture Meteorological (AGRMET) module. The Land Surface Model (LSM) has enabled a better coupling of land and oceanic models for a seamless initialization of the earth's surface.

NGMS continues to perform system management and maintenance tasks with the GTWAPS program, including logistics support and systems engineering

4. SDHS/CDFS II

Northrop Grumman Mission Systems (NGMS) currently supports SDHS through the SEMS umbrella in system engineering, management, and sustainment. The Air Force Weather Agency's (AFWA) SDHS is responsible for receiving and processing all available meteorological satellite data from national and international sources and making it available to DoD and other government users on a timely basis for daily operations and mission support.

SDHS is capable of handling all current geostationary and polar orbiting satellites, and is periodically updated in order to receive new products from evolving sensors and new sources of data. We are currently preparing to engineer the system to accept and process data from the next generation of geostationary and polar orbiting satellites.

The back end processing and visualization of SDHS received data is performed on the Cloud Depiction and Forecast System - Version II (CDFS II). This complex system significantly upgraded the operational global cloud analysis and forecasting capabilities of the United States Air Force. CDFS II provides near real-time global cloud analysis operations at AFWA. CDFS II integrates new science algorithms and operational infrastructure to analyze combined global-coverage data from the Defense Meteorological Satellite Program (DMSP), the civilian Polar Operational Environmental Satellite (POES) program, and the international constellation of geostationary environmental satellites operated by the United States, Europe, Japan, and other foreign entities.

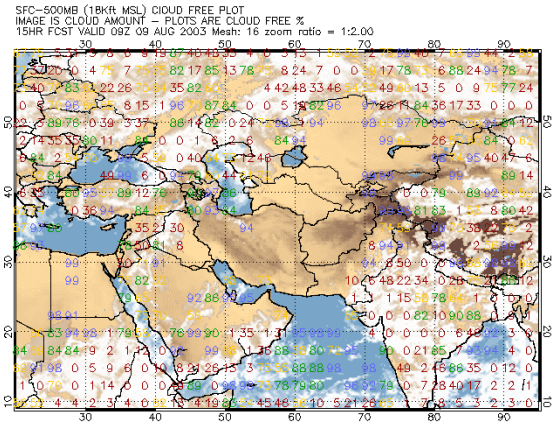

Figure 2: Sample CDFS-II output, forecast cloud free amount, southwest Asia.

While AER developed the CDFS II science algorithms and leads the Science IPT, NGMS provides the systems engineering, management and sustainment of the CDFS II system.

5. SWAFS

With the exploitation of space for defense systems, satellite communications, space travel, and high-level reconnaissance the impacts of space weather have become increasingly important for military operations planning and execution. Events that take place in the middle and upper atmosphere can have very significant impact on both commercial and military communication systems, in the form of degradation and disruption of communications. One of the objectives of the Air Force Weather Agency (AFWA) is to provide analysis and forecast products that provide military communicators and the end users with a "single picture of potential environmental effects" that may impact their systems.

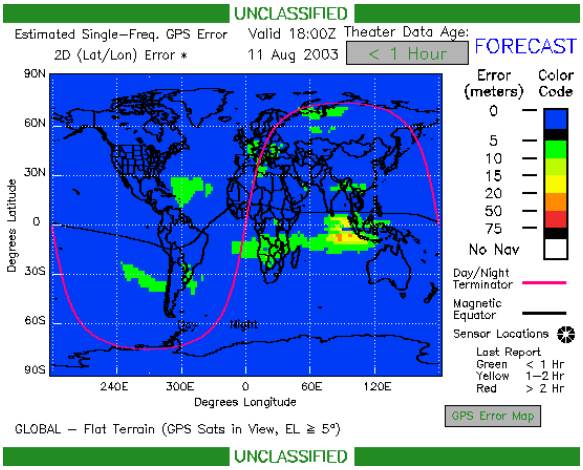

Figure 3: Example of a SWAFS forecast product, global forecast of single frequency GPS error. The inclusion of space weather completes the environmental picture for planning and operations.

