25th International Conference on Interactive Information Processing Systems for Meteorology, Oceanography, and Hydrology
89th American Meteorological Society (AMS) Annual Conference
Phoenix, AZ 11—15 January 2009

GOES Enterprise Managed System (GEMS), Re-Architecting GOES Operations Ground Equipment (OGE)

Shahram Tehranian[1], Abhishek Agarwal[1], Subir Vasanth[1], Rachid Dahmani[1], Robert DiRosario[1], Harris Zang[1], Houria Madani[2], Harold Minus[3], Keith McKenzie[4], Pong Yu[4]
[1]Nortel Government Solutions (NGS)
[2]Carr Astronautics
[3]Integral Systems Incorporated (ISI)
[4]National Environmental Satellite, Data, and Information Service (NESDIS)

Abstract – The Office of Systems Development (OSD) Ground Systems Division (GSD) intends to make a number of architectural upgrades to the Geostationary Operational Environmental Satellite (GOES) ground system components in an effort to extend the longevity of the system, increase operational reliability, combine functional components into a single architecture, and reduce long-term maintenance and operations costs. The Operations Ground Equipment (OGE) components supporting the GOES I-M and GOES NOP series of satellites need to be maintained at least through 2020. Given the need to maintain the OGE, an enterprise managed system for the GOES constellation based on blade architecture is designed and developed under the acronym of GOES Enterprise Managed System (GEMS). Blade alternatives have demonstrated reduced number of computer systems and footprint, as well as increased I/O capacities in a scalable architecture. The planned architecture will significantly reduce ground system life-cycle costs, improve future standardization between component systems with an enterprise approach, standardize operation and maintenance of operational ground equipment, provide reliable operation with hot backup and fault-tolerant component systems, enhance IT security, and provide the ability to perform system hardware and software upgrades without incurring long system downtimes.

The intent of the new architecture is to have an enterprise managed system, which could potentially host the entire GOES OGE components with a few exceptions. The first OGE component hosted within GEMS is the Replacement Product Monitor (RPM) Server. The primary functions of the RPM are to provide landmark registration, and to monitor and analyze the quality of image and non-image data in the GOES VARiable (GVAR) data stream. RPMs reside at NOAA Satellite Operations Facility (NSOF), Wallops Command and Data Acquisition Station (WCDAS), Fairbanks Command and Data Acquisition Station (FCDAS), and Wallops Backup Unit (WBU), each capable of supporting one GVAR data stream at a time. The first GEMS unit is installed at WCDAS, while the second unit is scheduled for deployment at NSOF in January 2009. Other OGE components are planned for migration to the GEMS architecture in the future.

Index Terms – GOES, Ground System Data Processing, Blades, Storage Area Network (SAN)

I. INTRODUCTION

Operational weather forecasting depends critically on the Geostationary Operational Environmental Satellite (GOES) [1] system. The U.S. normally operates two meteorological satellites in geostationary orbit over the equator. Each satellite views almost a third of the Earth's surface: one monitors North and South America and most of the Atlantic Ocean, the other North America and the Pacific Ocean basin. The two operate together to produce a full-face picture of the Earth, day and night. Coverage extends approximately from 20° W longitude to 165° E longitude. The GOES constellation consists of an eastern satellite stationed at 75° W longitude, a western satellite stationed at 135° W longitude, and the eXtended GOES Operations at High Inclination (XGOHI) [2, 3] satellite stationed at 60° W longitude, plus an in-orbit spare satellite. Currently, GOES-12 occupies the eastern slot, GOES-11 occupies the western slot, and GOES-10 operates as the XGOHI satellite providing coverage over South America. Due to GOES-12 thruster anomalies, GOES-13 as the in-orbit spare at 105° W longitude assumed east operational duties beginning December 15th, 2008.

The Operations Ground Equipment (OGE) [4] for the GOES spacecraft consists of components located at the National Oceanic and Atmospheric Administration (NOAA) Wallops Command and Data Acquisition Station (WCDAS) in Virginia, and its backup at the Goddard Space Flight Center (GSFC) in Maryland, Fairbanks Command and Data Acquisition Station (FCDAS) in Alaska, as well as the Satellite Operations Control Center (SOCC) at the NOAA Satellite Operations Facility (NSOF) in Maryland. The Sensor Processing System (SPS) [5-7], SPS Database Server [8], Replacement Product Monitor (RPM) Server [9] and

Client [10] are some of the functional elements, comprising the GOES OGE.

