2nd Annual GSFC-JPL Quality Mission Software Workshop

Goddard Space Flight Center
Jet Propulsion Laboratory

Session 5: Mission Software Subdisciplines

San Diego, California
May 16-18, 2000

AGENDA
Session 5: Mission Software Subdisciplines

Day 3
Thursday – May 18, 2000

Mission Software Subdisciplines

8:30 pm	Topic Introduction and Rules	K. Rehm/R. Lee
9:30 pm	Team Discussions (6-8 people per group)	JPL/GSFC
10:30 pm	Break	
10:45 pm	Team 1 Recommendations	Team 1 Lead
11:15 pm	Team 2 Recommendations	Team 2 Lead
Noon	Lunch	
1:00 pm	Workshop Wrap-Up	All
2:00 pm	Adjourn	

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2nd Annual GSFC-JPL Quality Mission Software Workshop

Mission Software Subdisciplines
Topic Introduction and Rules

Ken Rehm

18 May 2000

Introduction

- Purpose
  - Identify major issues that are common between major subdisciplines of mission software and centers.
  - Identify major issues that represent significant differences between major subdisciplines of mission software and centers.
  - Identify areas of potential collaboration between major subdisciplines of mission software and centers.

Introduction (Cont'd)

- Scope
  - Subdisciplines Involved:
    - Flight Software: any software residing on board the spacecraft
    - Real Time Ground Software: Ground Test Systems, Control Center Software and (JPL only) Ground Station and Tracking Software (includes both DSN and AMMOS)
    - Planning and Scheduling Software: Science and Mission Planning, Sequence Generation
    - Spacecraft Trending and Analysis Software: Spacecraft Subsystem analysis software.
  - Centers Participating:
    - Goddard Space Flight Center, Greenbelt, Maryland
    - Jet Propulsion Laboratory, Pasadena, California

Process - Offline

- Data Gathering - Conducted survey with questionnaires and responses
- Data Analysis - Boiled down responses into Summary Charts
- The data gathered is by no means a complete representation of every mission at every center.
- Individuals were selected (not at random) for the interviews.
- Details in following presentation

Process Real Time Workshop

- Split into 2 Subgroups, Management and Engineering
  - Identification of Issues
  - Recommendations of Prescriptive Actions
  - Identification of Areas of Collaboration
  - List “Surprises” (Unexpected responses)
- Recombine into a Discussion Group
  - Prioritization of Issues
  - Prescriptive Recommendation(s)
  - Areas of Collaboration
  - “Surprise” Discussion

Process - Post Workshop

- JPL-GSFC team to continue to work top priority issues, corrective actions, and and areas of collaboration

Subgroup Template - a

- What are the top 3 issues across major subdisciplines of mission software and centers?
  - Issue 1:Schedule compression together with resource compression. Lack of good estimates/metrics for determining resources.
  - Issue 2: Lack of formality in requirements management, capture.
  - Issue 3: Lack of System Engineering, lack of time to do SE and lack of SE authority.

Subgroup Template - b

- What are the prescriptive actions recommended for the top issues from part (a)?
  - Prescription 1: Ability to produce a valid business case, be able to advocate & influence decision process, more s/w roles reporting directly to project managers (e.g. Project s/w architect/mgr, (7120 Requirement addition?))
  - Prescription 2: Associate cost/impact with reqs., side effect of build to cost, role of s/w mgr in project, forcing key project members to sign off on reqs., collaboration tools for reqs development, strong system engineer (authority),make s/w leads review/sign sys/func. Reqs., clear assignment of Req. capture responsibility,
  - Prescription 3: Need to make SE jobs more attractive, Clearly ID roles (e.g. S/W SE, mission Ses); Curriculum for IT SE Training; Career path to Proj. management.

Subgroup Template - c

- What are the top 3 areas of collaboration between major subdisciplines of mission software or centers?
  - Collaboration 1: Tools, Training
  - Collaboration 2:
  - Collaboration 3:

Subgroup Template - d

- What Responses were unexpected (the ones where you thought - “wow”, “huh” or “what the ?”) ?
  - Surprise 1:Rejection of COTS, Its not the silver bullet we first thought
  - Surprise 2:Pattern: We did things more carefully in the past (impact of time/resource compression)
  - Surprise 3: Lack of formality in Process (e.g. Reqs.)

