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Assuring Space Mission Success

Integrating Legacy Software: Lessons and Hurdles

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The Aerospace Corporation
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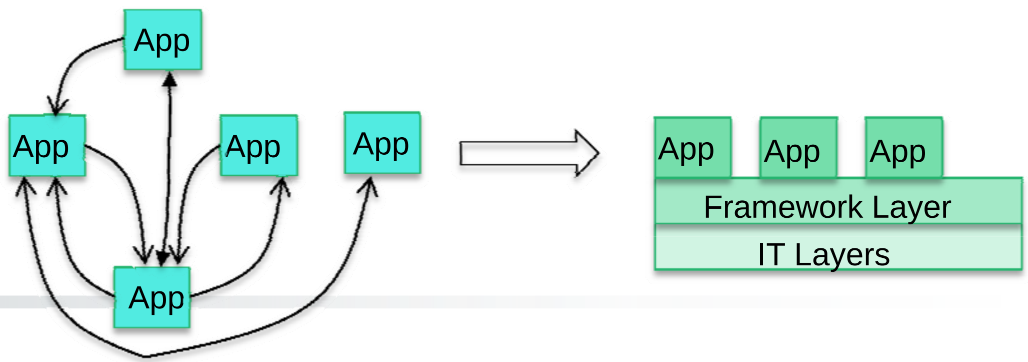
Introduction to Panel Discussion

- General observations based on The Aerospace Corporation's participation in an on-going "Think Tank" effort that is looking across the National Security Space (NSS) for lessons and hurdles relevant to migrating legacy systems to new ground system architectures

- These observations are associated with the integration of legacy software in support of migration efforts towards common-service architecture approaches and are being presented in order to spur panel discussions relevant to the challenges and opportunities of harmonizing systems and components for a wide range of stakeholders



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Observations and Lessons Learned

- Observations:
  - *Reuse of legacy software to support new missions is not always compatible with the legacy systems*
    - Undesirable results can include lower performance and missed requirements
  - *Transition costs to go from legacy to new are not always assessed*
  - *Interface complexity plays an important role in determining the impact to legacy software and overall system costs*
  - *Development and maintenance costs of the common services (or shared capabilities) need to be supported by the missions using those services*
    - Not all participants have an equal share of benefit and may resist paying the “tax” or discontinue participation
  - *System closure, performance, and interfaces are not being modeled prior to acquisition*
    - May find out sometime after ATP that it won’t meet requirements
  - *Life cycle costs are not being assessed prior to acquisition*
- Commonality achieved through the consolidation of legacy "stove-pipes" isn't always the best alternative for reducing program costs

Challenges and Hurdles

- Common assumption is there's not enough time or resources to do a thorough evaluation of alternatives using concept modeling tools
- Its hard to dispel the notion that consolidation implies cost savings
  - *Just as with the fallacy that all software reuse implies cost savings*
- Fairness and equality are not traits that are consistently applicable to aerospace software system performance
  - *Some missions have performance needs that far exceed the capability of the common services*
- How can we implement both a common-service and mission-unique approach within the same ground system architecture?
- Wrapping the legacy code and adding more processors is a neat trick, but at some point we reach diminishing returns on performance
  - *Amdahl's Law*
  - *Gunther's law*

$$C(N) = \frac{N}{1 + \alpha(N-1) + \beta N(N-1)}$$

C - relative capacity
N - number of processors or users
β - contention
α - coherency delay

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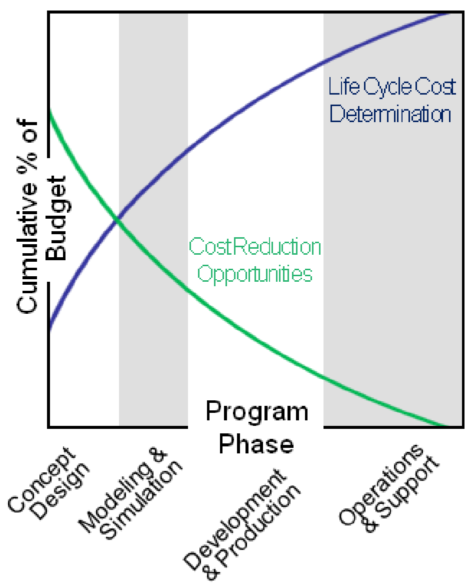
Opportunities