The SPS component performs all the functions associated with processing Imager and Sounder instrument data from the GOES spacecraft, one spacecraft per SPS. The SPS performs the functions necessary to generate a GOES VARiable (GVAR) [4] formatted data stream for real-time transmission to the GOES spacecraft. The spacecraft, in turn, relays that data to the primary user receiver stations. There are currently SPS units at WCDAS, FCDAS, and Wallops Backup Unit (WBU) to support GOES operations. The WCDAS SPS units support the GOES East (GOES-12) spacecraft, GOES West (GOES-11) spacecraft, XGOHI (GOES-10) and a spare (GOES-13) spacecraft. The WBU SPS is for contingency operations, primarily for the GOES East spacecraft, but can also support the GOES West spacecraft. The SPS also provides input to the orbit and attitude determination function, contained in the Orbit and Attitude Tracking Subsystem (OATS) [4] through the GOES I-M Telemetry and Command System (GIMTACS) [4] for GOES I-M series, and through GOES Telemetry and Command System (GTACS) [4] for GOES NOP series.

RPM servers and clients reside at SOCC, WCDAS, FCDAS and WBU, each capable of supporting one GVAR data stream at a time. The primary functions of the RPM are to provide landmark registration, and to monitor and analyze the quality of the image and non-image data broadcast in the GVAR data stream.

SPS database servers provide real-time initialization, and online archival of data structures used by the SPS during operations. They also provide failover capabilities by continually obtaining the configuration of each SPS, so that recovery from one SPS to another is simplified and fully automated. This automated recovery process allows operators to swiftly fail over during a system failure, or clone an online system for hot backup purposes. SPS database servers are currently located at WCDAS and WBU.

The OGE components supporting the GOES I-M and GOES NOP series of satellites need to be maintained at least through 2020 as shown in Figure 1.

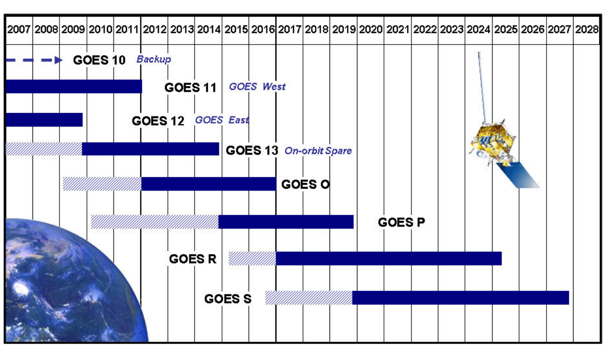

Figure 1 Existing and Future GOES Constellation [11]

Currently, GOES-O is scheduled for launch in April/May 2009 and will be operational until 2016, while GOES-P is scheduled for launch in early 2010 and is planned to be operational until late 2019. The GOES Enterprise Managed System (GEMS) was designed and developed in an effort to upgrade the GOES OGE to a centralized low-maintenance architecture with reliable short-term and long-term data backup and recovery. As an initial step, the Replacement Product Monitor (RPM) was migrated to a blade architecture based on the Sun Microsystems Solaris-10 Operating System (OS) [12] and AMD Opteron processors [13]. The first GEMS unit is installed at WCDAS while the second unit is scheduled for deployment at NSOF in January 2009.

II. SYSTEM ARCHITECTURE

The GOES Operations Ground Equipment (OGE) has been evolving over a number of years. Figure 2 shows an overview of some of the OGE components such as the SPS, RPM servers and clients, and database servers located at WCDAS. In the old OGE architecture, each component of the OGE is hosted on a different hardware platform as well as a different version of the Solaris Operating System (OS), depending on the compatibility of the software application with the version of the Solaris OS. Under the new architecture, the various OGE components will migrate to a unified scalable architecture. This architecture will host a number of enterprise-wide functions within the confines of a single blade-based system. Using a phased approach, the intent of the new architecture is to have an enterprise managed system, hosting a majority of the GOES OGE components on a single platform. In this fashion, key components can be individually migrated to the new architecture, with no or little impact on day-to-day operations and production of data products for end-users.

