



The Development of NASA's Fault Management Handbook

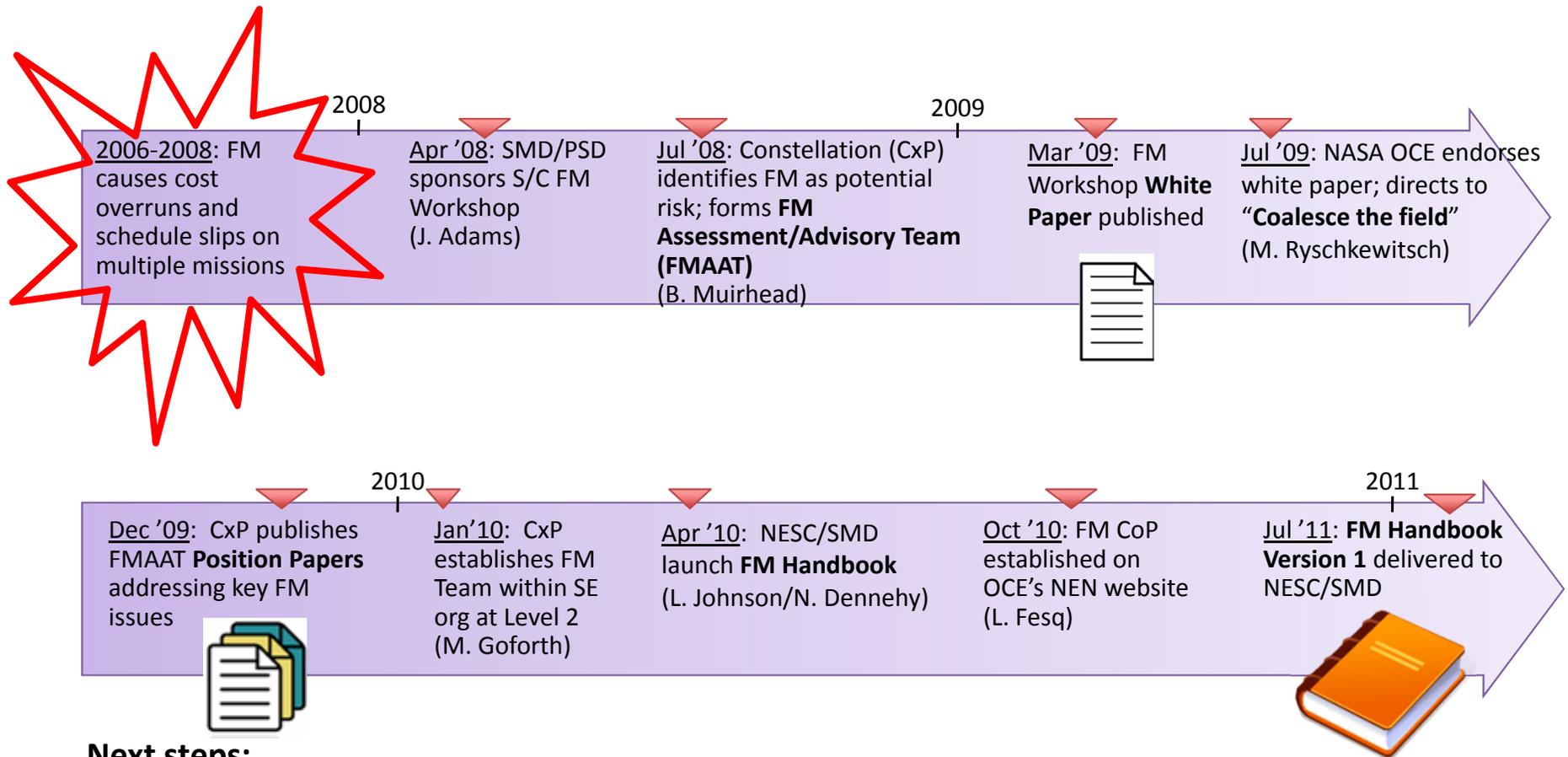
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Handbook Team Lead,
JPL/CalTech

