NASA's Software Architecture Review Board's (SARB) Findings from the Review of GSFC's "core Flight Executive/Core Flight Software" (cFE/CFS)

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NASA Software Architecture Review Board

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Background

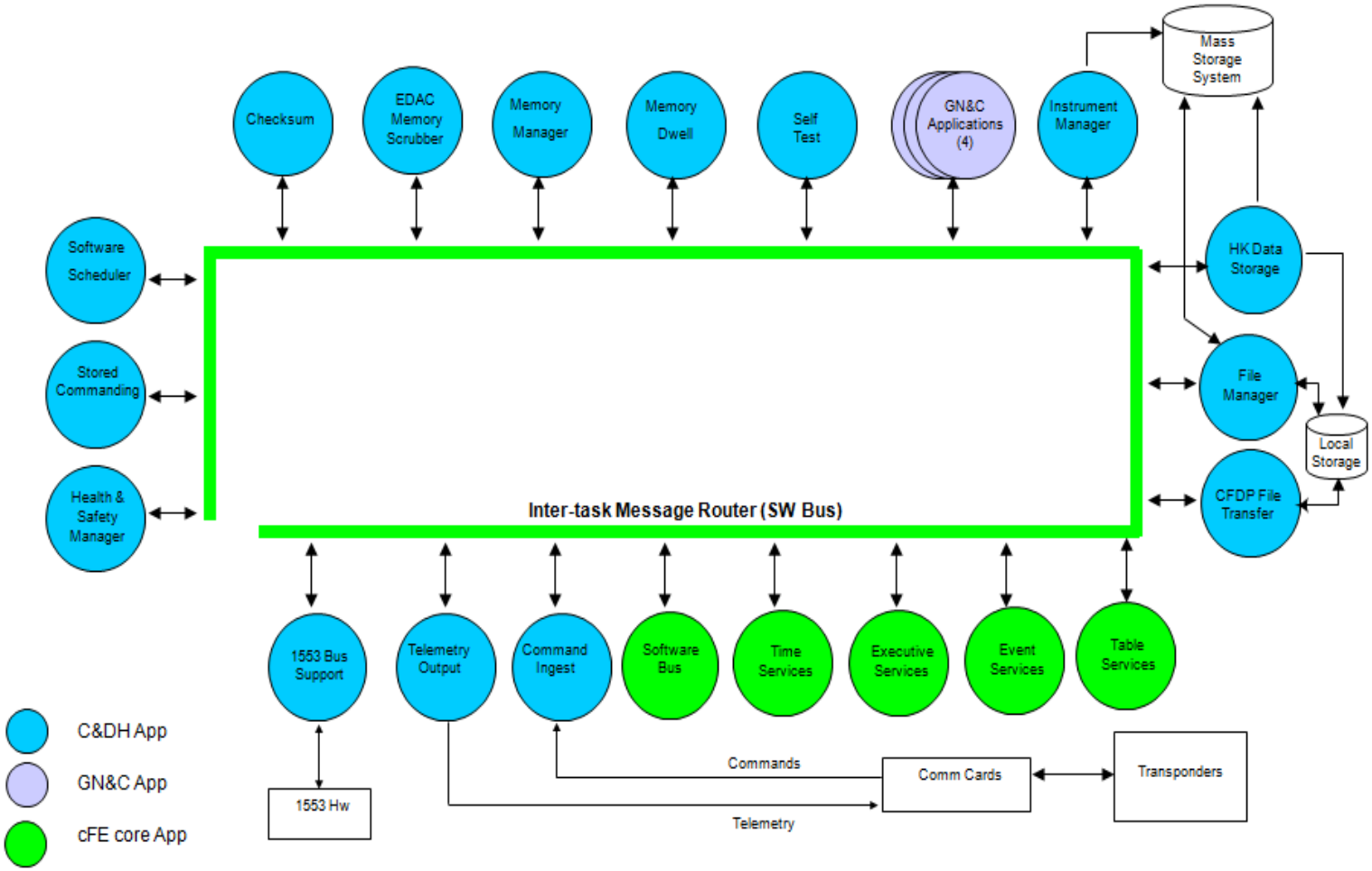
Software Architecture Review Board

- SARB establish in 2009 based on recommendation from FSW Complexity study to Office of Chief Engineer
- Funded as a NESC technical discipline team by Michael Aguilar
- Several reviews conducted, varying in duration and depth

