National Aeronautics and Space Administration

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

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GSAW 2014
Session 10: Data Distributions
Wednesday, Feb. 26th, 2014
Los Angeles, California

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

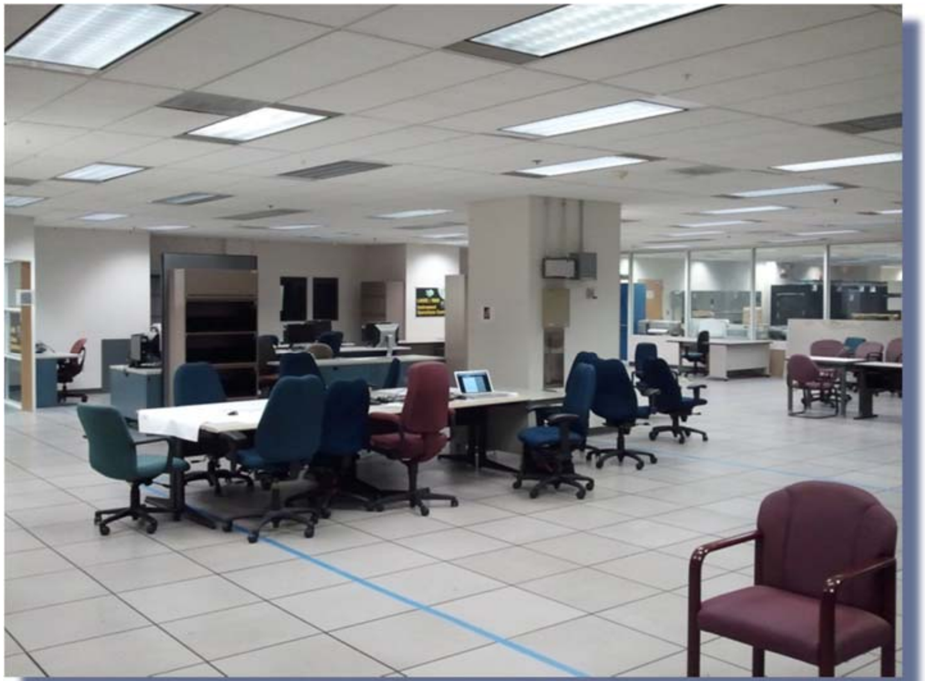
- We discovered many Goddard science payloads ran their ops out of someone's cube or office!
- The LADEE SOC would need to be a true ops facility, with advanced requirements such as:
  - Real-time remote commanding of payloads
  - Automated monitoring and alert
  - Automated real-time and offline data 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!

Friends in Low (Budget) Places

- 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)

Facility Build-out (3)

- 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

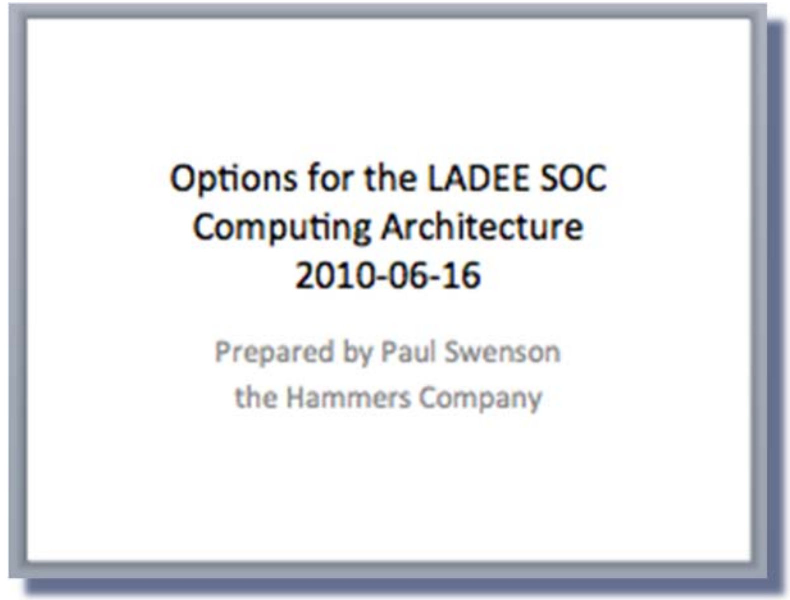
- **This saved our five projects an estimated $230k each – over $1million combined in additional facility build-out costs**