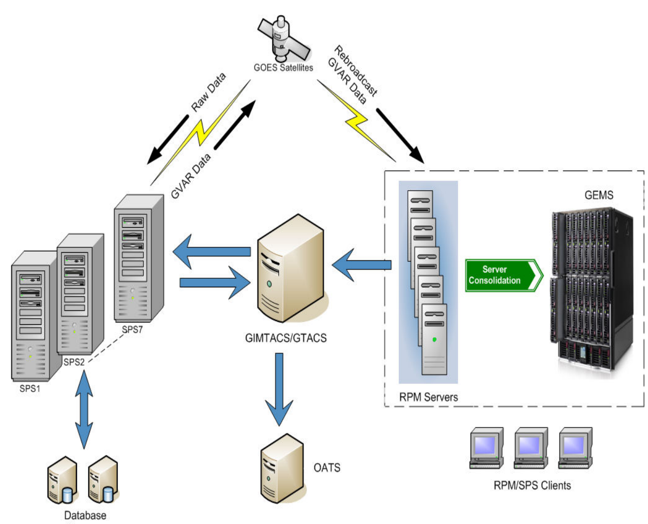

Figure 2 WCDAS GOES OGE Schematic

A. Technology Assessment

Table 1 shows the current state or "As-Is" assessment of the GOES OGE components currently planned for migration into the new architecture. Please note that the OGE consists of other components which are not discussed in this paper. A majority of the OGE components are currently hosted on obsolete hardware and older versions of the Solaris OS. The currently advertised Solaris retirement support status of each Solaris release is detailed in Table 2. As shown in Table 2, Solaris-2.6 has reached End-of-Live (EOL), Solaris-7 is currently in Retirement Phase-2, and Solaris-8 is in Retirement Phase-1, while both Solaris-9 and Solaris-10 are generally available and actively supported.

Table 1 "As-Is" Assessment of GOES OGE Hardware and OS

OGE Component	OS Version	Hardware	Units
SPS Servers	*Solaris-8*	*Sun Fire 280R / V440*	*WCDAS 21* *FCDAS 6* *WBU 3* *NSOF 3*
SPS Workstations	*Solaris-8*	*Sun Blade 150*	*WCDAS 7* *FCDAS 2* *WBU 1* *NSOF 1*
Database Servers	*Solaris-2.6*	*Ultra 60*	*WCDAS 3* *FCDAS 0* *WBU 1* *NSOF 1*
RPM Servers	*Solaris-9*	*Sun Fire V480*	*WCDAS 5* *FCDAS 1* *WBU 1* *NSOF 6*
RPM Clients	*Solaris-10*	*Sun Blade 1500*	*WCDAS 5* *FCDAS 2* *WBU 1* *NSOF 6*

Table 2 Solaris Retirement Support Status [14]

Release	Last Ship Date	Phase-1 End Date	Phase-2 End Date
Solaris-10	*TBD*	*TBD*	*TBD*
Solaris-9	*TBD*	*TBD*	*TBD*
Solaris-8	*February 2007*	*March 2009*	*March 2012*
Solaris-7	*August 2003*	*August 2005*	*August 2008*
Solaris-2.6	*July 2001*	*July 2003*	*July 2006*

The Sensor Processing System (SPS) is a highly complex system consisting of custom hardware, multiple servers, a front-end workstation, CISCO switch, time and terminal servers, and specialized telecommunication Peripheral Component Interconnect (PCI) cards for data ingest and broadcast. The details of the SPS are described elsewhere [5-7]. The SPS consists of three servers performing data ingest, calibration, ranging and GVAR output formatting functions for both the Imager and Sounder instruments. The SPS Servers consist of UltraSPARC Sun Fire 280R servers, running the Solaris-8 OS. The SPS has also a front-end workstation hosted on an UltraSPARC Sun Blade 150 running the Solaris-8 OS. Each spacecraft has a dedicated primary and backup SPS resulting in seven SPS racks at WCDAS, and one backup unit at WBU. There are two spare SPS units at FCDAS, and one development rack at NSOF.

Before being upgraded in 2008, the SPS database servers used the Sun Ultra 60 workstations, the Solaris-2.6 OS and Oracle 8.0.1 Database Management System (DBMS) [15]. The Sun Ultra 60 hardware is obsolete. Sun has also discontinued all support for Solaris-2.6, including security patches. It is imperative that the operating system be upgraded to Solaris-10 OS to meet the IT security requirements. The Oracle 8.0.1 DBMS is obsolete as well.