Follow Good Systems Engineering Practices

- Up-front modeling of the proposed new common-service architectures should be performed pre-acquisition
  - *Modeling to assure system closure (all requirements can be met)*
  - *Modeling to assess performance (latency, throughput)*
  - *Identify test and validation considerations*
- Concept studies enable even earlier programmatic decision making
  - *Rapid yet thorough tradespace exploration of new concepts and block upgrades provides better insight into system needs*
  - *Identify performance and cost drivers*
  - *Determine cost and technical feasibility*
  - *Assess margins and risks*
  - *Refine and validate requirements*
  - *Path pruning*



Of all decisions affecting life cycle costs, approximately 70% are made during Concept Design

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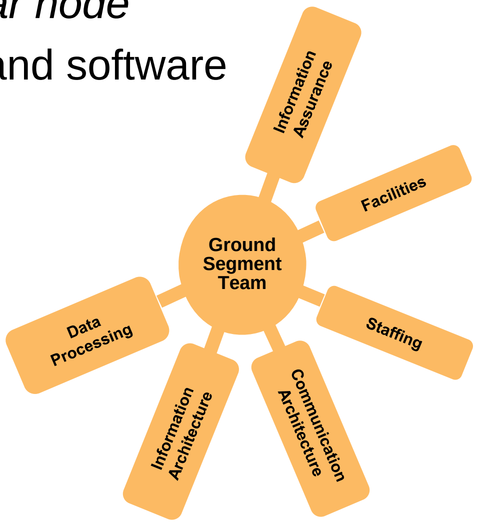
Example: Concept Design Center

- Ground Segment Team (GST)
  - *Designs the Ground Systems Architecture at a conceptual level*
    - Facilities, personnel, processing, communications, and cost estimates
- GST Architecture characterized by a Master Function List (MFL) mapped against a framework of nodes (sites) plus a definition of all possible communication links
  - *MFL indicates whether a function is performed or not at a particular node*
    - Capability-only is an option which typically provides hardware and software functionality, but not staff
  - *Possible functionality includes:*
    - Mission Processing
    - Mission Management
    - TT&C
    - Ground Control
    - Common Services
    - Facilities Management
  - *Communication links include terrestrial and space-to-ground links*



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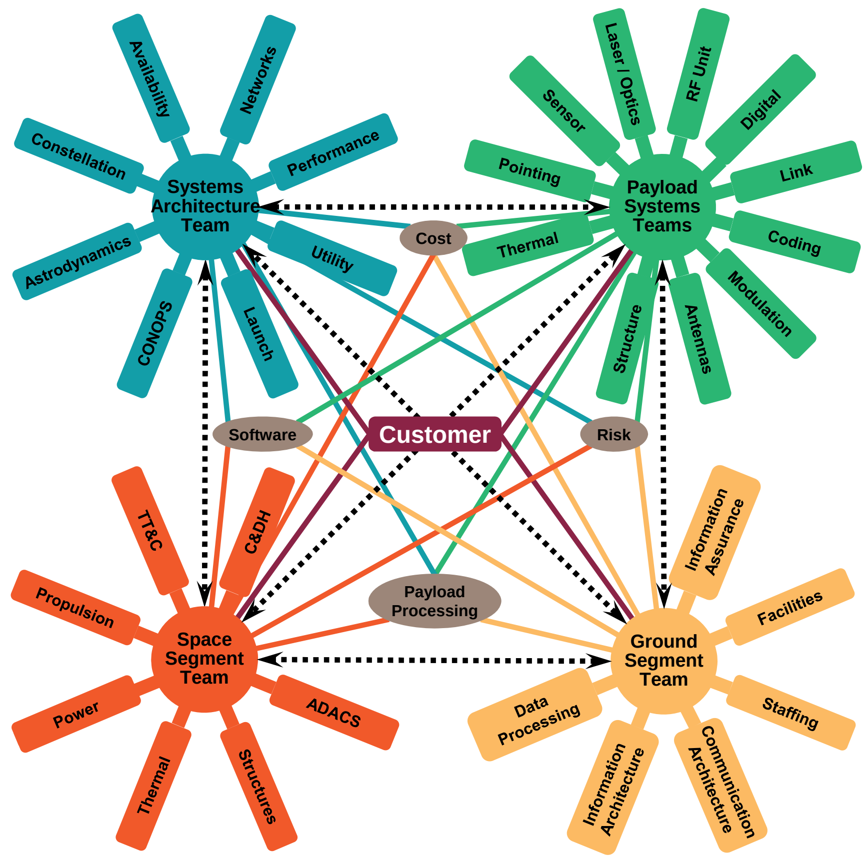
Backup

