Commercial Practices Applied to Operations and Maintenance of Satellite Constellations

A Ground System Perspective

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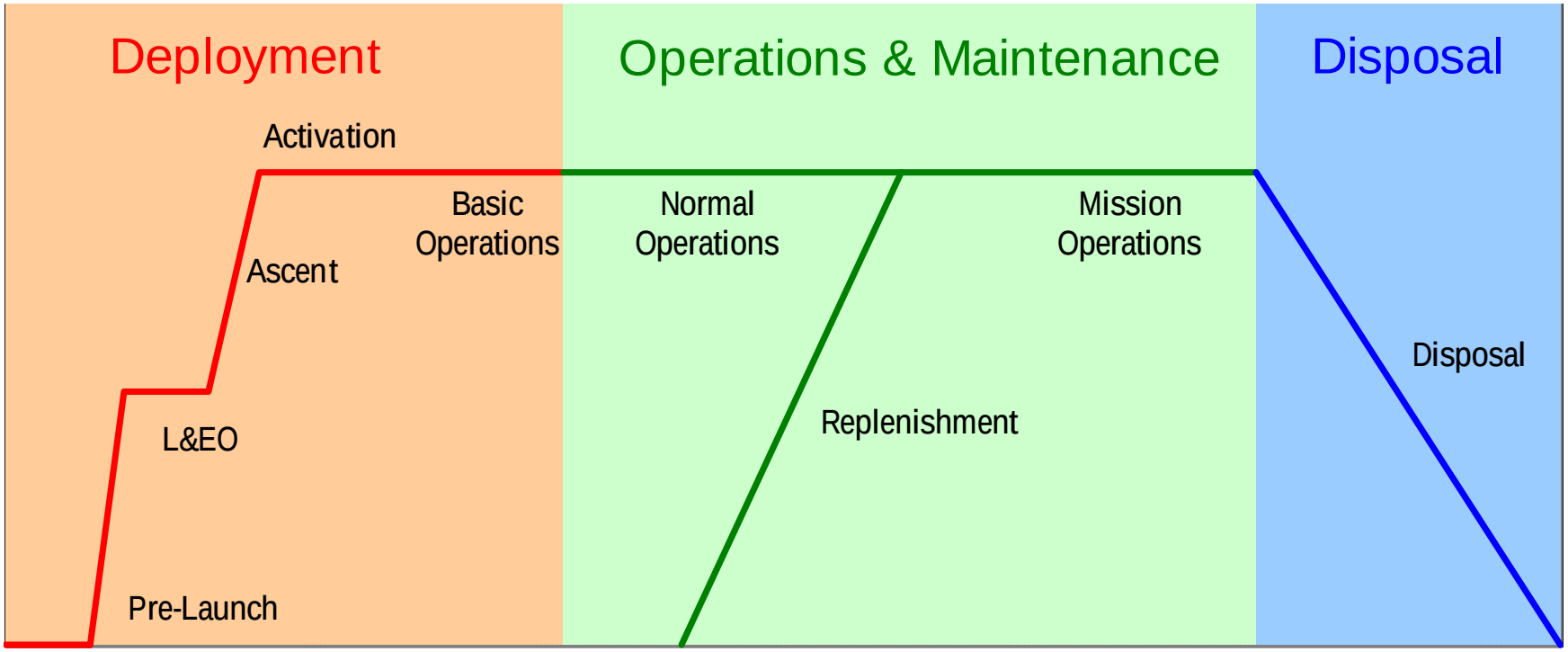
BOEING

Introduction

- Purpose
  - Consider operations & maintenance of large constellation-based space systems from a ground system perspective
  - Describe sustainment and obsolescence challenges
  - Show how proven Boeing commercial practices address these challenges to maximize operational effectiveness