The RPM consists of a server and client architecture. The primary input to the RPM server is a GVAR data stream. The RPM server uses Solaris-9 OS and consists of an UltraSPARC Sun Fire V480 server. It also uses specialized telecommunication PCI cards for data ingest. The RPM client consists of an UltraSPARC Sun Blade 1500 workstation and uses the Solaris-10 OS. Furthermore, Sun discontinued the SPARC-based workstations in July 2008, effectively ending the production of workstations with an UltraSPARC processor.

B. Consolidation Strategy and Roadmap

Figure 3 shows a roadmap for an orderly migration of the GOES OGE components to the blade architecture. Filled shapes indicate completed activities.

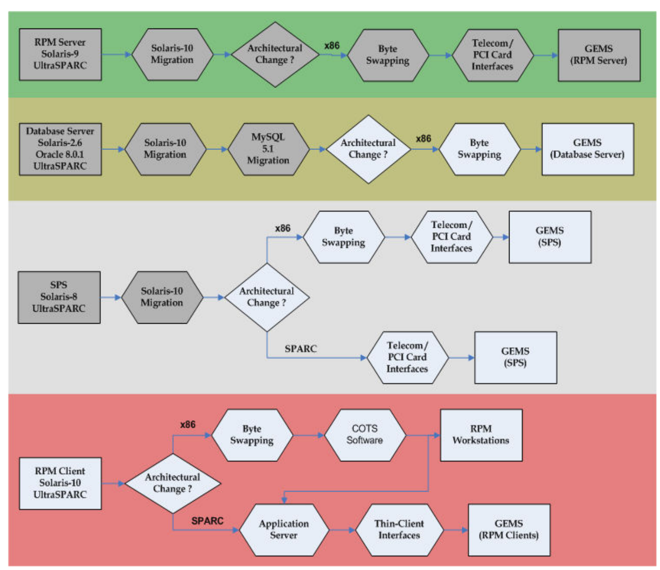

Figure 3 GOES OGE Components Migration Path

In order to migrate the GOES OGE components into the unified blade architecture, the OGE components need to be migrated to the Solaris-10 OS. Sun Solaris-10 operating system is supported on both x86 and SPARC-based systems, and can therefore provide hardware architecture independence. The x86 architecture offers:

- Significantly lower life cycle costs:
  - x86 processors are based on a standard and widely used processor, therefore available at much lower cost than SPARC-based systems,
  - lower cost for operations, maintenance and replacement parts,
- Compatability with a wide variety of current and future PCI I/O cards,
- Support for a wider selection of blade systems,
- Support for multi-CPU, multi-core architecture,
- Proven compatibility with Sun Solaris-10 operating system,
- Hardware assisted virtualization, for example through AMD Hypervisor [13], and
- Energy efficient design with reduced cooling costs.

In order to migrate from SPARC to x86 hardware architecture, Byte swapping is required due to the Big-Endianness of SPARC versus the Little-Endianness of x86 architecture. The Solaris operating system can be used both in Big-Endian mode (SPARC) and in Little-Endian mode (x86). Endianness is mandated by the hardware platform used. Sun's operating system software architecture allows Big-Endian applications for the Solaris SPARC platform to run on the Little-Endian Solaris x86 platform when they are recompiled. In general, no re-engineering is needed. However, the Endianness difference can cause problems, particularly if an application uses low-level code that takes optimal advantage of the hardware capabilities.

The RPM server has been migrated to Solaris-10 and the x86 architecture, and will be discussed in more details in section three of this paper.

The database servers have been migrated to the Solaris-10 operating system and the MySQL DBMS [16]. Once the code base has been migrated to the x86 architecture, the database servers can easily transition to the GEMS architecture as well.

The SPS has already been migrated to Solaris-10. Due to the complexity of the SPS software and the existing custom hardware, the SPS servers and workstations may remain on the SPARC platform, in which case blade systems from Sun Microsystems would be used for the migration of the SPS software and hardware to the GEMS architecture. Further studies are needed to conclude the migration path for the SPS.