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


Options for the LADEE SOC
Computing Architecture
2010-06-16

Prepared by Paul Swenson
the Hammers Company

Option #1: Physical Servers

Physical Architecture	Cost	Quantity	Total
Dell R610 Server 4 cores / 8GB RAM	$2,800	26	$72,800
Wyse R50L Thin Client	$450	12	$5,400
24" 1080p HDMI Monitors	$210	24	$5,040
Windows Server 2008 R2 License	$629	2	$1,258
8X8 HDMI Matrix Switcher	$2,075	1	$2,075
		Total Cost:	$86,573

- 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 **5833 kWh**
- At current Maryland commercial energy rates, this would cost the government **~$6558 / yr**, not counting cooling expenses

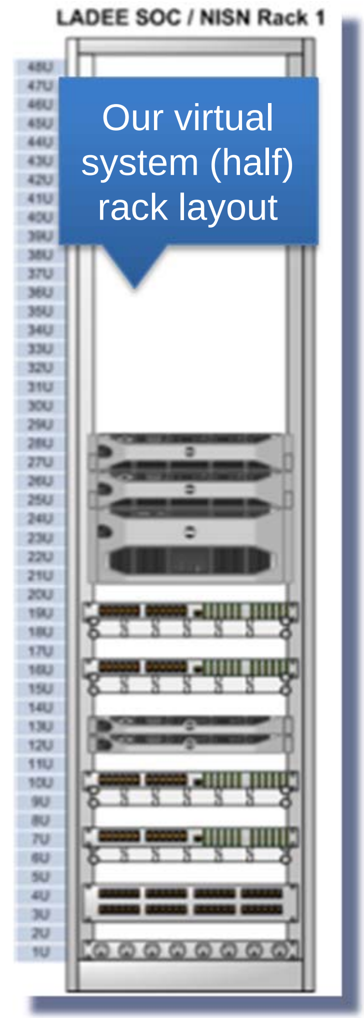
Option #2: Virtualized Servers

Virtual Architecture	Cost	Quantity	Total
PowerEdge R710 Server, 2 sockets / 24 logical cores / 96GB RAM	$7,755	2	$15,510
Raid Inc. Xanadu 230 6.5TB Direct-Attach SAS Storage Array	$14,818	1	$14,818
Vmware Essentials Plus License	$4,452	1	$4,452
Wyse R50L Thin Client	$450	12	$5,400
24" 1080p HDMI Monitors	$210	24	$5,040
Windows Server 2008 R2 License	$629	2	$1,258
8X8 HDMI Matrix Switcher	$2,075	1	$2,075
		Total Cost:	$48,553