Constellation Life Cycle

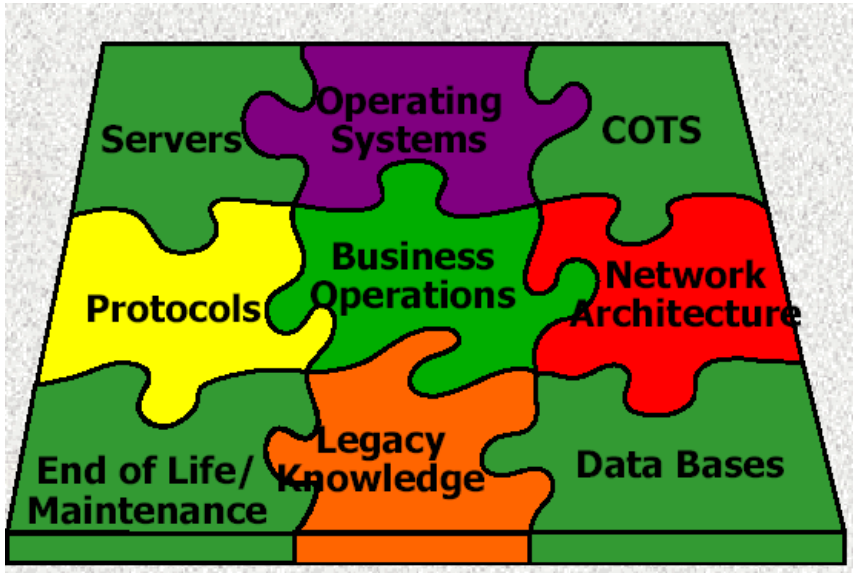


Constellation Life Cycle

- Deployment
  - Begins at first launch and ends when last satellite of the mission constellation is activated on-orbit
- Operations & Maintenance (O&M)
  - Begins when full mission functionality is achieved
- Disposal
  - Begins when constellation reaches the end of its useful life
  - The goal of disposal is to deplete all on-board energy sources such as batteries and fuel, and limit orbital debris after mission completion by re-entry within 25 years for LEO, or boosting for GEO
- This presentation addresses obsolescence challenges faced in the O&M phase of the constellation life cycle

Obsolescence Factors

- Hardware end-of-life and end-of-maintenance
- COTS no longer supported
- Increased maintenance costs
- Patches no longer available for operating systems
- New security vulnerabilities that cannot be addressed
- Employee knowledge
- Protocols no longer supported
- Tech support unable to assist in anomaly resolution



Obsolescence Risks

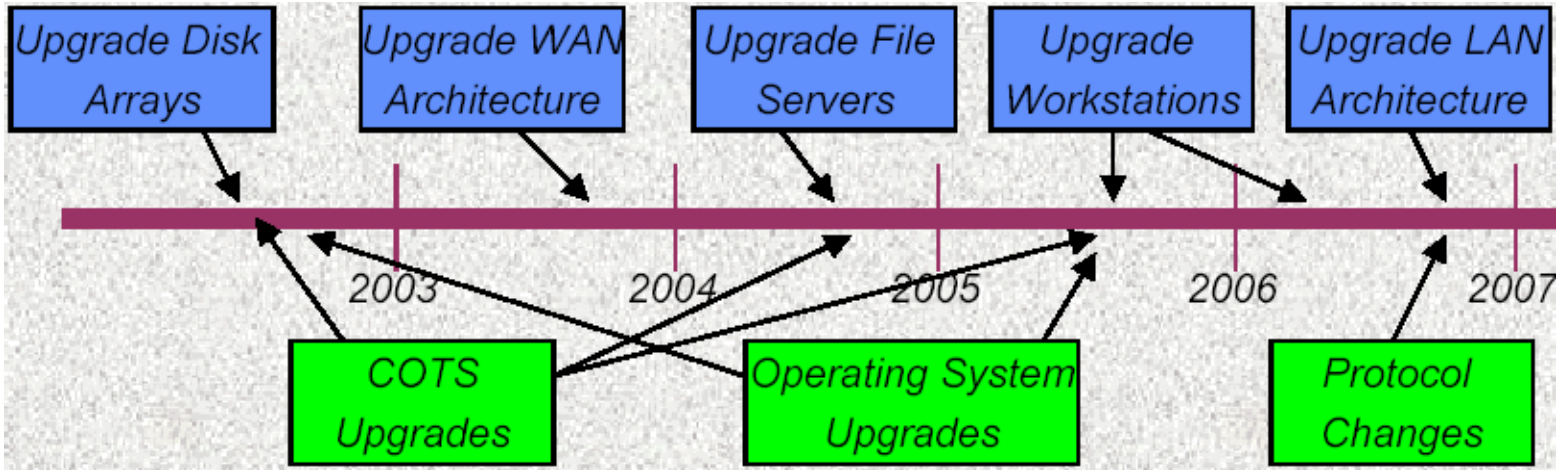
- Anomaly Resolution
  - Longer outage
  - Multiple workarounds
  - Tech support unable to assist
- Spare Parts Availability
  - High costs
  - Difficult to find
  - New HW/ SW compatibility
- Vendor Support
  - No technical expertise
- Increased Life Cycle Costs
  - Premium maintenance agreements
  - Increase on time and materials
- Reduced System Availability
  - Longer outages
  - Cannibalize systems
- Increased Failures
  - More frequent failures
  - Multiple failures