Considering Sun's discontinuation of the SPARC-based workstations, one potential migration path would be to migrate the RPM clients to the x86 architecture, and continue using stand-alone workstations as is done today. Another option is to use thin-client technology, and host the RPM client functionalities on the server side within GEMS. This solution would significantly reduce cost and system administration tasks associated with the operations and maintenance of stand-alone workstations.

C. Key Technical Drivers

The major objectives of the operational system architectural changes are:

- Reduced ground system life-cycle costs,
- Reduced system footprint and power requirements,
- Improved future standardization between component systems with an enterprise approach,
- Enhanced IT security,
- Standardized operation and maintenance of operations ground equipment,
- Reliable 24x7 operations with hot backup and fault-tolerant systems,
- Automatic logging of subpar components, failures, and major events,
- Strong predictive diagnostics to allow for manual or automated failover to backup components prior to the onset of failures,
- Ability to effectively tune and re-tune the blade system so that processor loading is effectively distributed,
- Ability to perform system hardware or software upgrades without incurring long system down-times, and
- Consolidated enterprise backup, archive, and recovery services.

D. Blade Systems

Blade technology is designed to eliminate old limitations imposed by conventional server design, in which each server would accommodate only one type of processor. Each blade in a chassis is a self contained server, running its own operating system and software technologies; therefore it can support a mix of blades, with varying speeds and types of processors. This rapidly developing technology offers real investment protection for the future. All critical components of a blade server can be made redundant or hot-swappable, including system cooling; power supplies; Ethernet components and switches; mid and backplanes; hard disk drives and service processors. Removing a server for maintenance simply means sliding the blade out of the chassis – no more complex than removing a hot-swappable hard disk drive. Advanced blade server systems offer smart ways of achieving highly sensitive maintenance. Blade server components can alert a systems management processor of impending failure, hours or even days before a failure occurs. Advanced diagnostics direct a service directly to a failing part, allowing for quick and efficient restoration.

E. Enterprise Management

In addition to the migration of the OGE components to the unified blade architecture, the designed system will consolidate a number of enterprise-wide functions within the confines of a single blade-based system. Below follows a list of some of the enterprise management functionalities provided by GEMS:

- Enterprise backup and recovery,
- Security scanning,
- System and network monitoring,
- Two-factor authentication,
- System imaging and provisioning, and
- Short and long-term archive using Storage Area Network (SAN) architecture.

III. Implementation

The GEMS rack delivered to WCDAS in December 2008, and the rack scheduled for delivery to SOCC in January 2009, each consist of:

- Five operational RPM servers based on dual-CPU, dual-core AMD Opteron processors,
- One deployment server for imaging and provisioning purposes,
- One Enterprise Backup Solution (EBS) server for short and long-term data backup and recovery,
- 8 TB of Storage Area Network (SAN) for short-term online data storage,
- Tape library for long-term off-line data storage,
- One management server connected to an LCD monitor,
- Fibre channel switches for end-to-end connectivity between the blades and the SAN, and
- Ethernet CISCO switches.

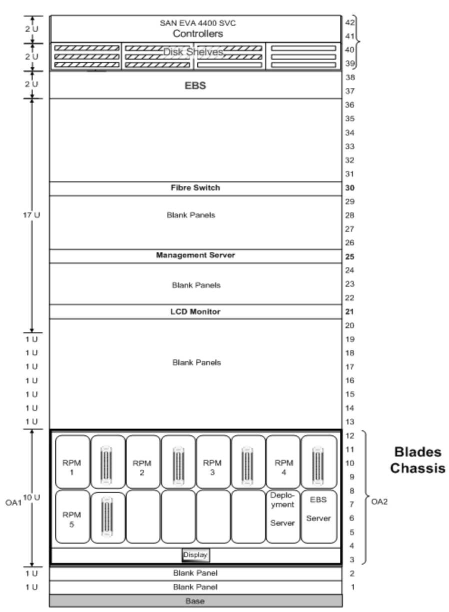

Figure 4 GEMS Hardware Configuration – Front View

The full system is enclosed in a standard 42U rack. The rack consists of a c7000 HP [17] blade enclosure, that houses the blade servers, Fibre and Ethernet switches, power distributions units, and cooling fans. An overview of the GEMS hardware configuration is shown in Figures 4 and 5. The components of the GEMS are briefly described below.