Group Issue Prioritization

- Prioritize the issues (1-Highest Priority, 6 Lowest)
- Issue: Priority:
- Issue: Priority:
- Issue: Priority:
- Issue: Priority:
- Issue: Priority:
- Issue: Priority:

Corrective Prescription for 3 Highest Priority Issues

- Issue:
  - Prescription:
- Issue:
  - Prescription:
- Issue:
  - Prescription

Three Areas of Collaboration

- Area of Collaboration:
  - Action:
- Area of Collaboration:
  - Action:
- Area of Collaboration:
  - Action:

Surprise Discussion

- What conclusion can be drawn from the unexpected responses and what if any action would be recommended to not have any more surprises?
  - Conclusion:
  - Recommendation:

Optional Discussion

- What additional Questions (like those on the subgroup templates or even the data gathering) might prove useful in this or future discussions of this topic?
  - Question: What are we doing right?
  - Question: What reduces stress?
  - Question: How do we do good teaming?

Interview Results

Roger Lee

May 18, 2000

Interview Summary

- JPL and GSFC conducted a survey of software practices across both centers and across four sub-disciplines:
  - Spacecraft Flight Software
  - Real-time Ground Systems Software
  - Planning and Schedule Software
  - Spacecraft Analysis Software
- The interview consisted of 72 questions in nine groups:
  - Mission Formulation Phase
  - Interfaces
  - Requirements Phase (Phase C/D)
  - Design Phase
  - Development Phase
  - Testing Phase
  - Maintenance Phase
  - Resources
  - Miscellaneous

Interview Summary

The following slides summarize the responses to selected questions in each of the nine groups. Answers are identified by subdiscipline and by center where there are significant differences in responses.

Question is stated in blue.

Subdisciplines are noted in green.

Answers are given in red.

Mission Formulation Phase

What creates the most stress on your team at this phase of development?

Flight

Incomplete S/C definition; lack of documented historical cost estimates; lack of skilled staff; trying to meet unreasonable budget constraints.

Ground

Software team usually not involved. Problems are created if design falls outside of capabilities.

Planning

The desire of new missions to start from scratch.

S/C Analysis

Lack of mission definition and what capabilities need to be supported.

Interfaces

How knowledgeable is your customer?

- Flight
  - *Typically has a H/W background, but is supportive.*
- Ground
  - *Program office knowledgeable and supportive; legacy projects resistant to change.*

Interfaces

What organizations limit the authority of the S/W team?

Flight

Flight hardware, flight dynamics, ACS, instruments, and FSW maintenance.

Ground

System engineering; requirement to use common services; instrument T&C interface (not determined until later in the development cycle.

S/C Analysis

Ground station interfaces (NCC for TDRSS, JPL for DSN, Wallops for their ground stations, JSC for Shuttle, etc.).

Requirements Phase (C/D)

What are the software functional roles during this phase?

Flight

Producing software requirements, interfaces documents, investigating prototypes, software management plan, FSW architecture.

Ground

Selection of COTS/GOTS products, specification of development environment, requirements mapping, requirements prioritization vs. available budget.

Planning and Scheduling

Interface with flight ops, planning for ops automation.

Requirements Phase (C/D)

What is the source of your requirements?

Flight

Systems engineering, mission requirements analysis, scientist inputs, operations inputs, hardware engineer inputs.

Ground

Matching requirements against existing capabilities. Requirements obtained mostly through the s/c subsystem leads (Flight HW, Flight SW), not directly from the s/c system engineer.

Planning and Scheduling

S/C Analysis: Flight operations team.

Requirements Phase (C/D)

Who signs off on requirements?

- Flight
  - *Goddard: FSW lead, ACS lead, C&DH lead, system engineer, test lead, hardware subsystem leads. Usually multiple documents.*
  - *JPL: S/C systems engineer.*
- Ground
  - *GSFC: Some combination of project manager, mission manager, S/C system engineer, software development team.*
  - *JPL: Service element manager.*
- Planning and Scheduling
  - *Becoming more difficult to get formal requirements. Sometimes word-of-mouth only.*
- S/C Analysis
  - *Development team leader. Branch management. GDS manager (represents project).*

Requirements Phase (C/D)

What requirements are most difficult to mature?

Flight

GSFC: Fault detection and correction, launch & early orbit insertion, instrument requirements, power subsystem.

JPL: H/W interfaces, including S/C bus; processor throughput and memory.

Ground

GSFC: Ground station interfaces, details of on-orbit checkout, instrument requirements, overall science planning and scheduling.

JPL: Non-capability driven requirements, reliability requirements, user automation needs.

Requirements Phase (C/D)

How accurate are your requirements prior to I&T? Prior to launch?

GSFC

"Very accurate and complete"

JPL

Flight: Requirements typically incomplete at start of I&T; completion typically lags launch for smaller projects

Ground: Stable at beginning of I&T but require 2-3 updates.