Mitigation Approaches

- Direct
  - Planned Updates
  - Spares vs Maintenance
  - Build Repair Depot/Facility
  - Skills Training and Knowledge Capture
- Indirect
  - Continuous Process Improvement
  - Automation

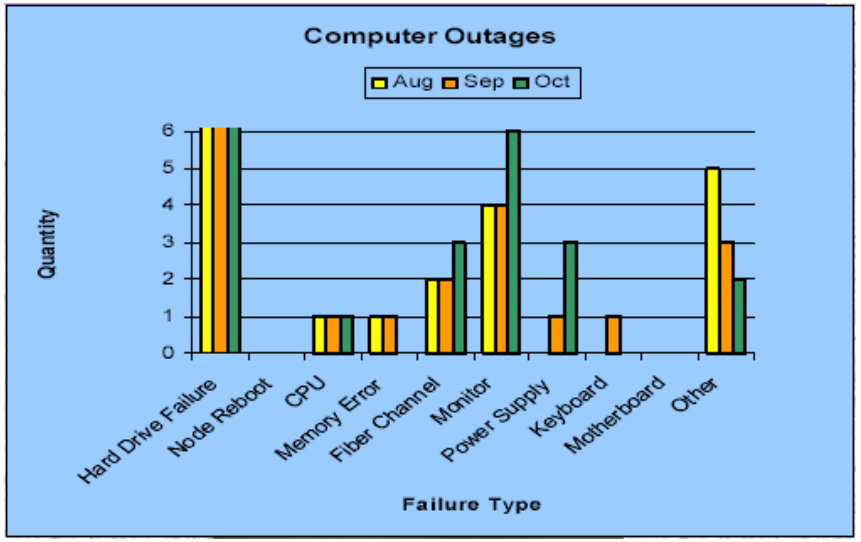
Planned Updates

- Plan for updates during O&M in the development phase of the program
  - COTS software upgrades
  - HW upgrades
  - Planned ground segment incremental software builds