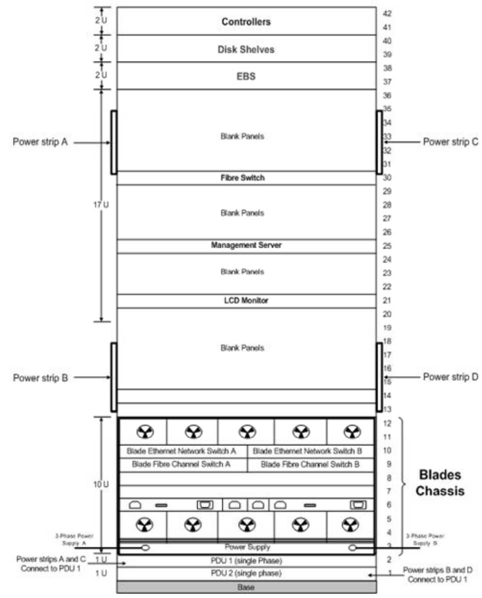

Figure 5 GEMS Hardware Configuration - Back View

A. Inside the Blade Enclosure

The HP c7000 enclosure contains eight half-height blade servers, each with a dual-CPU, dual-core Opteron processor and two hard disks in a RAID-1 configuration, two embedded integrated network controllers, and one embedded Fibre channel Host Bus Adaptor (HBA). In addition, each blade has an adjacent expansion blade with two slots for third-party PCI cards. Five of the blade servers are configured as RPM servers with an EDT [18] card in each expansion blade for GVAR data ingest. One blade is configured as a deployment server for rapid imaging and provisioning, and another blade is configured for EBS. The four remaining blade slots within the enclosure are empty and can be used for future expansion, for example an additional deployment server may be added for redundancy purposes.

In the back of the enclosure, there are two redundant Cisco Ethernet switches (with 16 1-Gb internal ports for downlink to the blade servers and 8 1-Gb external ports for network uplink) for Ethernet connection to several Virtual Local Area Networks (VLANs). The CISCO switches do not operate in redundant mode since the RPM requires connectivity to multiple VLANs at once. There are two redundant Brocade Fibre switches (with 16 4-Gb internal ports for downlink to the blade servers and 8 4-Gb external ports for network uplink) for Fibre connectivity to the SAN. The four switches communicate with the blade servers through the mid-plane of the enclosure. This configuration minimizes wiring and provides non-stop high-speed data transfer and connectivity between the blades, the networks, and the SAN. Efficient power and cooling are provided by six redundant hot-swappable Power Distribution Units (PDUs) and ten redundant hot-swappable cooling fans.

Two redundant Onboard Administrators [19] (one active and one backup) provide remote monitoring and operation of all components residing in the blade enclosure. They offer seamless failover capability without operator intervention or system interruption. The HP Systems Insight Manager (SIM) [20] provides unified infrastructure management of all servers, storage, and other GEMS components.

B. Outside the Blade Enclosure

Other GEMS components located outside the enclosure are:

- Management server, running Windows 2003 OS, with an LCD monitor providing local and remote centralized monitoring of all components through Integrated Lights Out (ILO) management,
- Fibre switch with 16 4-Gb ports for Fibre channel connectivity between the blades and SAN,
- SAN controller and disk array with 8 disks in a RAID-5 configuration, and
- EBS system for data backup and recovery.

C. System Administration and IT Security

System management and administration is performed using the HP Rapid Deployment Pack (RDP) [21], which provides a fast, easy, drag-and-drop solution for deploying server images on multiple blades at the same time using multicast. This saves time for server deployment, and improves overall consistency of configurations across multiple servers. RDP can be used to deploy Windows, Linux and Solaris-10 on various x86 servers. System monitoring is provided by HP Systems Insight Manager (SIM) [20], which offers enterprise-wide monitoring of various devices including servers, clusters, storage devices (SAN and NAS devices), network devices (switches and routers), and printers. It can monitor servers running various operating systems including Windows, Linux, and Solaris from one centralized GUI based monitoring console. It also supports user notification in case of unexpected events.

The GEMS system includes PatchLink Scan [22] software used for network-based threat management. It provides a comprehensive vulnerability scanning of all network devices including servers, switches, storage devices, and printers. It also provides reporting capability to confirm policy and regulatory compliance.

