Virtualization – A Key Cost Saver in NASA Multi-mission Ground System Architecture

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**Introduction**

- Today’s Sci/Ops Outlook:
  - Science Budgets are being slashed, very little money is allocated for Science Operations activities
  - At Goddard, operations space is extremely limited, expensive, and mainly reserved for flight operations (who tend to have deeper pockets)
- It was mid-2010, and the LADEE Science Operations Center was looking for a home
Science Operations Challenges

- We discovered many Goddard science payloads ran their ops out of someone’s cube or office!
- The LADEE SOC would need to be a true ops facility, with advanced requirements such as:
  - Real-time remote commanding of payloads
  - Automated monitoring and alert
  - Automated real-time and offline data distribution
  - 24/7 keycard-restricted secure access
  - Battery and Generator-backed power distribution
  - Access to the NASA Secure Mission Networks (data and voice)
- We realized quickly–these reqs. couldn’t be met by a server or two living in someone’s cube!
For many of the options open to us, the cost-of-entry for facility build-out was just too high for LADEE to foot the bill alone.

Luckily we were able to make some friends with a similar set of needs and timetable to our own!

- LADEE Neutral Mass Spectrometer (NMS) Instrument Ops
- MSL Sample Analysis at Mars (SAM) Payload Ops
- MAVEN Neutral Gas Neutral Gas and Ion Mass Spectrometer (NGIMS) Instrument Ops
- MAVEN Backup Mission Support Area (bMSA) Backup Mission Ops
Facility Build-out

- We held many meetings with the other groups and Science Directorate management over the next 6 months.
- We were offered up a large space that had formerly housed the Goddard Distributed Active Archive Center.
- Our build-out began with the collection of excess tables, chairs and other computer/printer hardware.
- We also went shopping for modular, affordable cubicle walls + lockable doors.
Facility Build-out (2)

- In order to have access to existing pressurized-floor cooling and additional UPS-backed power circuits for our racks, we received permission to extend our room into an adjacent server datacenter by constructing a server cage.

- This saved our five projects an estimated $230k each – over $1 million combined in additional facility build-out costs.
A “SPOCC” is Born—SPOCC On!

- Selected Science and Planetary Operations Control Center, or “SPOCC”, as our name
  - An “unofficial mascot,” the SPOCC, was born!
- Now to define the LADEE Ground System Architecture
  - To meet LADEE SOC requirements
  - To evolve into a multi-mission SPOCC Ground System Architecture!
Trade-off: Physical vs. Virtual

- We passed LADEE PDR with an architecture that could go either virtual or physical.
- Our biggest hurdle towards virtualization was selling it!
- (At the time) Goddard didn’t have much of a heritage with virtualization on the mission ops side, but as a Class D mission LADEE was encouraged to demonstrate new emergent technologies for future missions to build upon.
Option #1: Physical Servers

<table>
<thead>
<tr>
<th>Physical Architecture</th>
<th>Cost</th>
<th>Quantity</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dell R610 Server 4 cores / 8GB RAM</td>
<td>$2,800</td>
<td>26</td>
<td>$72,800</td>
</tr>
<tr>
<td>Wyse R50L Thin Client</td>
<td>$450</td>
<td>12</td>
<td>$5,400</td>
</tr>
<tr>
<td>24&quot; 1080p HDMI Monitors</td>
<td>$210</td>
<td>24</td>
<td>$5,040</td>
</tr>
<tr>
<td>Windows Server 2008 R2 License</td>
<td>$629</td>
<td>2</td>
<td>$1,258</td>
</tr>
<tr>
<td>8X8 HDMI Matrix Switcher</td>
<td>$2,075</td>
<td>1</td>
<td>$2,075</td>
</tr>
<tr>
<td><strong>Total Cost:</strong></td>
<td><strong>$86,573</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- For Option #1 (Physical Servers), the total cost was **$86,573** for the base set of hardware and licenses.
- Net Datacenter Mean Load = **8.1 kW**
- This equates to a net monthly energy usage of **5,833 kWh**
- At current Maryland commercial energy rates, this would cost the government ~**$6,558 / yr**, not counting cooling expenses.
Option #2: Virtualized Servers

For Option #2 (Virtualized Servers), the total cost was $48,553 for the base set of hardware and licenses.