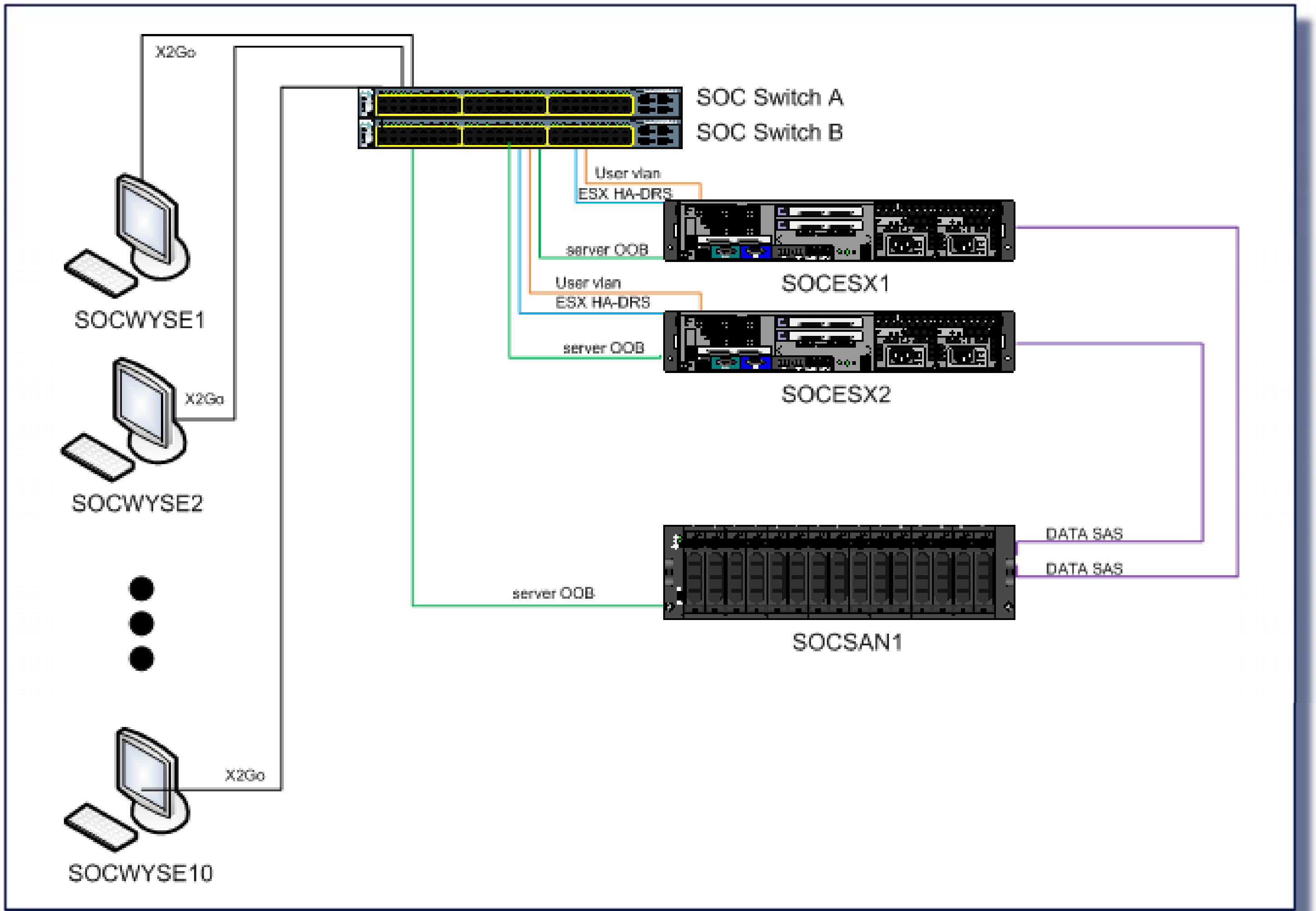
- For Option #2 (Virtualized Servers), the total cost was **$48,553** for the base set of hardware and licenses
- Net Datacenter Mean Load = **0.9 kW**
- This equates to a net monthly energy usage of **659 kWh**
- At current Maryland commercial energy rates, this would cost the government **~$742 / yr**, 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

