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Consolidating GOES Analysis Workstations using Virtualization and Thin-Client Technology

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Abstract – The Geostationary Operational Environmental Satellite (GOES) program is a critical NOAA satellite mission that provides complete and timely global weather monitoring including access to global environmental satellite data to help track major weather systems to protect the Nation's economy, security, environment, and quality of life.

The GOES Operations Ground Equipment (OGE) major components are the Sensor Processing System (SPS), Replacement Product Monitor (RPM), Orbit and Attitude Tracking System (OATS), OGE Data Acquisition and Patching Subsystem (ODAPS), SPS Database Servers, and Consolidated Analysis Workstations (CAWS). These components have traditionally been based on standalone hardware systems that use legacy and outdated hardware platforms and operating systems, some of which have reached End-of-Life (EOL) and have been discontinued. With these constraints, a hardware and software migration is a necessity in order to keep the current GOES I-M and GOES NOP series of satellites in operations until the new GOES-R series of satellites are deployed and put into operations.

The Office of Systems Development (OSD) Ground Systems Division (GSD) and Avaya Gov conducted a comprehensive "As Is" assessment of the existing GOES ground system components. This was followed by an implementation of a software and hardware migration strategy to a next-generation state-of-the-art architecture for the entire GOES OGE and Spacecraft Ground Support System (SSGS) in an effort to extend the longevity of the GOES ground system, increase its operational reliability, combine functional components into a single architecture, and reduce long-term Operations and Maintenance (O&M) costs. Avaya Gov developed and implemented the GOES Enterprise Managed System (GEMS) architecture that facilitates continuity of operations for GOES OGE and SSGS, in addition to providing other key mission-support capabilities. The GEMS architecture was developed based on emerging hardware and software technologies providing unified enterprise management capabilities and economies of scale. It reduces ground system life-cycle costs, improves future standardization between component systems, standardizes O&M of OGE and SSGS components, provides reliable operation with hot backup and fault-tolerant component systems, and enhances IT security.

The latest OGE component that is being migrated to the GEMS architecture is the Consolidated Analysis Workstation (CAWS). Currently, CAWS is installed on a single platform and hosts several OGE applications, including (1) RPM client used for real-time and archive data display and analysis, landmarks, and image navigation and registration analysis, (2) Star Sense Data Archive (SSDA) client used for long-term archiving and analysis of imager and sounder star sense data, (3) SPS Modernized History Browser (MHBR) used for display and analysis of historical data archived on the SPS, and (4) Dynamic Interactive Diagnostic (DID) software used for plotting and analysis of telemetry data received from the Multi-use Data Link (MDL) Receive System & Server (MRS&S) within the SSGS environment.

CAWS is migrated to a GEMS virtualized environment based on AMD Opteron blade servers and thin-client technology. Virtualization allows several workstations to be installed as virtualized machines (VMs) on a single server. This allows the consolidation of multiple workstations on a single blade server, where each workstation is operating independently within a separate VM. Individual CAWS VMs can be accessed through thin clients. This paper describes the migration of the CAWS workstations at WCDAS, NSOF, FCDAS, and WBU to a GEMS virtualized environment with access through thin clients.

Index Terms – GOES, Ground System Data Processing, Blades, Virtualization, Thin Clients, GOES Enterprise Managed System (GEMS)

I. INTRODUCTION

The CAWS is a single platform that hosts multiple analysis software applications, associated with the

OGE, within the same workstation. Many of the CAWS applications make use of PV-WAVE, a commercially available software used to support scientific data analysis and visualization providing engineers, scientists, and meteorologists with a fourth-generation programming language to build and deploy Visual Data Analysis (VDA) applications. Some of the CAWS applications are tightly integrated with the PV-WAVE software. The CAWS concept provides consolidation of analysis applications to one workstation.

The CAWS workstation is connected to both the Sensor Processing System (SPS) and Replacement Product Monitor (RPM) networks. Depending on the CAWS application and the required access to OGE components, the CAWS workstation is connected to either the SPS or the RPM network. For example, when an analyst uses the SPS Modernized History Browser (MHBR), it is connected to the SPS Virtual Local Area Network (VLAN). Similarly, when an analyst uses the RPM Client application to access the RPM Server, the CAWS workstation is connected to the RPM VLAN. The existing CAWS hardware consists of an UltraSPARC Sun Blade 1500 workstation and uses the Solaris-10 operating system.