Planning and scheduling: At the start of I&T, we expect many changes to detailed requirements. At launch, the commands and rules are somewhat firm. Activity definitions requirements continue to change well after launch.

Requirements Phase (C/D)

What is the main source of requirements creep and what techniques have been used to contain it?

Overall: It is naïve to think that requirements won't creep up until the launch freeze date and maybe after that.

Flight

GSFC: Lack of decision authority

JPL: Delayed decision on H/W definition; late decisions on mission requirements impacting throughput and memory.

Ground

GSFC: Lack of s/c definition, flight s/w changes, late participation of flight operations. Mismatch between project vision and operations staff goals.

JPL: Changing program office direction. Overly optimistic development team. Use GDS for flight I&T as early as possible.

S/C Analysis

FOT not involved in early stages of requirements definition. Personnel changes in FOT: new people typically bring new requirements

Requirements Phase (C/D)

How critical is documentation during this phase?

All Subdisciplines

Documentation is critical to have clear understanding of requirements and to make sure all parties are in agreement. (Requirements change management and documentation of COTS/GOTS products were cited as extremely critical.) However, documentation is becoming less formal over time.

Requirements Phase (C/D)

What creates the most stress on your team during this phase?

All Subdisciplines

Lack of alignment between S/C system engineer, H/W engineer, and S/W development team.

Holding back coding and doing a requirements analysis: developers "understand" the requirements by coding.

Requirements based on mirrors and magic. GSFC: The 100 Hz guiding control law is an example. The ACS team said that 30 Hz is more than enough but since the project picked 100 Hz two years ago that is what we will use.

Design Phase

What percentage of your product is based on COTS?

Flight

Real-time operating system only. COTS tools used extensively in development.

Ground

Display system (SAMMI), database (ORACLE), freeware (GNU), third-party software.

Planning & Scheduling

GSFC: MOPSS is Oracle-based. Corba used in Java client. Possibly 50% total.

JPL: None.

S/C Analysis

GSFC: 10-30%, plot package typically COTS.

JPL: 20% but declining.

Design Phase

What percentage of your product is typically based on re-use?

Flight

GSFC: C&DH: 60%; ACS: 10%

JPL: Conceptual design: 70%; Code: 10%

Ground

GSFC: 70-85%

JPL: Very little on the DSN side, over 95% on the AMMOS side.

Planning and Scheduling

GSFC: Base system (MOPSS): 90%

JPL: Very high for multimission core. Adaptations re-sue is 50%

S/C Analysis

GSFC: 40-60%; JPL: 80-90%

Design Phase

What percentage of re-used components are used with zero changes?

Flight

GSFC: C&DH ~ 20 of the 60%, ACS ~ 9 of the 10%.

JPL: Very little.

Ground

GSFC: Anything from 20% to 95%.

JPL: Very little on DSN side, over 95% on AMMOS side.

Planning and Scheduling

95-100%

S/C Analysis

20% - 60%. Display system could often be used unchanged, but typically users can't resist the temptation to change the requirements.

Design Phase

What level of internal and external review is mandated during this phase?

JPL: CDR, peer technical reviews.

GSFC:

Flight: Extreme internal visibility.

Ground: Some internal peer reviews, no formal reviews.

Planning and Scheduling: Very variable: maybe PDR, CDR, maybe nothing.

S/C Analysis: In the past, formal PDR, CDR. Usually does not happen anymore.

Design Phase

What creates the most stress on your team during this phase of development?

All Subdisciplines

Schedule pressure, supporting dependencies. Requirements variability. Problems with COTS development tools.

Development Phase

What level of internal and external review is mandated during this phase?

Flight

GSFC: Internal walkthroughs. No external reviews required, but walkthroughs are open to external participants.

JPL: Module Acceptance Test is used to demonstrate required capabilities to the Integration Lead.

Ground

GSFC: Almost none. Periodic demonstrations of user interfaces. Periodic status meetings to monitor progress.

JPL: Code walkthroughs.

Development Phase

What creates the most stress on your team during this phase of your software development?

Flight

Lack of stability in the test environment

GSFC: Problems with COTS development tools. Difficulty firming up flight hardware interfaces. Communications between FSW groups. Requirements changes with no schedule relief.

JPL: Inadequate debugging tools and training in use of same; requirements not understood; broken interfaces; unstable development environment.

Testing Phase

Do you use an independent test team?

Flight

GSFC: Yes, the test team is a different set of people than the developers, but report to the same s/w manager.

JPL: Not typically.