D. Enterprise Backup Solution (EBS)

An Enterprise Backup Solution (EBS) system is implemented as part of the GEMS architecture for providing Continuity of Operations (COOP) and Disaster Recovery (DR). The EBS will initially support the GOES OGE components discussed previously, but can be expanded in the future to support other critical components of the OGE.

The EBS provides capabilities for systems administrators to schedule automated system backup from a centralized location. System administrators are able to perform the following activities:

- Local and remote backup and restore of OGE components using back-end Fibre connectivity,
- Automated backup of complete systems, data and applications,
- Selective restore of data as needed,
- Short-term data backup on SAN facilitating faster data retrieval, and
- Offline data migration to tapes for long-term archive.

The architecture of the GEMS EBS system is shown in Figure 6. The HP Data Storage Data Protector [23] software is used for the EBS implementation within GEMS. This software provides an automated high performance backup and recovery from disks or tapes. HP Data Storage Data Protector provides a unique zero-downtime backup capability with instant online recovery functionality. It supports fast online backup to disk, after which the data can be transferred to tape in offline mode.

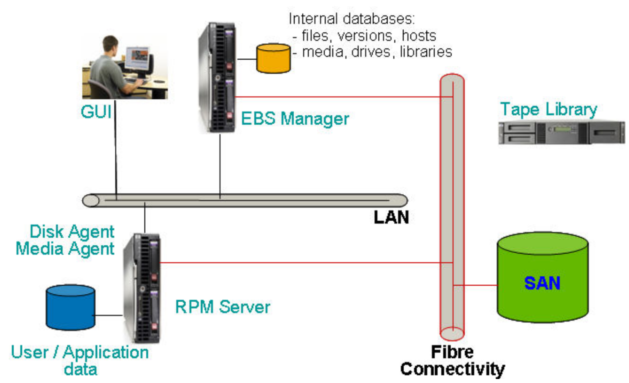

Figure 6 High Level System Architecture of GEMS EBS

E. Replacement Product Monitor (RPM)

The RPM is the first OGE component to be hosted within GEMS. In addition to being used to monitor and analyze the quality of GVAR image and non-image data, the RPM is also an important component of the GOES Image Navigation and Registration (INR) subsystem. The RPM provides absolute landmark positions to the GOES Orbit and Attitude Tracking System (OATS). These landmark measurements are used by OATS in its orbit and attitude determination function.

The RPM architecture is based on a server-client paradigm. The RPM server provides real-time and archived GVAR data to the RPM client, which in turn performs automatic landmarking and stripe detection, and generates long-term calibration statistics. The RPM client capabilities also include display of GVAR data in several forms such as images, plots, and data pages and reports. Figure 7 shows an example of images provided by the RPM server, and displayed by the RPM client.

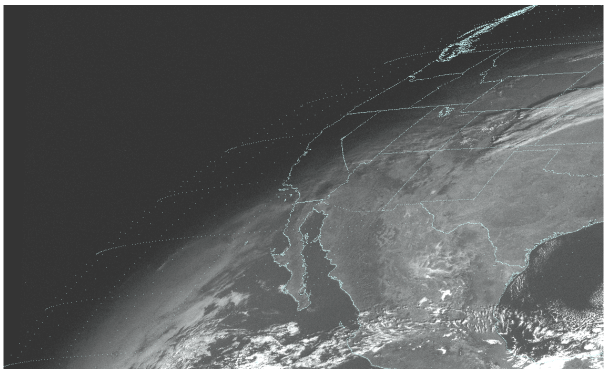

Figure 7 GOES-10 Imager Data

As of this writing, only the RPM servers are re-hosted on blade architecture with minimal impact to the RPM client software, and virtually no impact to the RPM user. The RPM server software is a multi-process system written in the C and C++ programming languages. The migration to the blade architecture involved modification of the software for several of the RPM server processes. The main reason for the modifications is to insure the compatibility of the server data with all of the systems which receive the data. The software modifications consisted in converting data that is passed to the client or other OGE components from Big-Endian to Little-Endian format.

As part of the RPM migration path, the RPM server software was initially ported to stand-alone Sun Fire V40z servers based on AMD Opteron processors. After this migration, the server software was transitioned to the HP blade system. GEMS units are planned to reside at WCDAS and NSOF, while stand-alone Opteron servers will be used at WBU and FCDAS. The same RPM software baseline will be used for GEMS and stand-alone servers.