- Net Datacenter Mean Load = 0.9 kW
- This equates to a net monthly energy usage of 659 kWh
- At current Maryland commercial energy rates, this would cost the government ~$742 / yr, not counting cooling expenses.
Virtualization Benefits

- Datacenter Cost! Virtual is better:
  - Procurement is **44% cheaper**, uses **89% less power**!
- Takes up less space in the rack (a half-populated rack instead of fully-populated!)
- Provides other benefits:
  - More efficient SysAdmin management (snapshots / patching)
  - Increased fault tolerance (any single hardware failure would only result in minutes of downtime for a system)
  - Flexibility in provisioning: Several times during implementation, we realized life would be easier if we had an extra Linux instance to assign to some task—with Virtualization were able to simply provision a new VM (this applies to new missions too)!
- Needless to say, it didn’t take too much work to convince our stakeholders that virtualization was the most appropriate choice for the SPOCC!
SPOCC Virtualization Architecture
Deployment Environment / IT Security Controls

- The SPOCC uses a Cobbler PXE boot server / Puppetmaster server and Kickstart files to automatically image new Linux systems.
- All system configuration and software installation is performed and enforced by the Puppet agent (done at install-time and then every 30 minutes).
- Puppet is responsible for implementing all host-specific CIS benchmark / NIST 800-53 controls.
- Puppet provides for continuous monitoring and enforcement of those controls, software upgrades and allows for centralized system-level Configuration Management.
Thin Client Management

- The SPOCC thin clients are PXE booted into a Linux Terminal Services Project (LTSP) 64-bit Enterprise Linux 6 desktop environment
- LTSP utilizes a centralized server to distribute thin client and kernel images to boot all thin clients
- Adding new thin clients simply requires updating the MAC addresses configuration file
- Performing patching / configuration updates across all thin clients requires simply updating the root image
The SPOCC utilizes a GMSEC message bus architecture to allow applications to communicate via a standard interface. GMSEC is used for telemetry event monitoring, system and device heartbeat/health information transfer, event filtering/analysis and automated notification via email and text message.
Moving Forward

- As of early 2014, four new tenant missions are in various phases of planning their integration into the SPOCC architecture:
  - DSCOVR Science Operations Center (DSOC)
  - Icesat2 ATLAS Instrument Support Facility (ISF)
  - Magnetospheric Multiscale Mission (MMS) Backup Mission Operations Center
  - NICER Payload Operations Center
- Each is planning on taking advantage of some level of virtualization + shared resources
Lessons Learned

- “If you build it, they will come!”
- It’s definitely worth spending the extra time up-front when engineering a solution to make it generally applicable.
- Documentation is key—document early, and document often! It easily takes 1/10th the time to document something as you are doing vs. after-the-fact…
- When implementing something new, make sure you research industry best practices before settling on a single technique or approach!
- Traditional practices on sparing and string management are not applicable the same way in virtualization, it requires a re-evaluation of core concepts.
Back-up Slides
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SPOCC Facility Layout
## GMSEC Component Roles

<table>
<thead>
<tr>
<th>GMSEC Tool</th>
<th>Description</th>
<th>Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT</td>
<td>Criteria Action Table</td>
<td>Process software component messages</td>
</tr>
<tr>
<td>GEDAT</td>
<td>GMSEC Environmental Diagnostic Analysis Tool</td>
<td>Visualization of SA data, heartbeats and Middleware Health</td>
</tr>
<tr>
<td>GREAT</td>
<td>Event / log messaging for bus</td>
<td>Debugging GMSEC; message archive</td>
</tr>
<tr>
<td>ANSR</td>
<td>Paging system</td>
<td>Page operations users via outgoing IONet e-mail gateway in response to specified events</td>
</tr>
<tr>
<td>SA</td>
<td>System Agents</td>
<td>Provide heartbeats for middleware and operating system instances, provide rolled-up system status to the GMSEC bus</td>
</tr>
<tr>
<td>ActiveMQ</td>
<td>Open-source Middleware</td>
<td>Provide reliable connectivity between SOC systems that will be generating alerts, CAT and ANSR</td>
</tr>
<tr>
<td>GMSEC-API</td>
<td>GMSEC Application Programming interface</td>
<td>Serve as an interface between different software programs</td>
</tr>
</tbody>
</table>