Ground

GSFC: Not as part of the development effort. Test conductors, etc. are using the ground system in their testing (mission SIMs, etc.) so they provide independent testing.

JPL: Yes the test team is organizationally independent from the developers

Planning and Scheduling

GSFC: FOT does independent testing of releases before deployment.

JPL: Lead develops requirements, design effort, and test plans. Leads testing, but coders are usually not the testers.

Spacecraft Analysis

GSFC: Yes. They are separate teams, but they work for the same company. In the past, development was carried out by CSC, testing by Allied.

JPL: Yes, organizationally separate from the development team.

Testing Phase

What is the nature of your test facilities?

Flight

GSFC: Build testing done with breadboards and simulators. System verification done on as flight-like equipment as possible, preferably ETUs.

JPL: Developer workstation, single processor board testbed; flight-like testbed used for HW-SW integration.

Ground

GSFC: Internal test facility consists of installations on PC/Sun workstations for each supported OS and an external data source. Low fidelity data generators and pre-recorded data.

JPL: DSN: Very hard to duplicate tracking station. AMMOS: Verification on development string and through parallel operations string.

Testing Phase

What do you wish the test facilities could do better?

Flight

Come together earlier. Earlier delivery, more access, higher fidelity. Not get cut.

Ground

GSFC: Provide a low fidelity spacecraft simulator that is remotely controllable.

JPL: Be closer to end environment. Have all the platforms used by customers.

Testing Phase

Describe the requirements traceability to your software test process.

- Flight
  - *GSFC: Typically Word document. Manual traceability matrix.*
  - *JPL: A System Validation and Verification Matrix is used.*
- Ground
  - *GSFC: Informal. Test process maps to product capabilities, not directly to customer requirements.*
  - *JPL: Test cases trace to functional requirements.*
- Planning and Scheduling
  - *GSFC: Formal mission -- very rigorous. Not the norm for recent missions - more word-of-mouth.*
  - *JPL: Test cases trace to functional requirements.*
- S/C Analysis
  - *GSFC: End-to-end requirements traceability is typical, when we have good written requirements (which we don't always get anymore)*
  - *JPL: Moving towards use of trace matrix to validation of requirements.*

Testing Phase

What level of contingency (non-nominal) test scenarios must be done for your product delivery?

Flight

GSFC: Exhaustive.

JPL: All fault protection scenarios are examined.

Ground

GSFC: Limited. The system is exercised by other organizations.

JPL: No standard requirement for this.

Testing Phase

What percentage of your product is 100% available before launch?

Flight

GSFC: 100%

JPL: 90%

Ground

GSFC: 100% is planned. Requirements creep can change this.

JPL: 100%

Testing Phase

What are the launch-ready criteria for your software?

Flight

GSFC: All requirements met and tested, software under CM, maintenance team and facility in place, any discrepancies are signed off by project.

JPL: Ability to deploy the S/C and complete all procedures for S/C initialization and safing.

Ground

GSFC: Criteria established by Missions Ops team. Minimally, zero Urgent or Critical DRs open. Successful completion of long-form functional test and all launch SIMs.

JPL: Software needs to be operational and validated by end to end tests 6 to 12 months prior to launch.

Testing Phase

What are the launch-ready criteria for your software (continued)?

Planning and Scheduling

GSFC: 100% mission SIM compliance (FOT sign-off)

JPL: Completed GDS testing and operations readiness tests without critical anomalies.

S/C Analysis

GSFC: No critical discrepancies open. All launch critical requirements implemented. Participate in ORR -- typically ineffective. (Developer telling ops that software is ready for launch instead of the other way around.)

JPL:Software needs to be operational and validated by end to end tests 6 to 12 months prior to launch.

Testing Phase

What level of internal and external review is mandated during this phase?

All Subdisciplines

Test readiness review, system delivery review, operational readiness review. Scenario walkthroughs, test procedure walkthroughs.

Testing Phase

How critical is documentation during this phase?

All Subdisciplines

Requirements document and test plan and procedures very important. Test plan critical for testers with limited experience. Critical to document any problems encountered and workarounds.

Testing Phase

What creates the most stress on your team during this phase of development?

All Subdisciplines

Schedule crunch. The software may be late because of requirements changes, yet the end data for the delivery doesn't move, so the test time gets squeezed. Realizing that our testing is not anywhere near as good as it should be. Not having documentation needed from the development team. Problems that are not repeatable.

Maintenance Phase

When does maintenance begin for your product with respect to S/C launch?

Flight

GSFC: Begins at S/C I&T. From then to IOC, products delivered in normal fashion (not patches). Maintenance team takes over after launch.