Formerly at Schriever AFB, CO, the SWAFS component has been moved to and integrated with the AFWA weather systems. SWAFS receives data from multiple ground based and satellite based sensors to detect variations in the ionosphere, the earth's magnetic field, and solar condition to provide analyses and forecasts of factors that affect communications across the globe. Numerical models ingest the collected data and provide for regularly scheduled forecasts of upper atmospheric phenomena, providing for a complete depiction of the weather affecting operations at all levels, from the ground to space. The integration of SWAFS into SEMS gives the end user complete "mud to sun" support for military operations, particularly in communications.

Aside from systems NGMS directly maintains and manages, we man a 24-hour 7 day a week customer service center or help desk for a number of Air Force Weather systems. These include the tactical weather radar (TWR), the very small aperture terminal (VSAT), tactical very small aperture terminal (T-VSAT), the Mark IV-B satellite ingest and distribution system, Operational Weather Squadron-II (OPS-II), New Tactical Forecast System (N-TFS), Tactical Metrological Observing System (TMOS), and automated meteorological station (AMS)/FMQ19- the automated observing system, and the tactical automated observing system

6. SUPPLYING THE END-USERS

Data are distributed from the various applications running on the AFWA subsystems to users in several ways including subscription service (WDA), the internet (JAAWIN) and by direct transmission via communications modes such as through satellite feeds. In the past decade, the amount of data ingested, processed and distributed has increased by over an order of magnitude, requiring advances in communications and information processing technology to be implemented as soon as they become available. This trend is expected to not only continue into the future, but to accelerate as new data sources come on line. Aside from the processing systems described above, SEMS has integrated into its enterprise view the subsystems responsible for distributing the data to the end users. SEMS, and NGMS personnel are integral in performing the trade studies and ensuing recommendations necessary to take advantage of and incorporate emerging technologies to maintain AFWA's capabilities at the leading edge.

JAAWIN, or the Joint Air Force and Army Weather Information Network is AFWA's primary web site for meteorological information requests. Averaging approximately 8 million hits per month, JAAWIN provides a one-stop source for METSAT imagery, alphanumeric

Figure 4: End users in the field include Operational Weather Squadrons, Combat Weather Teams, Fixed Base Operations as well as a host of military and government non-military users dependent upon weather information. NGMS plays an integral role in the sustainment of these functions through SEMS.

data, TAFs, lightning / NEXRAD radar data, model visualizations, space weather information, interactive applications, and aviation hazard depictions. As part of the AFWA enterprise, JAAWIN relies heavily upon the other subsystems operating under the AFWA umbrella for raw and processed data to be distributed to Operational Weather Squadrons, Combat Weather Teams, and users in the field and at fixed base

operations. The system is available in unclassified, secret and SCI (Sensitive Compartmentalized Information) environments.

7. SYSTEM METRICS IN A SYSTEM OF SYSTEMS

As our role is being defined as system managers, sustainers, integrators and developers in this immense system, it is important to continually gauge the system performance to ensure that system component capabilities are not outstripped by the needs of an ever increasing data environment. Sustaining such a complex system has set the demand for developing a complex set of performance metrics. The metrics we provide to AFWA performs several functions: they allow for diagnosis of problems in ingesting, processing or disseminating data, they give an estimate as to the capabilities of components as the system grows, and they provide valuable information for both near-term and long-range planning and system design. Metrics monitor both system health (hardware) and software (system centric), and product flow, timeliness and completeness (product centric).

System performance metrics that are routinely monitored include disk usage, CPU usage, wait I/O time, and memory usage, and trends are defined based on the continual monitoring process that SEMS has placed on all of the component systems. Given the complexity and interdependency of the AFWA component systems, these metrics allow us to not only diagnose system problems, but also help us plan for effective use of resources and to plan future upgrades with limited government funding.