cFE/CFS Background

- Developed by GSFC Flight Software Systems Branch in response to growing costs and schedule for SW development due to increasing system complexity
- Project-independent FSW provides run-time environment and services for hosting applications
- Targeted for Class B FSW for Robotic s/c and instruments
- Domain: C&DH, GN&C, thermal, power, instrument control
- Users: ARC/LADEE, JSC/Morpheus, APL/RBSP

cFE/CFS Diagram



"Lollipop" Diagram shows cFE core applications and software bus (green), plus CFS applications that plug into the bus (blue and purple).

cFE/CFS Review Team

- Michael Aguilar (NESC, NASA Software Discipline Expert)
- Dan Dvorak (JPL, SARB Lead)
- Lorraine Fesq (JPL, review chair)
- Robyn Lutz (Iowa State University) – Product Line expert
- Michael Madden (LaRC)
- Pedro Martinez (JSC)
- Alex Murray (JPL)
- John Weir (MSFC)
- Steve Williams (APL)

Review Objectives & Focus

- Objectives:
  - Help project identify issues that may have been overlooked
  - Recommend actions to minimize downstream problems
- Focus will be on software *architecture*
  - not detailed design, not code, not avionics
- This is an engineering peer review
  - Tabletop review style, not primarily presentations to board
- Report:
  - Board report finalized January 2012
  - Report restricted to GSFC 582 management unless they permit broader release

What an architecture review is NOT

An architecture review is …

- not a gate, not a mandatory review
- not a pass/fail judgment
- not an audit for a cancellation decision
- not an evaluation of architect's performance
- not a tutorial
- not a code review

Findings

- Well thought-out, perhaps partly due to systems engineers and FSW engineers in same organization, promoting collaboration
- Four categories of findings
  - Governance
  - Use on Projects
  - Architecture
  - Documentation

Findings: Governance

Meets a need across NASA, used by several projects at multiple Centers

- Has potential to become a dominant architecture framework for NASA FSW
- Lacks a business model - requires formal support for full benefit of product line to be realized

Findings: Use on Projects

Users at Multiple Centers were interviewed

- Technology viewed as mature – easy to build and test
- Promotes collaboration across Centers
- Code violates some standards
- Applications outside of original scope likely will require enhancements
- Could provide valuable training for pipelineing students – open-source availability

Findings: Architecture

Highly regarded by the Board

- Development guidelines for app layer exert a positive influence on architecture
- Use of pub/sub SW bus
  - allows for distributed development and easy integration
  - Well-encapsulated apps improve abstraction, flexibility, reuse, division of concerns
  - Could result in non-deterministic/non-repeatable execution

Findings: Architecture – cont.

- Modular components, well-defined I/Fs
- cFE shields apps from data structure formats
- OSAL allows easy use of different Operating Sys
- cFE can be used Stand-alone
- Message queue overflow handling
  - Drops newer messages
  - Subscriber not notified
- Seconds and sub-seconds derived from different sources, which could lead to timing issues

Findings: Documentation

SARB often find that the documentation doesn't describe all the key aspects that future users ought to know. Utility/longevity limited by quality, depth, maintenance of architectural description

- ADD incomplete
- ADD uses ad-hoc graphical notation
- Discrepancies in representation and terminology
- Document what has been used on projects
- ADD does not identify required vs optional

Findings: Documentation – cont.

- Distinction between cFE and CFS components not clear in ADD
- Need view of connections between publishers and subscribers
- Need description of dependencies among source packages
- Need rationales for design decision and underlying assumptions
- Need testing guidelines
- Conceived to meet GSFC's Earth-orbiter needs; no insight into architectural

Findings: Documentation – cont.