The CAWS workstation hosts the following applications:

- Rehosted Product Monitor (RPM) Client
- Sensor Processing System (SPS) Modernized History Browser (MHBR) and Data Analysis Toolkit
- Grid Database Utility (GDBU), and
- Star Sense Data Archive (SSDA) Client

The **RPM Client** provides real-time and archived image display of the GOES VARiable (GVAR) as well as analytical tools for Landmarking, and Image Navigation and Registration (INR) through the RPM server.

The **SPS MHBR** provides a user interface to select and analyze historical data archived on the GOES Sensor Processing System (SPS). Imager and Sounder data can be retrieved for analysis, plotting and processing. The MHBR is used extensively by Radiometric Calibration scientists as part of their regression testing and analysis. This software application was developed using Unified Modeling Language (UML), Java, and eXtensible Markup Language (XML), providing NOAA with an operational data telemetry and extraction toolkit that is platform and operating system independent.

The **Grid Database Utility** (GDBU) is an offline tool to create and edit grid databases for the GOES Sensor Processing System. It consists of a Source Database Utility to create a grid database from the Global Database at a specified subsatellite point. The Global Database has 1,794,206 points of the entire world, and is extracted from the Digital Chart of the World. It also consists of an Operational Database Utility that allows users to thin the SDB, in whole or in part, to zoom to a specific area, to add, delete or filter grid points, and to save it as an operational database.

The **Star Sense Data Archive (SSDA)** application provides long-term archiving of the imager and sounder star sense data. It has access to all operational SPSs at WCDAS, WBU and FCDAS, and ingests star sense data from the SPS for short-term storage twice an hour. It uses the ingested data for analysis of the visible channel detectors to provide quantitative measurements on the degradation of the channels. SSDA is accessed from the SSDA clients installed on CAWS workstations. The client software is developed using the Java programming language.

Figure 1 illustrates the existing infrastructure for the CAWS workstations at the various NOAA facilities including Satellite Operations Control Center (SOCC) at the NOAA Satellite Operations Facility (NSOF), Wallops Command and Data Acquisition Station (WCDAS), Fairbanks Command and Data Acquisition Station (FCDAS), and Wallops Backup Unit (WBU).

Site	RPM Workstations	SOCC Workstations	Total
SOCC (NSOF)	9	5	**14**
WCDAS	5	0	**5**
WBU	1	0	**1**
FCDAS	2	0	**2**

Figure 1. List of CAWS workstations deployed at NSOF, WCDAS, FCDAS and WBU.

II. SYSTEM ARCHITECTURE & DESIGN

This section provides an overview of the migration of the CAWS to a virtualized environment based on Opteron blade servers and thin clients. Oracle, formerly Sun, has discontinued the production of SPARC-based workstations effective July 2008 in favor of virtualized servers and thin-client technology. The Avaya Gov Team performed software and hardware cost benefit analysis to evaluate various alternative solutions including SPARC, Opteron and Itanium processors. The analysis was performed based on project risk, system reliability, availability and maintainability of both hardware and software including system and application software.

A solution of using thin clients, virtualization, and x86/Operon blade servers with the GOES Enterprise Managed System (GEMS) was proposed to NOAA and was accepted. In this solution, user access is provided through thin-client technology, giving users the same look and feel as the existing CAWS workstations. Considering that the x86/Opteron processors are significantly faster than the SPARC-based processors, multiple virtualized CAWS workstations will be consolidated onto a smaller number of blade servers, thereby providing NOAA with greater manageability, better use of resources, tremendous cost savings, ,and lower total cost of ownership.

CAWS Virtualization: Virtualization is a proven software technology that enables multiple Virtual Machines (VMs) to run on a single physical machine,

sharing system resources (e.g., CPU, memory, network, and hard drive) of that single machine. Using virtualization, multiple VMs can be hosted on a single physical server, thus providing server/workstation consolidation. This consolidation increases server utilization while reducing power, cooling and space requirements. Virtualization also provides enhanced IT security controls. There are a number of commercial-off-the-shelf (COTS) virtualization software products available such as VMware Workstation software, Zen, Solaris Zones, Sun Virtual Box, etc.

Virtualization software provides the perfect platform to host the CAWS application for the following reasons:

- COTS virtualization software is inexpensive and easy to manage from a centralized console;
- Allows consolidation of multiple CAWS workstations onto a single blade server;
- Allows configuration and testing of new software and patches in an isolated *sandbox* environment and improves software distribution. Mission-critical applications are unaffected during operating system upgrades and migrations;
- Provides significantly enhanced administrative capabilities through centralized management. A single image containing the operating system and application software can be deployed across all CAWS virtualized servers, thus enforcing consistency;
- Provides the same look and feel as the existing CAWS workstations and is transparent to users; and
- Provides centralized data and application for greater IT security.