AFRL's Integrated Systems Health Management (ISHM)
Conference
Boston, MA
19, 20 and 21 July 2011

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Recent Developments in FM



Next steps:

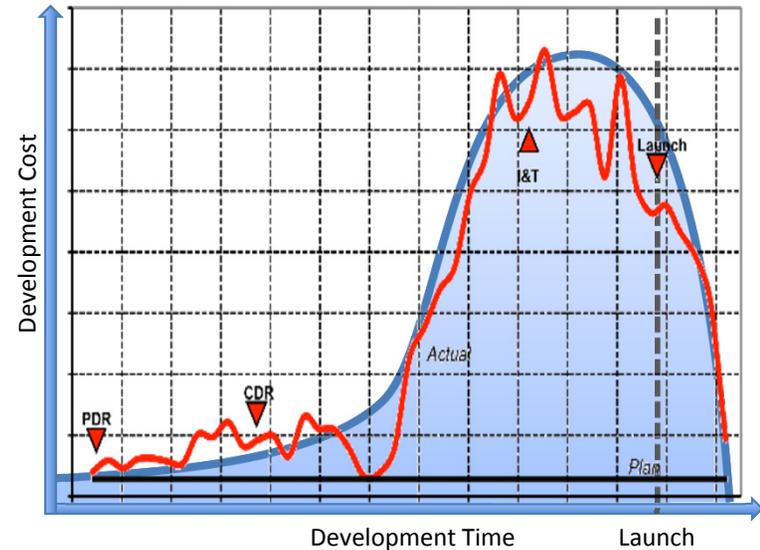
- 1. Develop agency-wide FM Handbook, Version 2** -- engage Human Spaceflight Programs (ESMD), Mission/Ground Systems (SOMD), Aeronautics (ARMD), OSMA.
- 2. Training/Exposure** -- e.g., NESC Brochure/Tech Update, Academy Online, JEO Workshop, NASA courses
- 3. Integrate/coordinate** FM concepts with other organizations (e.g., DoD, NRO) and with other documents (e.g., NASA Systems Engineering Handbook, NPRs)

Fault Management Workshop



SMD sponsored a workshop to uncover underlying causes of cost overruns on numerous missions

- Held April 14-16, 2008 in New Orleans, LA
- +100 attendees from 31 orgs – government, industry, academia
- Objective: Ameliorate schedule, cost and predictability challenges that often are faced when building, testing, and operating FM systems
- Goals: Document key findings and make recommendations for future missions
- Approach: Assemble key players in the spacecraft FM field across NASA, industry and other organizations, to
 - Capture current state of FM
 - Identify challenges associated with engineering/operating FM systems
 - Identify/describe issues underlying these challenges and propose steps to overcome/mitigate them
 - Discuss and document best practices and lessons learned in FM
 - Explore promising state-of-the-art technology and methodology solutions to identify potential investment targets.



FM Workshop Recommendations



[n] = Section in Handbook where Recommendation is addressed

2. Find a home for FM within Project organization

[3,5]

5. Establish FM Metrics

7. Assess mission-level requirements on FM complexity

[57,8]

9. Establish and maintain mission-level risk req

11. Provide adequate testbed resources

[10]

8. Assess if FM architecture is appropriate for Mission

6. Apply CPI to FM

[8]

10. Be skeptical of inheritance claims

[12]

1. FM should be “dyed into design” vs “painted on”

[3,6,8]

4. Identify FM representation techniques and FM design guidelines

[8]

12. Capture and understand FM cultural differences Among aerospace organizations

3. Standardize FM Terminology

[3,4]

FM Handbook Goal and Approach



Goal:

- Ameliorate schedule, cost and predictability challenges that often are faced when testing and operating FM systems
- Improve reliability and safety of NASA's flight and ground systems
- Coalesce the FM field

Approach:

- Identify qualified team of FM practitioners and systems engineers
- Evaluate findings and recommendations from 2008 FM Workshop
 - Initial emphasis on foundational issues; e.g. establish common terminology
- Capitalize on existing material
 - ESMD's Constellation Program's Fault Management Assessment & Advisory Team's (FMAAT) seven Position Papers and identified Risks
 - OCE's FSW Complexity Task results (D. Dvorak)
 - Aerospace TOR: "Effective Fault Management Practices" (S. Hogan)
 - NASA's Lessons Learned Database <http://llis.nasa.gov/offices/oce/llis/home/>

FM Handbook Scope

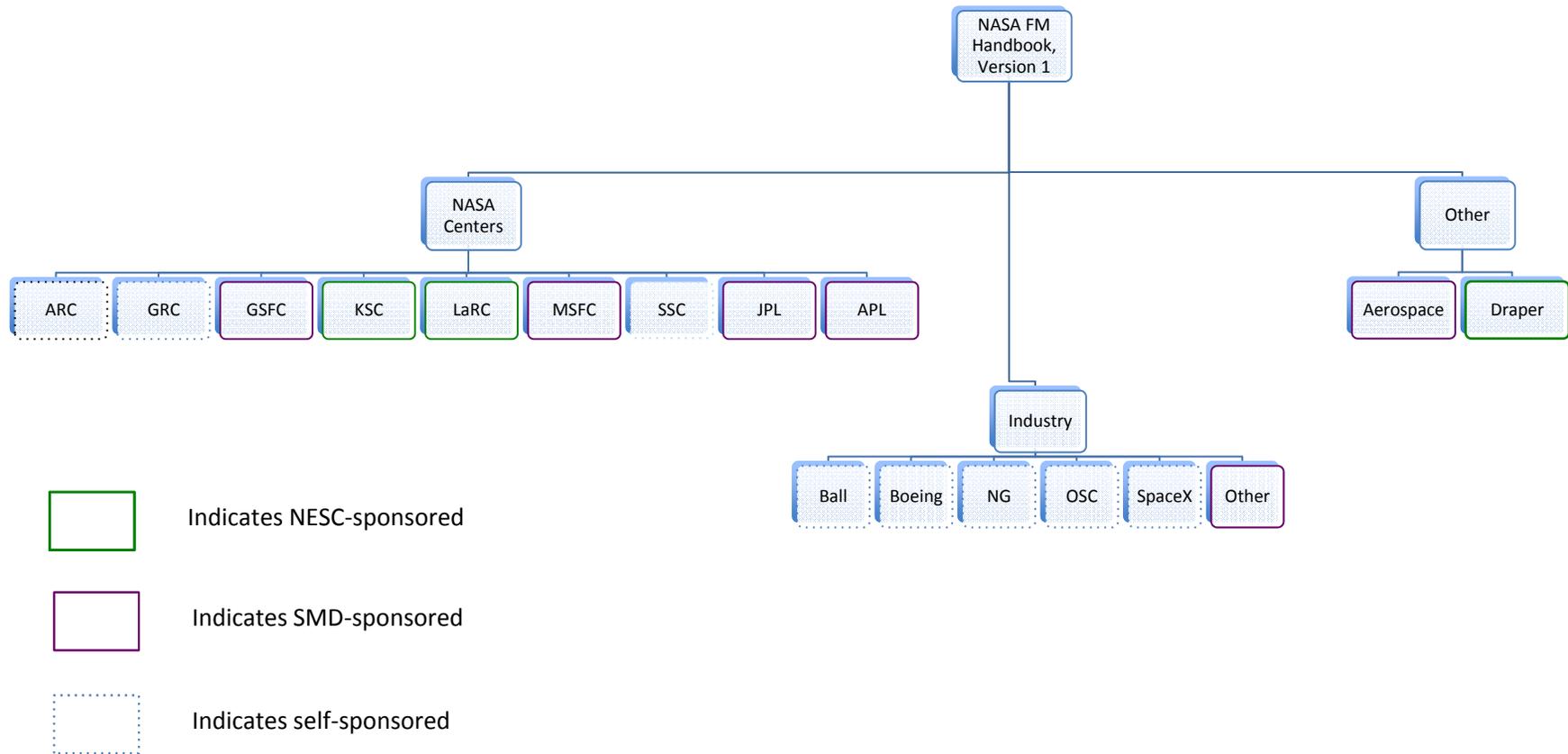


- **The envisioned users of the Handbook include:**
 - Top Level Management and Program managers
 - Systems and Subsystems Engineers
 - Mission Assurance/Reliability Leads
 - FM Practitioners
 - FM Trainees
 - Proposal Evaluators
- **Outline scoped to address needs of Agency – crewed and robotic missions**
- **Robotic emphasis in Version 1, due to SMD co-funding**
- **Suggested use as a “companion” to NASA Systems Engineering Handbook**

FM Handbook Participation



Goal: To produce a first draft of FM Handbook that will benefit NASA's current and future missions



FM Handbook Outline



Section	%*	Summary
Foreward	100	What does this Handbook provide? Why does NASA need a FM Handbook?
1. Scope	90	What is FM? Relevance and Purpose; FM within NASA and institutional challenges; Structure of the Handbook; intended audience
2. Applicable Documents	100	List of documents sited in the text; approved documents
3. Acronyms and Definitions	90	Acronyms and abbreviations used throughout the document; Definitions of key FM terms

* Percent complete for Version 1 DRAFT. To develop a NASA-wide Handbook, all Sections need additional expertise/review, especially from HSF, GS/MS, Aeronautics and OSMA communities.

FM Handbook Outline (continued)



Section	%*	Summary
4. Concepts and Guiding Principles	75	Fundamental concepts and guiding principles grounding the field -- FM functions, FM as part of SE, FM goals: asset and function preservation