Spares vs Maintenance

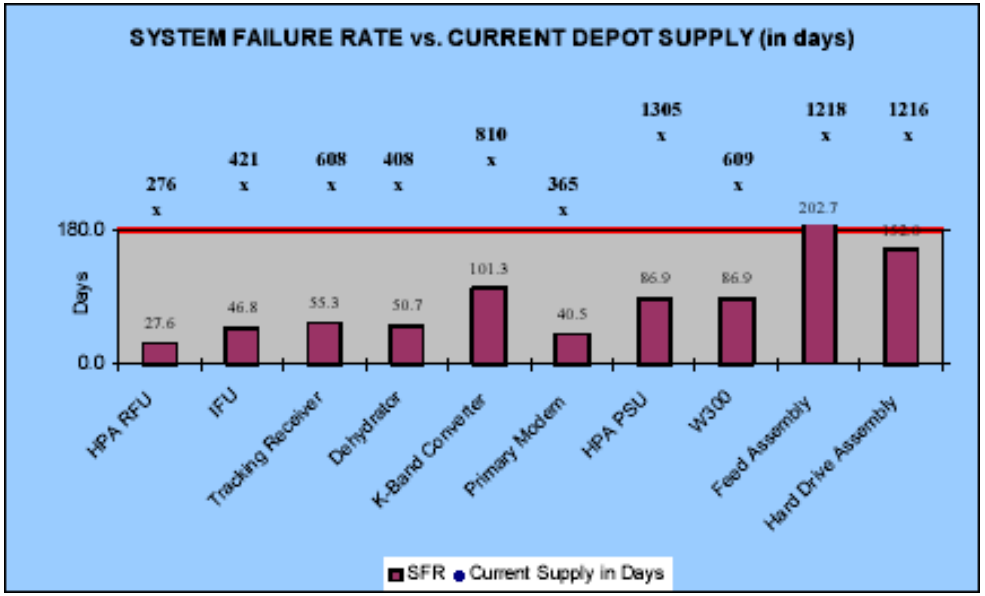
- Document failure rates
- Train in-house team for board level repairs
- Evaluate spares vs maintenance costs
- Consider operating system license implications
- Identify new/used spare parts vendors



Reduced workstation maintenance costs by over $500K in one calendar year

Build Repair/Depot Facility

- Evaluate vendor cost for maintenance and time and material
- Trend failure rates
- Define skills requirements
- Consider remote sites
- Estimate cost savings