CAWS Thin Client Access: A thin client simply provides a user interface to a remote server/workstation where the main processing activities take place. For the CAWS migration, Oracle's Sun Ray Thin-client technology will be used to allow users to remotely access the virtualized CAWS workstations on blade servers in the GEMS. The virtualization approach proposed in the previous section is fully compatible with the thin-client solution. The Sun Ray architecture consists of two components - Sun Ray Thin Clients and Sun Ray Server Software.

Sun Ray Thin Clients are simple, low-cost and low-power devices that require minimal administration. A Sun Ray Thin Client contains no resident operating system or applications, and is a true thin client as opposed to thin clients provided by other vendors. Because there are no mechanical devices inside a Sun Ray thin client, the device is highly reliable and inexpensive. They do not have any resident operating system and are therefore immune to viruses and service attacks, thus providing enhanced IT security. The Sun Ray clients are compatible with Sun monitors and standard Video Graphics Array (VGA) or Digital Video Interface (DVI) monitors, thereby enabling NOAA to leverage existing monitors at NOAA facilities.

Sun Ray Server Software is a secure and cost-effective way to deliver a rich virtual desktop experience for Sun Ray Thin Clients. It provides access to virtual CAWS desktop environment from any location, dramatically reducing the complexity and operational costs incurred in traditional standalone workstation deployments.

A summary of the benefits of using Sun Ray Thin Clients and Sun Ray Server Software are listed below:

- Significantly reduces the time and cost associated with the installation, administration and maintenance of CAWS workstations;
- Sun Ray Thin Clients are plug-and-play devices, easy to configure, inexpensive, and highly reliable;
- Sun Ray Thin Clients are true thin clients, where all computing and administration take place on the server;
- Provides enhanced IT security – no data resides on the client, and access to removable media can be centrally restricted as required;
- Users can move from any Sun Ray Client to another, and resume their workstation sessions with instant access; and
- Supports smart card implementation, where a user can simply insert the smart card into any available Sun Ray Thin Client, with the Sun Ray technology providing instantaneous access to existing/new sessions.

To complement the migration of CAWS workstations to a virtualized environment based on Opteron blade servers and thin clients, the following changes are required to the software applications that reside on the CAWS workstations:

- Migration of all CAWS applications to the x86/Opteron architecture; and
- Availability of PV-WAVE support on the target operating system and x86 architecture.

PV-WAVE is a COTS product owned by Rogue Wave Software, and is currently available only for specific operating systems on the x86 architecture. A formal agreement has been established between Avaya Gov and Rogue Wave to port PV-WAVE to the platform of choice for CAWS applications. This port will provide full support for all PV-WAVE Foundation modules, including PV-WAVE widgets and VDA tools, Mapping Library, XML tools, VTK OpenGL tools, and complete inter-process communication tools for C and FORTRAN.

This approach is the least risky for the migration of the CAWS workstations to a virtualized environment within the GEMS architecture. Figure 2 shows the hardware and software architecture for the virtualized CAWS workstations within a single blade-based server.

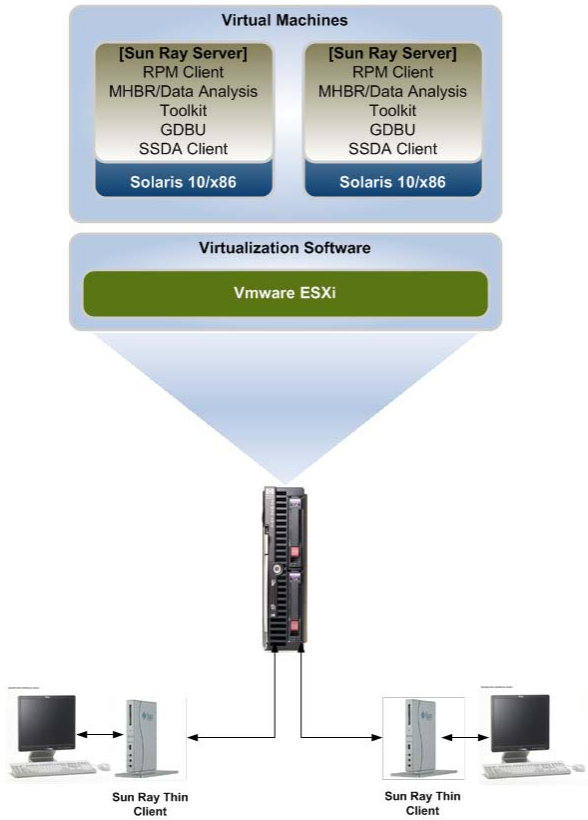

Figure 2. Hardware and Software Architecture of Virtualized CAWS Workstations Hosted Within the GEMS Architecture. *Each blade server hosts two or more virtualized CAWS workstations using virtualization software. Each virtualized CAWS workstation hosts CAWS applications and PV-WAVE software.*