5. Organization, Roles, and Responsibilities	75	Project organizational structure to support FM; interfaces; tasks
6. Process	90	Follows SE Process but focuses on FM products – Concept design, requirements, architecture, analysis, V&V, Ops and Maintenance
7. Requirements Development	90	FM requirements categories; driving requirements; flow-down

* Percent complete for Version 1 DRAFT. To develop a NASA-wide Handbook, all Sections need additional expertise/review, especially from HSF, GS/MS, Aeronautics and OSMA communities.

FM Handbook Outline (continued)



Section	%*	Summary
8. Design and Architecture	60	Impacts of mission risk posture, goals, characteristics and FM priorities; FM architectures, design features and approaches; mission-specific considerations
9. Assessment and Analysis	0	To be expanded in later releases
10. Verification and Validation	75	Identifies FM V&V planning/preparation; how to perform FM V&V and analyze results; selection and prioritization of FM scenarios; simulators, test-beds and flight hardware testing
11. Operations and Maintenance	0	To be expanded in later releases

* Percent complete for Version 1 DRAFT. To develop a NASA-wide Handbook, all Sections need additional expertise/review, especially from HSF, GS/MS, Aeronautics and OSMA communities.

FM Handbook Outline (continued)



Section	%*	Summary
12. Review and Evaluation	90	FM's presence in major milestone reviews; recommended FM-focused reviews; entrance and success criteria; key questions to ask at FM reviews
13. Conclusion	0	To be expanded in future releases
14. Future Directions (TBD)	0	Where this field is headed – new technology being developed that would offer technical solutions
Appendix A	100	References
Appendix B	0	Work Product Templates (TBS)
Appendix C	95	Relevant NASA Lessons Learned
Appendix D	100	Acknowledgements, historical background

* Percent complete for Version 1 DRAFT. To develop a NASA-wide Handbook, all Sections need additional expertise/review, especially from HSF, GS/MS, Aeronautics and OSMA communities.

