Fight Software Workshop 2007 (FSW-07)

Framework Based
Guidance Navigation and Control
Flight Software Development

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Outlive

- NASA/Goddard Guidance Navigation and Control (GN&C) Flight Software (FSW) Development Background

- GN&C FSW Development Improvement Concepts

- GN&C FSW Application Framework
Why the Need for Change?

- The cost of recent GN&C FSW efforts has remained fairly constant while only providing small, if any, incremental functional advancements.
  - Indicates the FSW development process is not capitalizing on work from previous missions (e.g. no code, test, and document reuse)
  - The GN&C FSW quality remains high, but at a high cost

- Specific Problem areas
  - Lack of integrated GN&C analysis and FSW development processes
  - Insufficient GN&C FSW infrastructure, documentation, and unit tests

- Consequences
  - Rewrite requirements for each new mission
  - Difficult analyst assessment of existing FSW for new missions
  - Limited integration of GN&C FSW with analyst’s simulations
  - Lack of a configuration management (CM) system for reusing assets
GSFC FSW Evolution

SAMPEX (launched 8/92)
SWAS (launched 12/98)
TRACE (launched 3/98)
WIRE (launched 2/99)
SMEX-Lite (waiting for launch)
Triana (12/04)

XTE (launched 12/95)
TRMM (launched 11/97)

IceSat GLAS (01/03)

MAP (launched 06/01)
ST-5 (5/06)

SDO (2008)

JWST ISIM (2011)

GPM (2013)

LRO (2009)

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Recent GSFC GN&C FSW History

- **MAP**
  - Object-based design (in ANSI C) but not mature enough to support a reuse library

- **ST-5**
  - Successfully tailored MAP design for it's needs
  - Controller class hierarchy useful

- **SDO**
  - Started with MAP's design
  - Shared some code with MAP but no formal reuse

- **GPM (sent out of house) & HRV (cancelled)**
  - Advanced MAP's design to be a framework

- **LRO**
  - Using a framework based development process

- **GPM (back in house)**
  - Using a framework-library development process
The Big Picture

Three phased bottom-up approach:

1. Establish framework-library based development environment
2. Create Integrated Development Environment (IDE)
3. Create Non-real-time desktop test environment
• Goal
  – Create a GN&C FSW development infrastructure that supports cost-effective reliable code reuse

• Develop GN&C application framework that supports reusable objects
  – Framework relies on stable core Flight Executive (cFE) Application Programmer’s Interface (API)
  – Framework viable because GN&C applications typically follow a common pipeline design
    • Series of objects that produce and consume data

• A framework is a collection of FSW modules that can be tailored to meet a mission’s specific requirements
  – Provides explicit tailoring and extension points

• Define rules and guidelines for using the framework and for developing reusable objects
  – All reusable FSW must have unit tests and documentation
• Unit test tools
  – Assist unit testing
  – Allows consistent library unit tests helping library maintenance

• Mission cost-benefit
  – Small learning curve that would almost be negligible if library established as branch standard method of business
  – Consistent application designs
  – Simplified unit testing
  – Current missions will help populate the library with minimal impact
  – Later missions would benefit from existing assets and continue to expand the library
Framework-Library Based Development Processes

GN&C FSW Application Framework

Math Library Object Library

Application Development Tools

GN&C FSW Application

Unit Test Tools

Unit Test Executable

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core Flight Executive (cFE) Overview

- Provides common flight executive functions
- Well documented application programmer interface (API)
- Project-independent configuration management
- Applications do not perform any platform specific dependent calls
GN&C FSW Application Framework

Architecture

GN&C Application Framework
- Provides standard application infrastructure with an API
- Layered architecture
- Project independent configuration management
- Implemented as a shared library
• GN&C Application Framework
  – Top-level container (App_Frame)
    • Contains and coordinates an application’s use of the cFE and GN&C framework utilities
  – cFE Utilities
    • Provide standard mechanisms for managing some of the interfaces to the cFE
    • E.g. registering command callback functions
  – GN&C Utilities
    • Provide standard mechanisms and infrastructure for creating GN&C FSW Applications
    • Contains an object manager that is used to coordinate the initialization and execution of reusable and mission-specific objects
    • E.g. fault detection reporting utility

• Templates
  – Application main and object manager
  – Candidates for automatic code generation
• **Math Library**
  - Developed by the FSW branch prior to the start of SDO and GPM
  - Based on heritage math libraries
  - Code, unit test, and documentation in branch reuse library

• **GN&C FSW Objects**
  - Provide functionality that meets a mission’s functional requirements
  - Can come from the GN&C FSW Library or written specifically for a mission
GN&C FSW Reusable Objects

- Two classes of objects defined based on the object’s dependencies
  
  - **Framework-independent Objects**
    - Objects that at most depend on branch standard common_types.h and math libraries
    - Easily reusable in other environments
      - Allow analyst to integrate objects into their simulations
      - E.g. solar and lunar models
  
  - **Framework-dependent Objects**
    - Have FSW architectural dependencies beyond framework-independent object dependencies
    - Reusable within the GN&C framework
    - For example the spacecraft ephemeris ground interface object
      - Has cFE event service and GN&C fault detection dependencies

- Unit test tools organized according to these dependencies
Conclusion

- Infrastructure is in place to mature a GN&C FSW framework-based development process
  - Mission independent configuration management
  - Mature framework design
  - Object library design, policy, and procedures under development

- LRO
  - Using the cFE and the GN&C application framework

- GPM
  - Mature object library concept
  - Start populating the object library

- MMS
  - Mature requirement process and IDE