Multidisciplinary CDC Teams

… and Their Interactions

- System Architecture Team (SAT)
  - *Constellation design and coverage analysis*
  - *Top-level element sizing and interface definition*
  - *Relative cost versus requirements and utility*
- Space Segment Team (SST)
  - *Payload and spacecraft subsystem design*
  - *Detailed cost and performance estimation*
  - *Top-level ground segment and software sizing*
- Ground Segment Team (GST)
  - *Facilities, personnel, processing, communications, and cost estimates*
  - *Top-level space segment sizing*
- Electro-Optical Payload Team (EOPT) & Communications Payload Team (CPT)
  - *Detailed payload subsystem trades*
  - *Performance and cost estimation*
  - *Mission requirements implications*
  - *Top-level spacecraft and ground segment estimation*



Core team members for each study plus additional unique expertise as required

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Master Function List (MFL)

- Master Function List (MFL) is input to the Node Module
  - *Defines the functions required by the system in the GST study*
  - *Communicates system design elements to each of the GST modules*
    - Ensures that the GST modules comply with the functions required by the program in the study
    - Deletes functions that are out of scope or GFE'd for the study
    - Requires supporting program / GST study documentation and discussions to interpret correctly for each module
      - *Complexity, heritage elements*
  - *Is tailored for each program to add, modify or delete functions*
    - Functions can be
      - *Provided*
      - *Provided and Not Staffed (for example, backup facilities)*
      - *Not Provided*
    - Tailored MFL elements are defined in the GST architecture documentation (report, memo or briefings)

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Sample Master Function List

Mission Processing
- Mission Data Capture
- Mission Data Processing
- Report Dissemination
- User Interface
- Optical Data Processing

Mission Management
- Mission Planning & Scheduling
- Schedule Optimization
- Constraint Analysis
- Space & Ground Resource Monitoring
- Mission Assessment
- Task Satisfaction Analysis

Ground Command & Control
- Acquisition & Tracking
- Command & Control
- Telemetry Processing
- Orbit & Attitude Determination