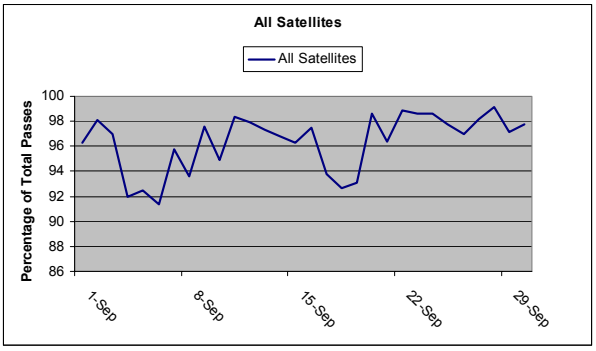

Figure 5: Metrics are collected and analyzed to depict system health, and the ingest and distribution of products through the complex systems. In this example, satellite ingest is represented as a percentage ingest into the system of all possible satellite passes.

Product centric metrics are collected on specific systems where timeliness and completeness are of paramount importance. As in any operational weather forecast process, it is important to get the products out to the end users in the shortest possible time frame to maximize their utility, and provide for as close to real-time weather support that can be accomplished using present day techniques.

Metrics are also collected and available to determine the health of the various component AFW systems related to the customer service center activities and their role as the primary central point of contact for service related issues on these observing, data collection, processing and distribution systems.

All metrics collected on the various AFWA systems are processed and analyzed under the SEMS Systems Management team. Aside from providing a measure of system health, performance, and isolating operational problems, they are useful in providing guidance in planning for future system upgrades and configuration changes. In the migration from “stovepiped” systems to an integrated enterprise view, the collection of a comprehensive set of enterprise wide metrics allows systems engineers and planners insight and projections into future needs as new data sources come online, and the amount of meteorological data increases to grow with these new sources.

8. THE FUTURE AS AN ENTERPRISE VIEW

Operational requirements for ever increasing amounts of data from new sensors and measurement systems, forecast products from fine resolution mesoscale models, and secondary or derived products has placed a large demand for technology that can address the problem of timely delivery of meteorological data in the operational environment. Anticipated additional data in the near future from next generation satellites such as POES, NPOESS and GOES-R will place additional stress on bandwidth and communications. Improvements in numerical modeling with operational model runs having grid spacings of 2 km will contribute to the increased flow of real-time meteorological data needed to support operations. The sheer complexity of the data coupled with tightly interlaced systems processing this data and feeding requisite output under stringent timelines complicates the engineering that will be incorporated into the AFWA system of systems.

In planning for future needs, it is necessary to anticipate the growth from new sensor systems and improvements in the operational forecast tools at our disposal. At the same time, legacy system support is needed to ensure continuity in maintaining meteorological support during the transitioning of

current systems toward accommodating these new sources. One of the challenges we face in SEMS is in maintaining this backward compatibility, yet allowing for future system growth. Timeliness, reliability, and accuracy must be maintained and improved in light of the increased demands on technology. As data sources are more closely linked in order to provide for synergy in the production and distribution of meteorological data to users with increased demands, it becomes necessary to build and support weather systems with an enterprise wide view. SEMS takes this approach, that of an integrated enterprise, or a system of systems. One can no longer take an independent systems approach toward maintaining and developing operational weather systems in the global environment.

To obtain the best possible real-time picture of the environmental factors affecting the decision making and planning for the battlefield at the global level will require the correct and rapid harnessing of technologies as they become available. The integration of space weather is essential in this planning. Surface to sun, or "mud to sun" support is essential in supporting military operations across the globe. Our enterprise view in SEMS, treating the various AFWA component system as a "system of systems" is essential, in this light, to not only maintaining the various AFWA components, but for allowing for rapid growth, availability of new technologies on a timely basis, and providing the necessary cost savings to the government that make improved and expanded meteorological support possible to the government and the armed forces.

9. REFERENCES

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