Flight Software Ground System Impacts

Mark G. Walker

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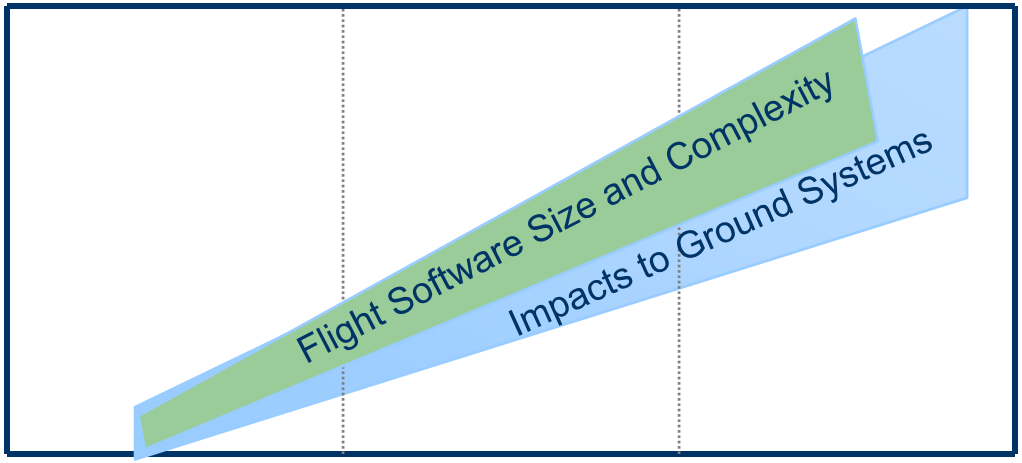
Contributors:
Judy Kerner, Larry Miller, and Phil Schmidt, The Aerospace Corporation
James Kramer, Integral Systems, Inc.

Outline

- Motivation
- Flight software impacts on ground systems
- Areas for improvement
- Next steps

Motivation

- Spacecraft flight software is increasing in size and complexity
- Flight software has major impact on ground systems
- More development time is spent on software vs. hardware issues
- Greater complexity and capability drive rethinking system design assumptions, both ground and space



Flight Software Major Impacts

Flight Software	Ground Impact
Changing processor types and architectures - Memory organization - Memory dump and reprogramming telemetry and command interfaces - Upload formats - Non-standard table structures	**Changes to core memory management functions** - Memory mapping and compare - Upload utilities - Downlink data formats and conversions (1750, IEEE, …); custom conversions and calibrations - Custom table readout algorithms
Increased autonomy - On-board maneuver schedulers - Dynamic tasking - Constellation-based control - Maintain on-board state / configuration	**Custom tools** - Create and upload maneuver tables - Format and upload goals - Evaluate autonomy performance - Provide “observability” to software actions

Flight Software Major Impacts (continued)

Flight Software	Ground Impact
Increased fault handling complexity and autonomy - Autonomous spacecraft reconfiguration in response to faults - Threshold uploads and response configurations - Software faults as well as hardware **Variations in spacecraft "Product Lines"** - Flight software changes -Even if it's "just another __ bus" - Software customization to meet requirements - Software evolution (often arbitrary)	**New requirements** - Manage fault handling configurations - Provide "observability" of automatic responses - Trying to identify anomalies through "alarm storms" **Unexpected changes** - Changes needed to accommodate unexpected variations in product line architectures - Often occur late in program, which increases cost

Flight Software Major Impacts (continued)

Flight Software	Ground Impact
Stored program languages - Uploadable macros to customize software after launch	**More operator requirements** - Compile and validate uploads - Monitoring and reporting
Proprietary interfaces - Satellite manufacturers use proprietary telemetry and command interfaces - Standards (e.g., CCSDS) not yet widely embraced - No higher layer standards	**Multiple interfaces must be supported** - Satellite-specific telemetry decommutation and command formats
Increasing payload processing - Late changes to space-ground partitioning	**Late changes to ground system requirements**