- QoS attributes not well documented
- Need guidance for complex, FT, autonomous control systems
- Need definition of FM philosophy – Limit Checker meets EO needs
- Need start-up procedures
- Need expanded time-services description
- Provide info to configure, execute, analyze performance data
- Document/analyze flight/ground division

Conclusions/Summary

- cFE/CFS Architecture highly regarded by the SARB
- Well-thought out – much potential
- Needs improved documentation
- Needs Governance and support to reach full potential
- Users outside of EO community should proceed with caution

SARB's website is a sub-Community of the Software Engineering Community of Practice

https://nen.nasa.gov/web/software/sarb

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Upcoming SARB Reviews

By Lorraine Fesq at JPL, 10/20/11

Upcoming SARB Reviews

Solar Probe Plus (SPP) Mission Definition Review (MDR) (November 1-3 at APL)
Core Flight System (CFS)/core Flight Executive (cFE) review (Delayed at TBA)
+ Read More

TOP STORIES: ALL ANNOUNCEMENTS

- Call for Papers: IEEE Aerospace Conference, Collaborative Model-Driven Aerospace Engineering - 5/27/11
- SEI Architecture Technology User Network (SATURN) 2011 Conference - 3/3/11
- CNN Names Software Architect as Best Job - 1/19/11

COMMUNITY LINKS

Conferences and Events — Software architecture conferences

Reading Room — SARB Reading Room

Contact List — SARB Contacts

Sample Architectures and Reviews — SARB Sample Architectures and Reviews

Lessons Learned — Software architecture lessons (coming soon)

Forums — Discuss software architecture

Preparation for Review — Supporting materials for architecture reviews

FAQ — Frequently asked questions

WELCOME

Welcome to the Software Architecture Review Board (SARB) community! SARB is a NASA-wide board that engages with flight projects in the formative stages of software architecture. The objectives of SARB are to manage and/or reduce flight software complexity through better software architecture and help improve mission software reliability and save costs.

SARB Charter

Why Review Software Architecture?

Lead: Dan Dvorak (Bio)
Facilitator: Daria Topousis

Backup Slides

SARB Mission:
Manage flight software complexity through better software architecture

Charter

- Provide constructive feedback to flight projects in the formative stages of software architecting
- Focus on architectural improvements to reduce and/or better manage complexity in requirements, analysis, design, implementation, verification, and operations
- Spread best architectural practices, principles, and patterns across flight software centers

Benefits of Architecture Reviews

- "Architecture reviews tend to increase quality, control cost, and decrease budget risk."
  - [Bass, Clements, and Kazman, *Software Architecture in Practice*, 1998]
- "In our experience, the average [architecture] review pays back at least twelve times its cost."
  - [Daniel Starr and Gus Zimmerman, *STQE Magazine*, July/August 2002]
- Beneficial side effects:
  - The review process trains people to be better architects
  - Cross-organizational learning is enhanced
  - Architectural reviews get management attention without personal retribution
  - Architectural reviews assist organizational change
  - [Maranzano et al, *IEEE Software*, March/April 2005]

Perceived benefits of architecture review*

	Benefits/goals of architecture review	Responses (%)
A	Identifying potential risks in the proposed architecture	88
B	Assessing quality attributes (for example, scalability, performance)	77
C	Identifying opportunities for reuse of architectural artifacts and components	72
D	Promoting good architecture design and evaluation practices	64
E	Reducing project cost caused by undetected design problems	63
F	Capturing the rationale for important design decisions	59
G	Uncovering problems and conflicts in requirements	59
H	Conforming to organization's quality assurance process	55
I	Assisting stakeholders in negotiating conflicting requirements	43
J	Partitioning architectural design responsibilities	40
K	Identifying skills required to implement the proposed architecture	40
L	Improving architecture documentation quality	40
M	Facilitating clear articulation of nonfunctional requirements	31
N	Opening new communication channels among stakeholders	31

* Muhammad Ali Babar and Ian Gorton, "Software Architecture Review: The State of Practice", *IEEE Computer*, July 2009.

What's different about <u>this</u> review?

- cFE/CFS is a reference architecture, not a point design architecture
  - It is intended for a class of missions that share commonalities despite differing requirements
  - It has variation points to address differences
  - The developers in customer missions are *not* the architecture's developers
- Some reviewer questions will focus on such aspects