JPL: Development typically carries beyond launch, with many developers joining the maintenance and operations teams.

Ground

GSFC: Varies. Could be launch plus 30 days. If there is a post-launch delivery for early orbit checkout fixes, maintenance begins after that.

JPL: DSN: Not related to S/C launch. AMMOS: Since it is a multi-mission system there really isn't a maintenance phase but rather ongoing development.

Maintenance Phase

What level of internal and external review is mandated for this phase?

Flight

Extensive internal and external review.

Other Subdisciplines

Patches and changes are extensively reviewed and tested. Periodic meetings to discuss discrepancy reports. Meetings typically handled by program manager.

Maintenance Phase

What creates the most stress on your team during this phase of development?

Flight

GSFC: Unknown priorities from the project. Critical need to reinstate science after anomaly. Simultaneous demands by multiple projects.

JPL: Diagnosis and resolution of anomalies, especially during real-time events.

Ground

GSFC: Troubleshooting operational problems. Not having enough time to work on new development.

JPL: Missions that don't want to upgrade as products are upgraded. This can cause backwards compatibility problems.

Resources

What is the basis for your cost and schedule estimates?

All Subdisciplines

Past experience of team, historical data. Team Z (JPL only). Sometimes budget is handed down from project, so have to build to cost.

Resources

If you had additional resources for your team, where would you put them?

Flight

GSFC: Development and test personnel. Lab. Fidelity.

JPL: 1) Test 2) Integration 3) Design.

Ground

GSFC: System administrators/network security support. Maintenance. Automation.

JPL: Testing, specifically development of test tools. System engineering.

Planning and Scheduling

GSFC: Keeping products up with technology

JPL: System engineering. Lay out test program in finer detail.

S/C Analysis

GSFC: More testers, more computers, more developers.

JPL: System engineering (requirements and design). Additional developers. Now.

Resources

What percentage of your software effort do you typically expend in the requirements phase, the implementation phase, and the testing phase?

Flight

- GSFC: 25-30-45
- JPL: 20-20-40

Ground

- GSFC: 10-70-20
- JPL: 20-50-30

Planning and Scheduling

- GSFC: Spiral methodology -- hard to estimate
- JPL: 20-50-30

S/C Analysis

- GSFC: 30-55-15
- JPL: 30-50-20

Miscellaneous

What are the three most negative external influences on productivity of your software team?

Flight

GSFC: Awful requirements. Bad systems engineering. Project unsupportive or non-understanding of s/w issues.

JPL: Inadequate role definitions. Compressed schedule. Lack of skilled staff.

Ground

GSFC: Personality conflicts. Fear of downsizing. Lack of communication.

JPL: Changing/contradictory requirements. Dependencies on other tasks. Inadequate test facilities. Losing experienced people.

Miscellaneous

What are the three most negative external influences on productivity of your software team (continued)?

Planning and Scheduling

GSFC: Budget, budget, user indecisiveness.

JPL: Changing requirements. Requirements that don't say what is really desired. Acquiring GOOD people.

S/C Analysis

GSFC: Waiting on information from the project to implement a requirement or fix a problem. Continuity of contractor personnel. Prime contract changes during development can be very disruptive.

JPL: Institutional & program office push-ups. Lack of coordination. Insufficient test time.

Miscellaneous

Identify three lessons learned that you will implement on your next similar effort.

Flight

GSFC: Electronic requirements traceability. Labs in place early. SW development infrastructure independent of projects. Institutionalization of lessons learned.

JPL: Improved requirements documentation and management. Improved baselining of code changes. More disciplined build process.

Miscellaneous

Identify three lessons learned that you will implement on your next similar effort. (Cont'd)

Ground

GSFC: Early operations involvement, better prototyping of hardware. Triple estimated time for unplanned activities and interruptions. Foster ownership of product across team. Capabilities of COTS are usually exaggerated.

JPL: Use dedicated personnel (I.e., not x% of someone's time). Provide more support infrastructure (tech writers, schedulers). Spend more time cultivating relationships with external organizations (within JPL) that support task.

Planning and Scheduling

GSFC: Document agreements, even from informal meetings. Have tighter tracking of time spent on individual capabilities. Improve communication between mission lead developers.

Miscellaneous

Identify three lessons learned that you will implement on your next similar effort. (Cont'd)

S/C Analysis

GFSC: Allow enough time in the schedule to update documentation. Allow enough time to fix critical discrepancies. Need a more robust spacecraft simulator.

JPL: More disciplined build and installation process. Improved development practices and processes. Better understanding of user needs in operations -- more realistic assessment of requirements.