IV. Conclusion and Future Work

By combining functional components into a single architecture, OGE component workstations and servers can be migrated into a unified and scalable blade architecture. In this paper, we have presented a design for a state-of-the-art architecture for the GOES OGE, filling the gap between the existing GOES I-M/NOP and the GOES-R era. An implementation of this new architecture is deployed at WCDAS in Virginia and is scheduled to be deployed at the Satellite Operations Control Center at NSOF in January 2009.

References

[1] GOES I-M DataBook, DRL 101-08, GSFC Specification S-480-21A, Revision 1, August 1996

[2] Tehranian S., Car J. L., Yang S., Madani H., Vasanth S., DiRosario R., McKenzie K., Schmit T., Swaroop A., "Remapping GOES Imager Instrument Data for South American Operations, Implementing the XGOHI System", Fifth GOES User's Conference, 88th AMS Annual Meeting, New Orleans, LA, January 2008

[3] Tehranian S., Carr J. L., Yang S., Swaroop A., McKenzie K., "XGOHI, Extended GOES High-Inclination Mission for South-American Coverage", 87th American Meteorological Society (AMS) Annual Conference, San Antonio, TX, January 2007

[4] Geostationary Operational Environmental Satellite (GOES) Operations Ground Equipment (OGE) Interface Specification, DRL 504-01, Part 1, Revision 3, August 2007

[5] Geostationary Operational Environmental Satellite (GOES) Sensor Processing System (SPS) User's Manual, Revision 3, June 2008

[6] Geostationary Operational Environmental Satellite (GOES) Sensor Processing System (SPS) Software Maintenance Manual, Revision 3, June 2008

[7] Geostationary Operational Environmental Satellite (GOES) Sensor Processing System (SPS) Hardware Operation and Maintenance Manual, Revision 3, August 2008

[8] Geostationary Operational Environmental Satellite (GOES) Sensor Processing System (SPS) Database User's Manual, November 2008

[9] Geostationary Operational Environmental Satellite (GOES) Replacement Product Monitor (RPM) Software Maintenance Manual, Revision 2, August 2008

[10] Geostationary Operational Environmental Satellite (GOES) Replacement Product Monitor (RPM) User's Manual, Revision 3, August 2008

[11] Kicza M., "NOAA Satellite and Information Service, Satellite Update", NOAA's 2008 Direct Readout Conference, Miami, FL, December 2008

[12] Sun Microsystems Solaris-10 Operating System (OS), Retrieved (12/31/2008) from http://docs.sun.com/app/docs/prod/solaris.10

[13] AMD Opteron Processors, Retrieved (12/31/08) from http://h18004.www1.hp.com/products/servers/proliant-bl/c-class/465c-g5/index.html

[14] End of Service Life Status for Solaris Operating System, Retrieved (12/31/08) from http://www.sun.com/service/eosl/eosl_solaris.html

[15] Oracle Database Management System (DBMS), Retrieved (12/31/08) from

http://www.oracle.com/database/index.html

[16] MySQL Database Management System, Retrieved (12/31/08) from http://www.mysql.com/

[17] HP BladeSystem c7000 Enclosure Overview, Retrieved (12/31/08) from http://h18004.www1.hp.com/products/blades/components/enclosures/c-class/c7000/

[18] Engineering Design Team (EDT) PCI Cards, Retrieved (12/31/08) from http://www.edt.com/index.html

[19] HP BladeSystem Onboard Administrator User Guide, Retrieved (12/31/08) from http://h20000.www2.hp.com/bc/docs/support/SupportManual/c00705292/c00705292.pdf

[20] HP Systems Insight Manager 5.0 Installation and User Guide, Retrieved (12/31/08) from http://docs.hp.com/en/5991-4498/5991-4498.pdf

[21] HP Rapid Deployment Pack Users Guide, Retrieved (12/31/08) from http://bizsupport1.austin.hp.com/bc/docs/support/SupportManual/c01154887/c01154887.pdf

[22] PatchLink Scan, Retrieved (12/31/08) from http://www.lumension.com/data/?id=WCMContenido%20M24659418361419~S131980~NLumension%20PatchLink%20Scan.pdf

[23] HP Data Storage Data Protector Software, Retrieved (12/31/08) from http://h18006.www1.hp.com/products/software/im/biz_continuity_avail/dp/index.html