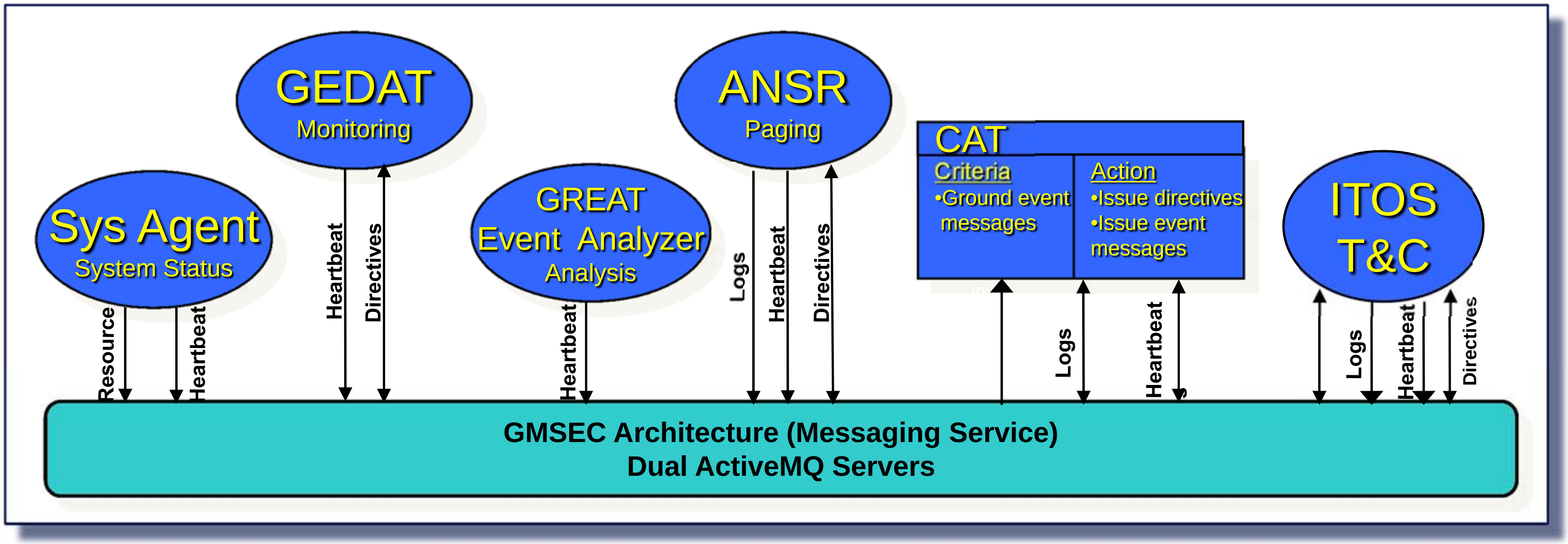
- The SPOCC uses a Cobbler PXE boot server / Puppetmaster server and Kickstart files to automatically image new Linux systems
- All system configuration and software installation is performed and enforced by the Puppet agent (done at install-time and then every 30 minutes)
- Puppet is responsible for 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