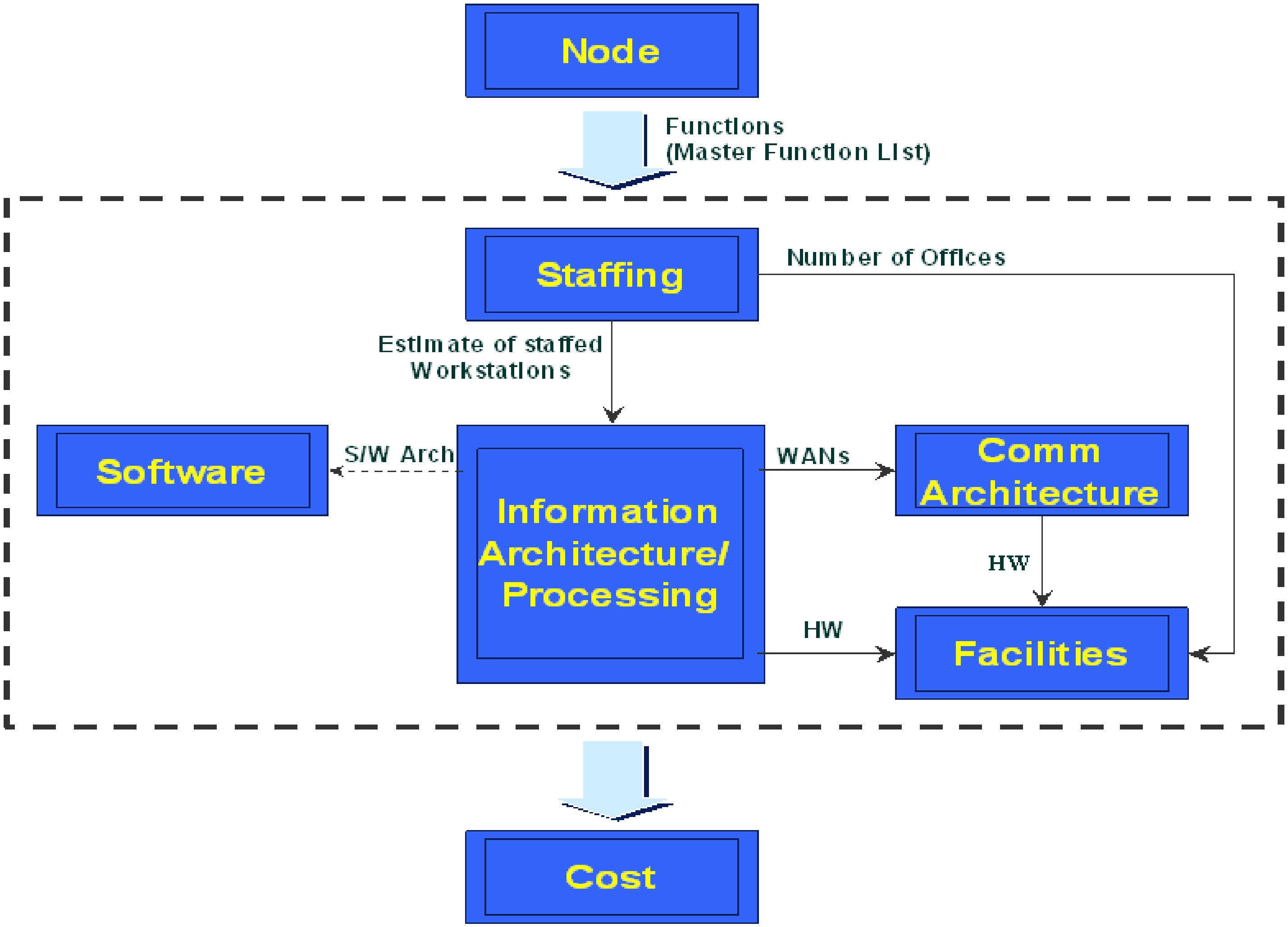
Ground System Management
- Communication Connectivity Interface
- LAN/WAN Management
- Ground Terminal Control
- Timing Services

Misc. Functions
- Launch and Early Orbit Support
- Anomaly Resolution
- Operations Management

Support Functions
- Telemetry Storage and and retrieval
- Training
- Data Base Management & System Administration
- Data Security
- Vehicle Simulation
- Development Environment

Facility Management
- Physical and Structural Control
- Security Control
- Maintenance

Key GST Module Interfaces



Functionality of GST Modules

System-Level Modules
- NODE
  - Distributes Master Function List to all Modules
  - Monitors/controls module status
- SYSUMM
  - Repository for system-level characteristics and costs

Staffing
- Specify functional positions and staff type at each position
- Specify number of seats per functional position
- Specify personnel type per seat

Communications
- Analyze connectivity options
- Size data rates, bandwidths
- Network and protocol design
- Determine required equipment

Software
- Identify software functions
- Specify characteristics
  – New/reuse / COTS
- Effort to adapt / integrate COTS
- Effort for databases, GUI, etc

Information Architecture
- Model flow of information
- Characterize information
  – Nature of data
  – Producers / consumers
  – Data rate
- Characterize network constraints

Processing
- Specify processing equipment
  – Workstations / Servers / PCs
  – Special purpose racks
  – Data archive
  – Hubs / routers / switches
  – Firewalls / guard boxes

