# Satellite Control - Then and Now

## 10 Years Ago
- Using COTS for Satellite Command and Control systems was considered “crazy”

- Primary requirements of Satellite Control Systems:
  - Functionality
  - Reliability
  - Efficiency
  - Cost

## NOW
- “Off the shelf” solutions are “common” in multiple phases of the satellite industry

- Primary requirements of Satellite Control Systems
  - Functionality
  - Reliability
  - Efficiency
  - Cost

The difference in requirements is defined mostly by how the results are achieved and the relative requirement priorities.
Current Control System Priorities

• Efficient Utilization of COTS
  – COTS based solutions are “here to stay”
  – Reduce acquisition and maintenance costs
  – Avoid unnecessary development costs required to create new software that might already exist
  – Challenge is to manage customer/vendor expectations, satisfy mission unique requirements and support customer administrative needs

• Satellite Control Automation
  – Improve operational efficiency, reduce errors, improve reaction time, improve operator morale
  – Consistent with the effort to improve efficiency, reliability and cost
  – Challenge is to balance automation with end user comfort

• Fleet Monitor and Control
  – More owner/operators are moving to a multi-satellite capability
  – Need to improve efficiency of control system for multiple satellites
  – Challenge is to control “more with less” without reducing or risking reliability and efficiency
Efficient Utilization of COTS

“Success or failure with COTS systems depends on understanding and adapting to the constraints, challenges, and opportunities of this environment.”

- Col. Ralph D. Monfort, USAF, Space and Missile System Center

• If you’ve had success with COTS, then you probably…
  – Have a strong technical staff committed to understanding/developing requirements
  – Can describe what need and want the system to do but are open to “how” the system will do it
  – Are capable and willing to work with vendors to perform tradeoffs on requirements, ops concepts and capabilities
  – Are willing to plan and coordinate system upgrades throughout the life of the mission.
Efficient Utilization of COTS

Early (important) decisions…

- Partnership with supplier vs. classic “customer/vendor” relationship
- Loosely vs. tightly integrated solution
- Is a 70-80% off-the-shelf capability….
  - “Good Enough”
  - “the foundation for a complete solution”
Effective automation provides multiple benefits…

• **Operational costs savings**
  – *Fewer staff to support more on-station assets*

• **Improved efficiency of operations staff**
  – *Operators focus more on critical/important tasks vs. repetitive/mundane tasks*
  – *Operator interest and motivation is improved*

• **Reduced error potential**
  – *Significant reduction in the chance of an operator error*
  – *Reduction of repetitive, boring and mundane activities*
Inmarsat Ltd. – A Success Story

• Success story for both Automation and effective use of COTS

• Established in 1979 as an Inter-governmental organization (IGO)
  – In April 1999, Inmarsat transitioned to a private limited company, Inmarsat Limited
  – Service portfolio includes maritime (including safety and distress applications), aeronautical and land mobile. Over 180,000 Inmarsat terminals in use world-wide

• Satellite Constellation
  – Four Inmarsat-2 satellites (MMS/Astrium Eurostar), launched 1990-1992
  – Five Inmarsat-3 satellites (LM 4000), launched 1996-1998
  – Recently ordered three Inmarsat-4 satellites (Astrium Eurostar 3000)

• Established “cooperative agreement” with L-3 Storm
  – Combine Inmarsat operations expertise with L-3 Storm technology
  – Leverage Inmarsat/L-3 Storm development efforts across multiple programs
Inmarsat’s Approach and Results

• Formed a small core engineering team to define SCC automation requirements for existing, well understood Inmarsat-2 class of satellites

• Performed Technical Validation Program - “Fly before Buy”

• Selected vendor/partner

• Automated Inmarsat-2 satellite operations

• Added each Inmarsat-3 satellite while incrementally migrating their daily and seasonal operations to an automated approach

• Results:
  – Added all five Inmarsat-3 satellites and associated ground equipment while cutting satellite operations staff in half.
  – Have applied similar automation to network control applications further reducing staff requirements
Fleet Monitor and Control

Critical items for effective Fleet Monitor and Control …

• Ability to concurrently monitor and control multiple assets from a single workstation
• Effective graphical user interface design
• Effective automation capabilities
• Ability to “take control” and “hand off” satellites to support health and maintenance commanding or to handle a specific problem
Fleet Monitor and Control User Interface
Specific Architectural Activities
L-3 Storm Architectural Evolution

• Multiple Goals
  – *Increase the commonality of fielded systems*
  – *Improve training and maintenance costs*
  – *Provide better value for customers*

• Specific Actions
  – *Definition of use cases for all current and future customers*
    • Focus on “users”
    • User-centric approach vs. system-centric
  – *Focus on well defined interfaces and clear component definitions*
  – *Integrate a distributed, object-oriented approach based on CORBA*
  – *Provide a “single system GUI” using Java*
Implement Strong Building Blocks

- **Strata**
  - Core (CORE)
  - Site (SITE)
  - Entity (ENTY)
  - Program (PROG)

- **Layers**
  - Interface (IF)
  - Application (AP)
  - Monitor and Control (MC)
  - Service (SR)

- **Computer Software Configuration Items (CSCIs)**
  - User Interface (GUI)
  - Programmatic Interface (API)
  - Mission Planning and Scheduling (MPS)
  - Flight Applications (FLT)
  - Mission Monitor and Control (MCM)
  - Commanding (CMD)
  - Telemetry (TLM)
  - External Interface (XIF)
  - System Data Access (SDA)
  - System Services (SYS)
  - Utilities (UTL)
Architectural Layers and CSCIs

- Interface Layer
  - User Interface CSCI
  - Programmatic Interface CSCI

- Application Layer
  - Flight Applications CSCI
  - Mission Planning and Scheduling CSCI

- Monitor and Control Layer
  - Telemetry Processing CSCI
  - Mission Control and Monitoring CSCI
  - Commanding CSCI
  - External Interface CSCI

- Service Layer
  - System Services CSCI
  - System Data Access CSCI

Legend:
- Third party COTS
- Site or mission-specific
- Architectural core
Architectural “Strata”

- Allows hierarchical customizations to system
- Functionality at Program stratum overrides Vehicle, which overrides Site, etc.
- The same layers and CSCIs exist in all strata
- Layers and CSCIs can be empty in a stratum
- Not all strata need be present for the system to work
- Applies to database as well as code
L-3 System Instance (example)
Analysis Mechanisms/Design Patterns

• A set of abstractions that work together to carry out common and interesting behavior

• Builds support for such non-functional requirements directly into the architecture

• Reduces complexity of analysis and improves its consistency by providing developers with a short-hand representation of complex behavior

• Typical patterns:
  – Process Activation
  – Multiple Mission Operations
  – Distribution/Communication
  – Persistence
  – Resource Management
  – On-line Definitional Changes
  – Multiple Operational Phases
  – Checkpoint/Restart
  – Fault Tolerance
  – Error Handling and Reporting
  – Authorization/Security
Last Chart...

• Summary
  - COTS software can provide significant cost savings for space applications
  - To effectively take advantage of COTS software, satellite operators must be flexible and adjust to a COTS procurement and ongoing support paradigm
  - If possible, pick a “partner” not just a vendor
  - If you are successful with the above, you can really save money through the intelligent use of automation

• The future...
  - Those operators who have flexibility and are willing to invest time, effort, and money to automate their operations can realize significant mission cost savings
  - Those who do it best can turn their satellite operations “cost” centers into “profit” centers by offering satellite launch and fly satellites for other satellite service providers