Over 15 month period, total savings were approximately $500K

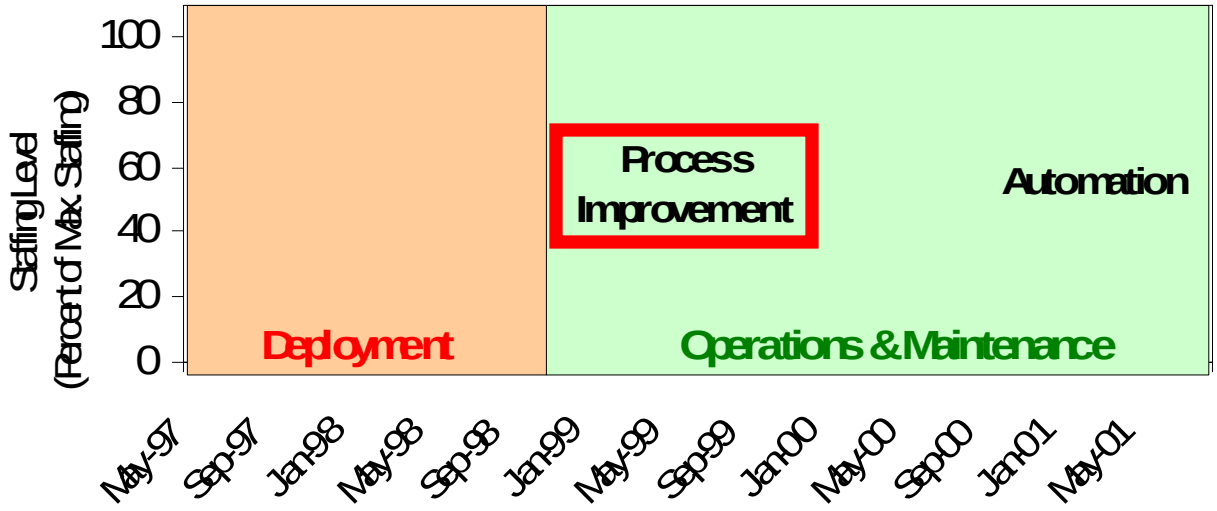
Skills Training and Knowledge Capture

- Maintaining legacy systems
  - Extensive training on hardware platforms
  - Extensive training on software products
- Take as much vendor training as possible
  - Become the expert in their product
  - Support contracts may be "right to use" only
- Keep the staff challenged and happy
  - Training on latest technologies
  - Job rotations
  - Continuous process improvement initiatives
- Avoid single points of failure
  - Have more than one expert
  - Implement a knowledge capture plan to counter effects of attrition
    - Document, document, document
    - Cross-training

Reduced database support costs by over $100K

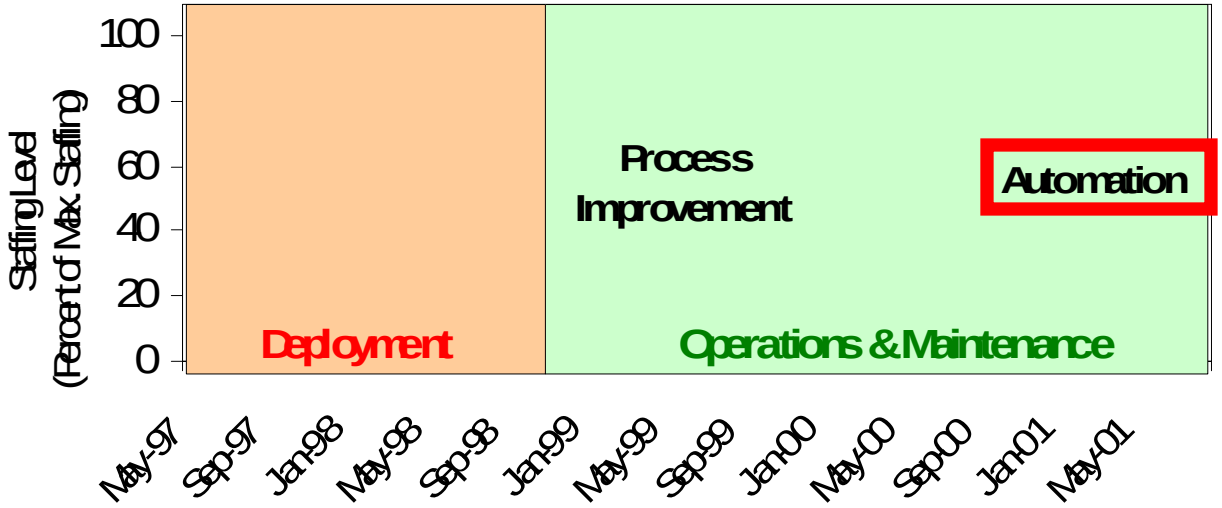
Continuous Process Improvement

- Continuous process improvement reduces workload and re-work required, again freeing up personnel to focus on other initiatives such as obsolescence mitigation
- Boeing tools/processes can be used, e.g. web-based crew information file, web-based issue reporting and defect resolution tool, Operations Performance Review Board, and lesson learned



Automation

- Automation of activities during O&M would reduce staffing requirements and workload for this function, increasing ability of staff to focus on other initiatives such as continuous process improvement and obsolescence mitigation



Dealing with Unplanned Updates

- Factors
  - Paid for maintenance agreements include software upgrades
  - New mission functionality
  - Changing infrastructure to support new technologies
- Issues
  - Compatibility issues with legacy system
  - Power requirements
  - Rack space and environmental specifications
  - Sequencing multiple upgrades
  - Staff training for new hardware/software

Conclusion

- There is no single solution for the issues associated with obsolescence, however with proper planning the overall costs can be reduced and system availability and reliability can be increased
- Existing Boeing tools and practices established in the operations of commercial constellations can be applied to address obsolescence risks during operations & maintenance of large constellation-based space assets