NASA FM Community of Practice



- NASA Chief Engineer hosts Communities of Practice (~18 technical, 4 management) on NASA Engineering Network (NEN)
- FM Community of Practice was established October 2010 on NEN website to coalesce the field
 - Provide a forum for subject matter experts, a library of collected FM material and a list of practitioners
 - nen.nasa.gov/web/faultmanagement

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ABSTRACT SUBMISSION DEADLINE EXTENDED: Integrated Systems Health Management in Boston July 2011
 By Lorraine Fesq at JPL, 4/19/11

WELCOME
 Fault Management (FM) is an engineering discipline addressing the need for operational systems to prevent, detect, contain, isolate, diagnose, and respond to anomalous and failed conditions that would otherwise interfere with intended operations or threaten crew safety. In operation, FM increases system reliability, availability, and robustness by actively preserving system functionality. In NASA missions, the operational aspect of FM is realized by hardware and software on-board a spacecraft/aircraft, by crew members/pilots, and by ground-based systems and operators.
Contact: Lorraine Fesq (Bio)
Facilitator: Daria Topousis

TOP STORIES: ALL ANNOUNCEMENTS

- NASA Broad Agency Announcement (BAA): Unique and Innovative Space Technology - 3/2/11
- Kepler Anomaly Investigation - 2/16/11
- Kepler Mission Manager Update: 64 Hour Safe Mode Ends - 2/10/11

COMMUNITY LINKS

- Conferences**
Conferences, workshops, events
- Contact List**
Practitioners working in Fault Management
- Document Library**
Papers, articles, other documents
- Forums**
Online discussions
- Lessons Learned**
Official Lessons Learned related to FM
- NASA Fault Management Handbook Wiki**
Fault Management Handbook
- References**
NPRs, handbooks, standards, etc.
- Training**
- Suggestions**

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Longer-term Vision



1. **Develop agency-wide FM Handbook, Version 2**
 - Engage Human Spaceflight Programs (ESMD), Mission/Ground Systems (SOMD), Aeronautics (ARMD), OSMA.
 - Address more Workshop Recommendations (e.g., representation techniques)
2. **Hold Workshop(s)** to bring NASA FM community together to achieve common understanding across Directorates (include SSME IVHM, Lunar Altair Lander, OSMA, Human Factors, etc.)
3. **Establish WG (part of SEWG?) or TDT to work through more challenging Recommendations (e.g., FM architecture trade space, metrics). Leverage FM CoP to identify potential members**
4. **Integrate/coordinate** FM concepts with other organizations (e.g., DoD, NRO) and with other documents (e.g., NASA Systems Engineering Handbook, NPRs)
 - Engage DoD, Aerospace Corp, NRO -- Contractors should be able to use consistent terminology, architectures, representation techniques regardless of customer
5. **Training/Exposure** -- e.g., NESC Brochure/Tech Update, Academy Online, JEO Workshop, NASA courses
6. **Eventual standardization**
 - Update relevant NPRs to make FM requirements consistent, complete (Risk: 8705.4, R&M: 8725, PM: 7120.5E, SE: 7123.1A, SW: 7150.2)
 - Develop FM NPR (perhaps as a roadmap into FM items in other NPRs) or address as part of SE NPR

Conclusions



- **Disciplined approach to FM has not always been emphasized by projects, contributing to major schedule and cost overruns**
 - Often faults aren't addressed until nominal spacecraft design is fairly stable
 - Design relegated to after-the-fact patchwork, Band-Aid approach
- **Progress is being made on a number of fronts outside of Handbook effort**
 - Processes, Practices and Tools being developed at some Centers and Institutions
 - Management recognition – Constellation FM roles, Discovery/New Frontiers mission reviews
 - Potential Technology solutions – New approaches could avoid many current pitfalls
 - New FM architectures, including model-based approach integrated with NASA's MBSE efforts
 - NASA's Office of the Chief Technologist: FM identified in seven of NASA's 14 Space Technology Roadmaps – opportunity to coalesce and establish thrust area to progressively develop new FM techniques
- **FM Handbook will help ensure that future missions do not encounter same FM-related problems as previous missions**
- **Version 1 of the FM Handbook is a good start.**
 - Still need Version 2 Agency-wide FM Handbook to expand Handbook to other areas, especially crewed missions
 - Still need to reach out to other organizations to develop common understanding and vocabulary
- **Handbook doesn't/can't address all Workshop recommendations. Still need to identify how to address programmatic and infrastructure issues.**

Acknowledgements



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