Facilities
- Site development
- Site access
- Security
- Space and infrastructure for equipment and personnel
- Antenna facilities incl. radomes

Cost
- COTS H/W
- Staffing
- Facilities
- Software
- Overall wraps

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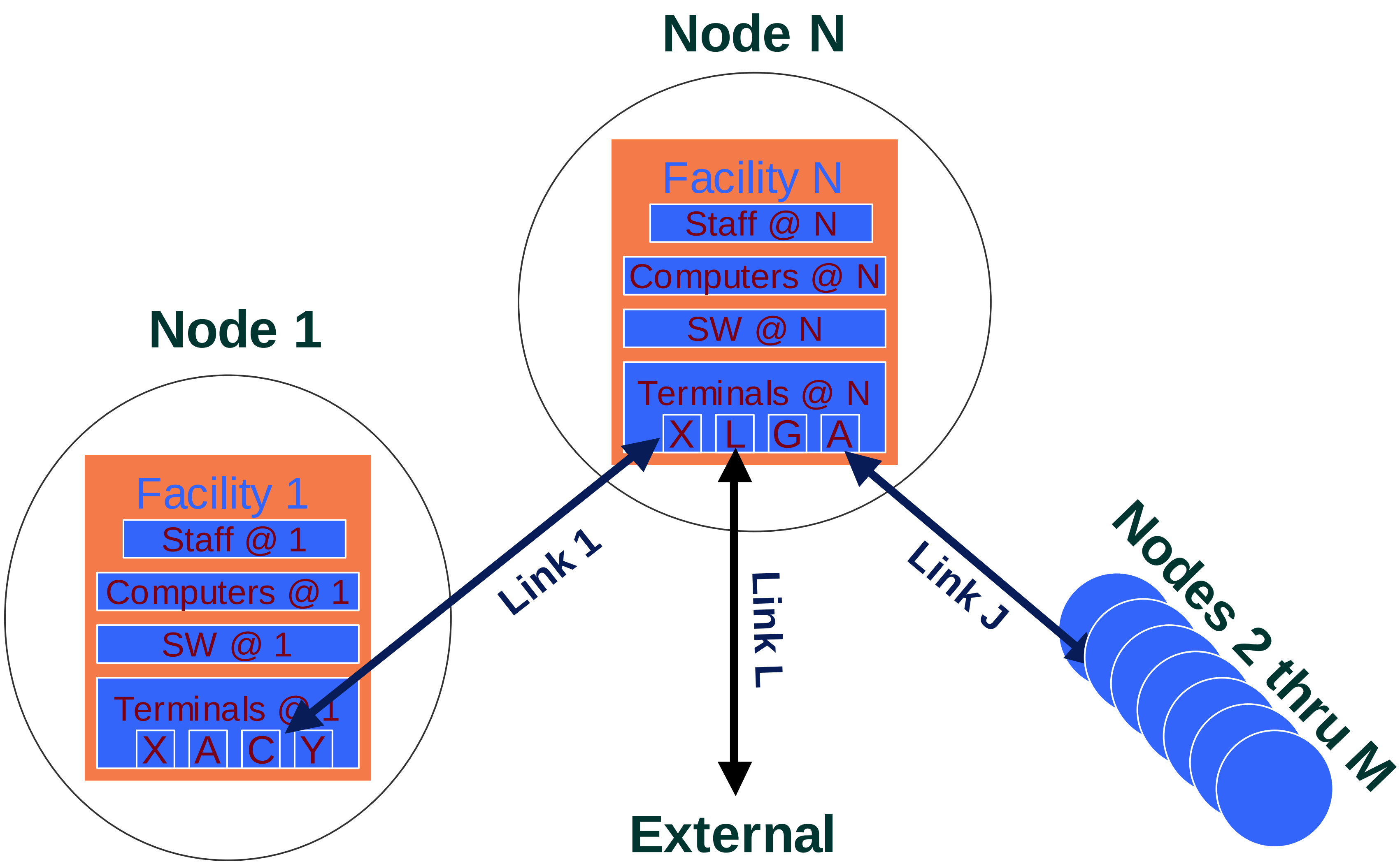
Ground Segment Architecture Framework



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