

# **Flight Software Ground System Impacts**

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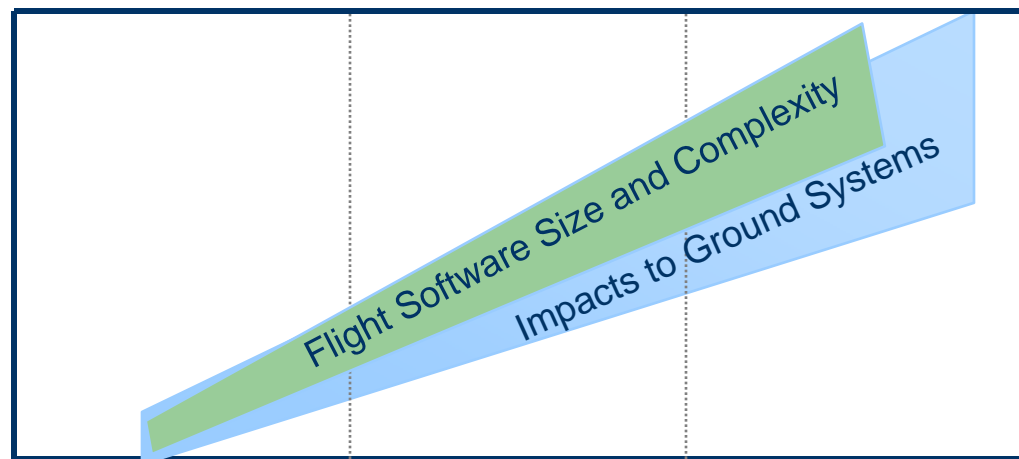
# Outline

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- 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

### Changing processor types and architectures

- Memory organization
- Memory dump and reprogramming telemetry and command interfaces
- Upload formats
- Non-standard table structures

### Increased autonomy

- On-board maneuver schedulers
- Dynamic tasking
- Constellation-based control
- Maintain on-board state / configuration

## Ground Impact

### 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

### 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

### 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)

## Ground Impact

### 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

### Stored program languages

- Uploadable macros to customize software after launch

### Proprietary interfaces

- Satellite manufacturers use proprietary telemetry and command interfaces
- Standards (e.g., CCSDS) not yet widely embraced
- No higher layer standards

### Increasing payload processing

- Late changes to space-ground partitioning

## Ground Impact

### More operator requirements

- Compile and validate uploads
- Monitoring and reporting

### Multiple interfaces must be supported

- Satellite-specific telemetry decommutation and command formats

### 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

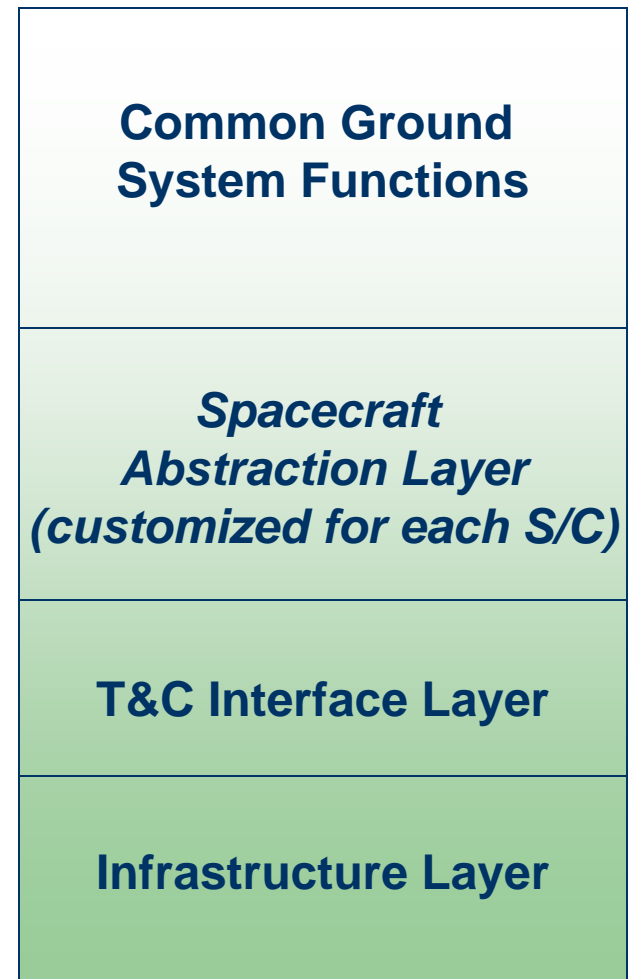
# Areas for Improvement (continued)

- 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