Using this approach, the CAWS applications are hosted within a virtualized environment with each blade server hosting multiple virtualized CAWS workstations. This approach requires software changes in order to successfully migrate the existing CAWS applications to the x86 architecture. Such software changes are associated with the differences between the *Big-Endian* format of the SPARC-based platform versus the *Little-Endian* format of the x86 architecture. In this approach, minimal or no changes are required for the CAWS application interfaces with PV-WAVE since a fully supported PV-WAVE version using Solaris-10 operating system on x86 architecture will be provided by Rogue Wave Software. This approach provides the best value and least project risk to NOAA, where the CAWS workstations are migrated to a fully supported hardware and software platform while leveraging the advantages of virtualized workstations and thin clients.

III. IMPLEMENTATION

The CAWS migration is being implemented in three phases. Each phase is designed to meet a fixed set of well-defined requirements, with each new phase providing more features and complexity.

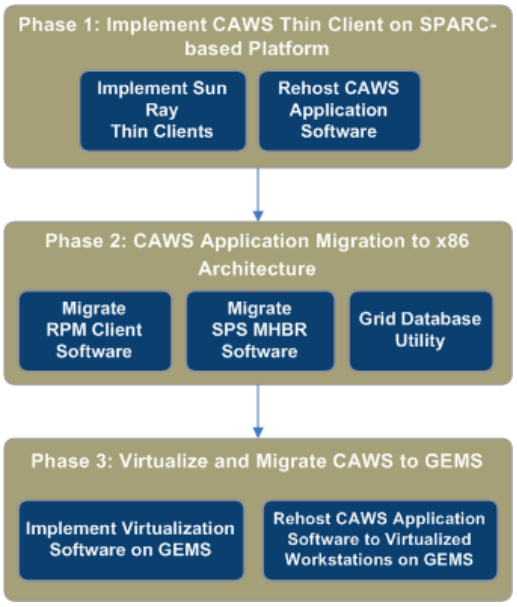

Figure 3. Phased Design and Development Approach to Provide Virtualized CAWS Workstations and Thin Clients.

The three proposed phases are illustrated in Figure 3. In *Phase 1*, all CAWS application software including the RPM Client, SPS MHBR and Data Analysis Toolkit, and GDBU will remain on the SPARC-based platform, and Sun Ray Server software will be used in conjunction with Sun Ray Thin Clients to provide thin client access to CAWS workstations. Activities in this phase identify and mitigate issues and risks associated with implementation of CAWS thin clients.

In *Phase 2*, the CAWS software will be migrated from Oracle's Solaris SPARC-based platform to Oracle's Solaris x86/Opteron architecture. Activities in this phase involve modifying the CAWS software applications to resolve any *Endian* issues when binary data is transferred between external systems that use different internal representations for multi-Byte data.

In *Phase 3*, the x86 version of the CAWS workstation application software will be migrated to a virtual environment within the GEMS architecture. This includes the use of virtualization software to provide virtualized CAWS workstations as shown previously in Figure 2. The Sun Ray Server Software and Sun Ray Thin Clients are used to access virtualized CAWS workstations hosted on the Opteron blade-based system as described earlier.

Software Migration Methodology and Tools

The legacy software applications hosted on the CAWS were developed for the Big-Endian architecture used by SPARC-based servers. Although the Solaris operating system (OS) will be used to host the software applications, migrating the CAWS software applications will require identification and modification of existing source code that is not portable. This will ensure that data can be shared between CAWS software

applications and other OGE components, such as the SPS, OATS and RPM Server.

To assist with the migration of software applications form SPARC-based platforms to the x86 architecture, we have developed a successful, effective, and efficient methodology to port legacy application software to run on x86 as shown in Figure 4. This methodology was developed from our experience of migrating the RPM Server software and the SPS to the GEMS architecture.

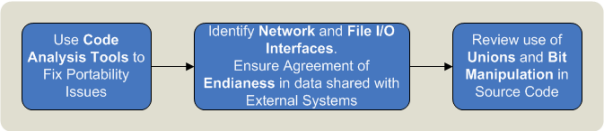

Figure 4. Methodology to Port Legacy Application Software to x86 Architecture.