GMSEC Message Bus Architecture

- 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

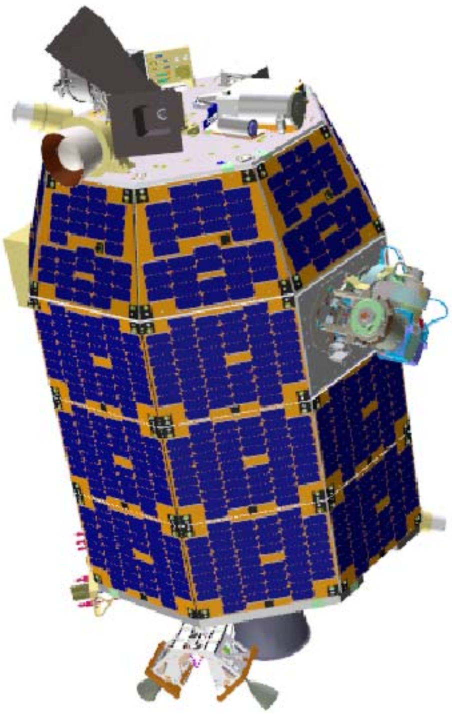
- As of early 2014, four new tenant missions are in various phases of planning their integration into the SPOCC architecture:
  - DSCOVR Science Operations Center (DSOC)
  - Icesat2 ATLAS Instrument Support Facility (ISF)
  - Magnetospheric Multiscale Mission (MMS) Backup Mission Operations Center
  - 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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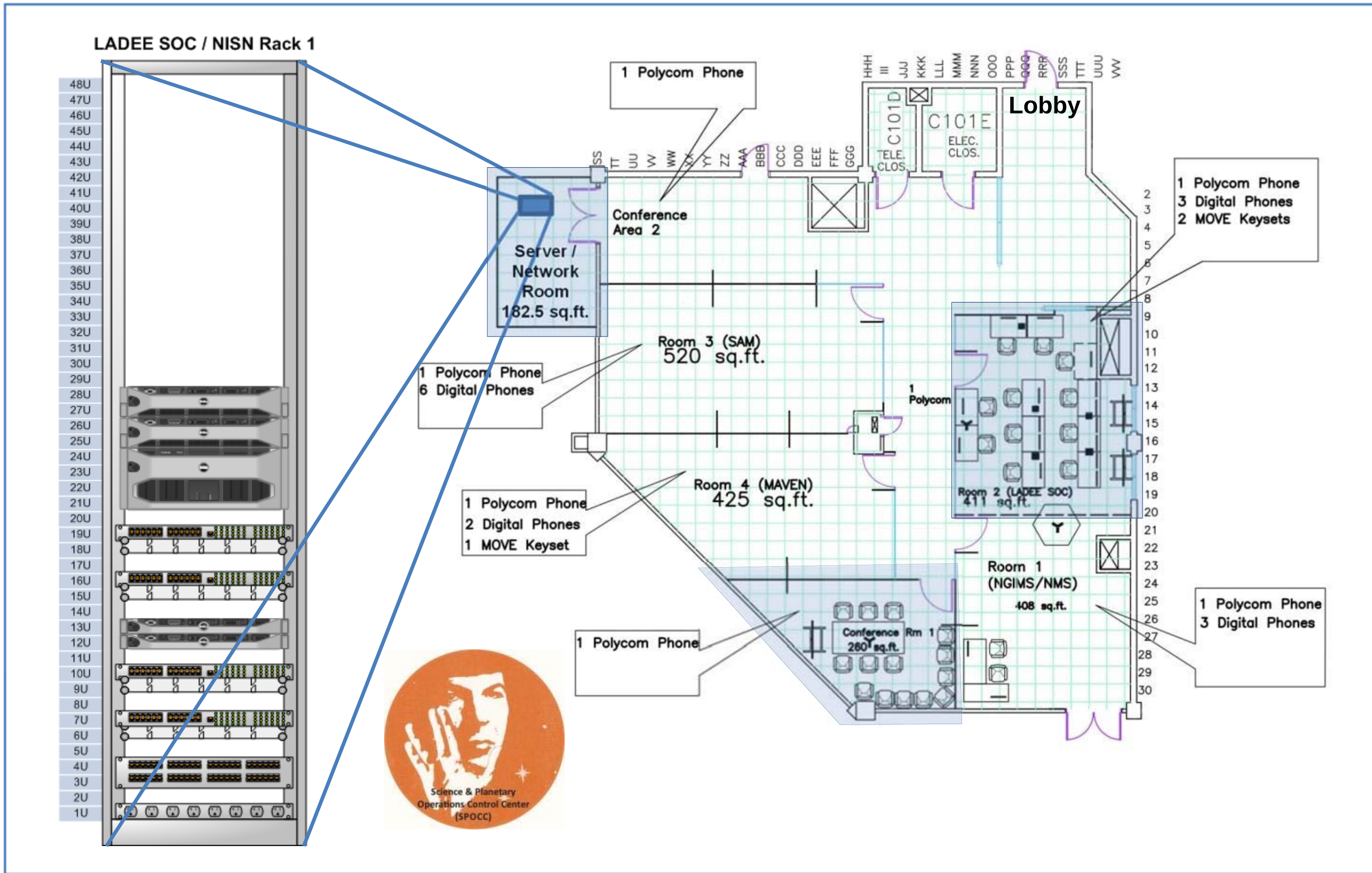
SPOCC Facility Layout



GMSEC Component Roles

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

NASA