Areas for Improvement

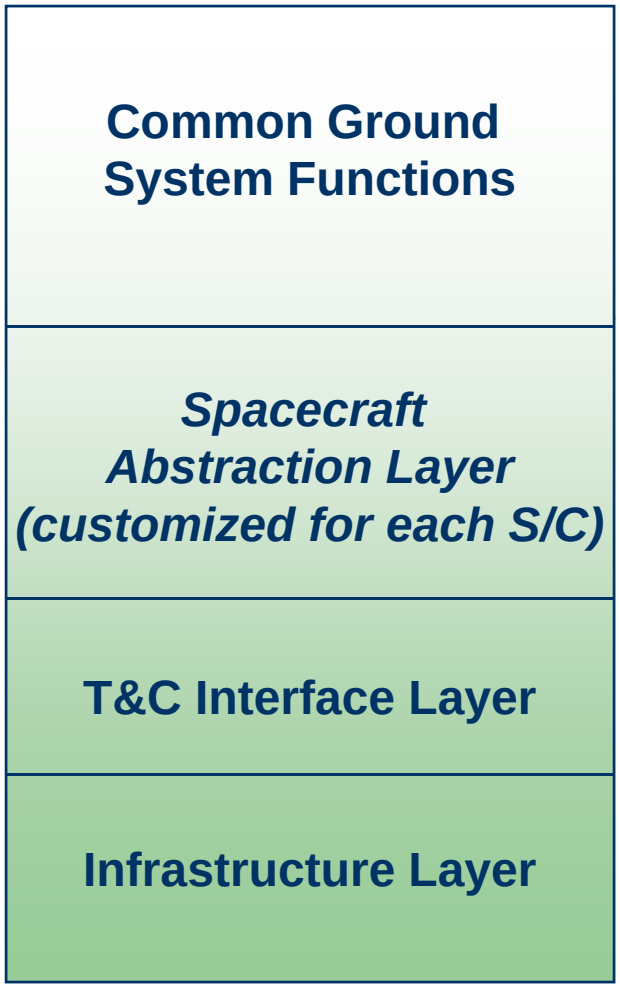
- Communication between flight and ground teams
  - Ground is usually expected to accommodate flight
    - Often ground impacts are not known by flight software teams
  - Resolve the “culture clashes”
    - Improve collaboration between flight and ground software developers
  - Develop standard methods of data delivery (e.g., via satellite attribute databases)
- Flight software development process maturity
  - Tight coupling with satellite hardware makes application of standard development processes difficult
    - Often results in late changes that impact ground system and architecture
  - Bring into the flight software development domain the same rigor that we’ve seen accomplished on the ground

Areas for Improvement (continued)

- Coordination between flight and ground architectures
  - Requirements and modeling need to be extended to cover flight software interactions with ground systems
  - Replace local flight code optimizations with system optimizations
- Support for multiple missions and mission types
  - Ground software often optimized for a specific application
  - Architect across a variety of spacecraft and flight software versions
    - COTS software benefits from a wider base of supported types and versions
    - Consider multi-mission architectures
- High-level “operational” standards
  - Standards are often discussed at GSAW, but at a low-level (e.g., communication and networking standards)
  - Abstract ground interfaces to on-board software

Operational Standards

- Spacecraft operations are often similar, but the details vary widely
  - Ground software often architected as a point solution
- A *Spacecraft Abstraction Layer* can provide standard interfaces for common spacecraft operations
  - Memory management, thermal tasks, battery operations, and maneuvers
- Allows “quick fit” of existing Common Ground System Functions to new bus types or flight software versions
- Apply standard interface approaches like those used in other industries
  - Robotics
  - Network management



Next Steps

- Architect ground systems to minimize impact of flight software
  - Accept that flight software may be different for each spacecraft
- Architect ground systems to be evolvable
  - Flight software can change over the mission
    - Before delivery and on-orbit (with uploaded patches/ macros)

How?

- Begin to address *Flight Software Ground System Impacts* through:
  - Working group at GSAW2009
  - Email discussion group to collect issues and share solutions