Our methodology uses sophisticated static analysis tools to analyze, detect, and repair portability issues in the legacy code. As part of this activity, we will identify non-portable code, fix portability issues, and address SPARC versus x86 Byte-order differences. Although these tools are very useful in detecting most issues in the legacy code, a good understanding of the operating environment and software architecture is also required to ensure that all issues with porting the software are detected and addressed. A brief description of static analysis tools that can be used for porting applications from SPARC to x86 platforms on Solaris is given below.

Oracle's *lint* Source Code Checker is a no-cost source code analysis tool provided by Oracle to check C code for errors that may cause a compilation failure or unexpected results at runtime. It is being used to identify and fix incorrect, error-prone, or non-standard code that compilers do not detect.

Oracle's *AppCert* is a no-cost static analysis tool that checks for binary compatibility problems in applications running on the Solaris operating system. It is being used to check for potential binary problems in the CAWS software applications; for e.g., the use of deprecated libraries.

IBM Rational Software Analyzer is a static code analysis tool that reviews software code and identifies software defects in the development cycle. This tool is being used to identify issues related to data structure differences between the SPARC and x86 platforms, and also to detect software errors and defects associated with non-standard code practices resulting in non-portable code or memory leaks.

Figure 5 shows how these tools are used to migrate the CAWS software to the x86 architecture.

Issues Associated with migrating CAWS Software Application to x86 Architecture	Oracle Lint	Oracle AppCert	IBM's Rational Software Analyzer
I/O Architecture			
Storage order differences	✓		✓
Data Alignment Differences			
Read and write structures	✓		✓
Padding	✓		
Coding Best Practices			
Portability	✓		✓
Initialization Issues	✓		✓
Operating System & Other Differences			
Binary Compatibility		✓	

Figure 5. Assessment of Tools to Identify and Fix Portability Issues in the CAWS Software Applications.

Our methodology also includes steps to ensure that I/O interfaces used to exchange data between the CAWS software applications and other OGE components, such as SPS and RPM Server, are identified and modified for conformance. This is especially important for the GOES ground systems where SPARC-based legacy systems and next-generation x86 systems co-exist and provide mission-critical services in tandem. The use of our methodology to analyze and fix legacy code, in addition to our experience and knowledge of the CAWS software applications, will greatly reduce the time required to port the CAWS software applications, and will significantly improve the robustness of the software on GEMS.

System Integration, Installation and Test

A systematic and rigorous process is in place to verify the correct implementation of the CAWS migration to the GEMS architecture using virtualized CAWS workstations and Sun Ray thin-client technology. Our comprehensive approach for ensuring quality control throughout the CAWS Migration task is detailed in Figure 6.

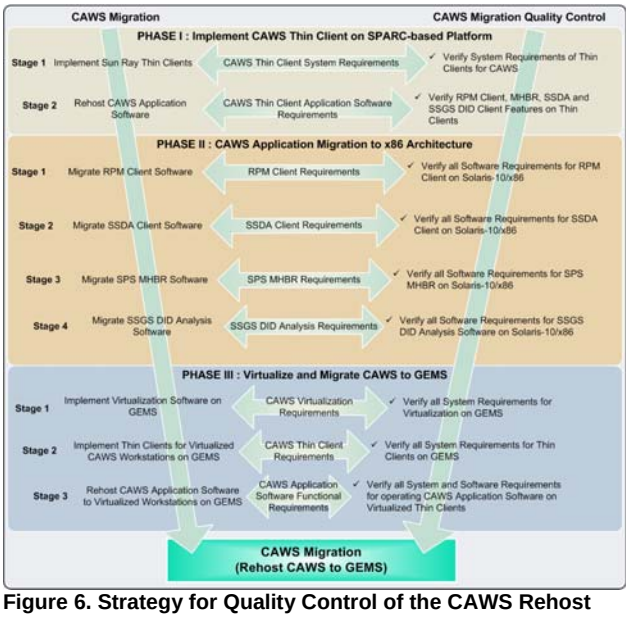

Figure 6. Strategy for Quality Control of the CAWS Rehost to GEMS at Each Stage of the CAWS Migration. *Quality-gate approach to ensure technical risks are detected and mitigated early on.*

IV. CONCLUSION

NOAA has selected a technically efficient and cost-effective solution to migrate CAWS workstations to virtualized servers. This solution, as described in this paper, provides a comprehensive, viable, low-risk, and cost-effective solution for operating CAWS workstations in a blade-based virtualized environment with associated user access through thin clients. It leverages the existing GOES GEMS architecture, and lays the foundation for extending the maintainability, reliability, and availability of CAWS workstations, while reducing the operations, maintenance and administrative costs of these workstations.

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