The Development of NASA's Fault Management Handbook

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Agenda

- Historical Perspective
- Results of the 2008 Fault Management (FM) Workshop
- FM Handbook Goals, Scope and Contents
- Future Plans
- Acknowledgements

Recent FM Developments

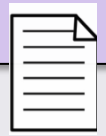
2006-2008: FM causes cost overruns and schedule slips on multiple missions

2008

Apr '08: SMD/ PSD sponsors S/C FM Workshop (J. Adams)

2009

Mar '09: FM Workshop **White Paper** published



Jul '09: NASA OCE endorses white paper; directs to "**Coalesce the field**" (M. Ryschkewitsch)

2010

*

Jul '08: Constellation (CxP) identifies FM as potential risk; forms **FM Assessment/Advisory Team (FMAAT)** (B. Muirhead)

Dec '09: CxP publishes FMAAT **Position Papers** addressing key FM issues

2010

Jan'10: CxP establishes FM Team within Level 2 SE org (M. Goforth)

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Apr '10: NESC/SMD launch **FM Handbook** – robotic focus (L. Johnson/N. Dennehy)

Oct '10: FM CoP established on OCE's NEN website – nen.nasa.gov (L. Fesq)

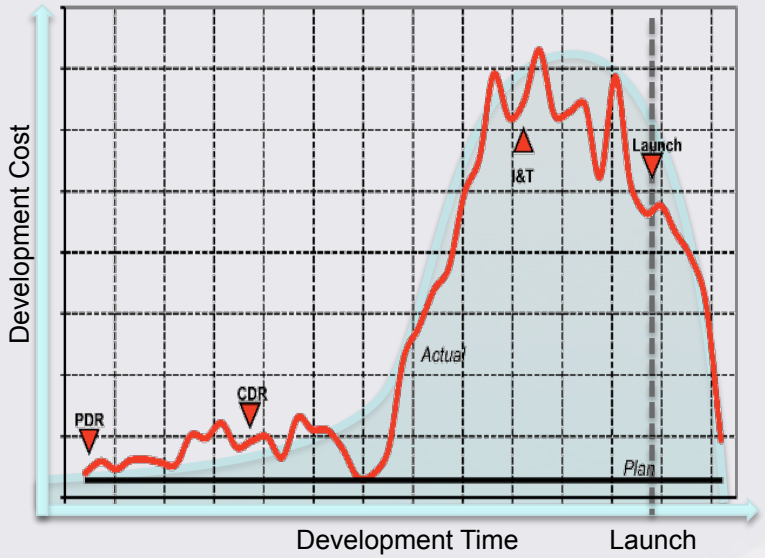
2011

Jul '11: **FM Handbook Version 1** delivered to NESC/ SMD and NTSPO

2008 FM 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 occur when building, testing, and operating FM systems



- Goals: Document key findings, 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

[5]

7. Assess mission-level requirements on FM complexity

[7,8]

5. Establish FM Metrics

9. Establish and maintain mission-level risk req

11. Provide adequate testbed resources

[7,10]

6. Apply CPI to FM

8. Assess if FM architecture is appropriate for Mission

[8]

10. Be skeptical of inheritance claims

[12]

1. FM should be "dyed into design" vs "painted on"

[5,8]

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/

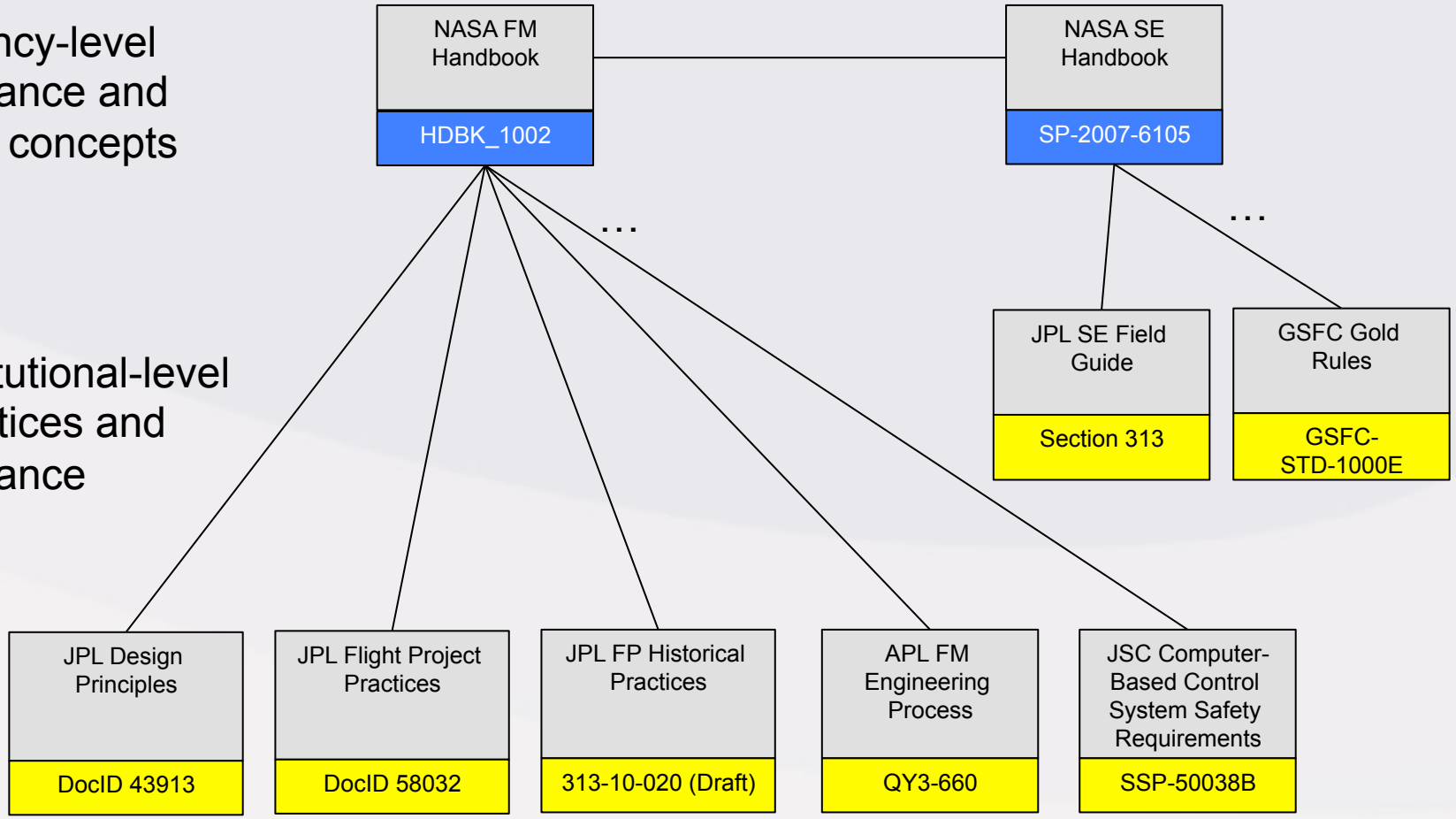
FM Handbook Scope

- **Co-funded by Science Mission Directorate (Lindley Johnson, Discovery/New Frontiers Program Exec) and NASA Engineering & Safety Center (Neil Dennehy, GN&C Technical Fellow)**
- **The envisioned users of the Handbook include:**
  - FM Practitioners
  - FM Trainees
  - Systems and Subsystems Engineers
  - Mission Assurance/Reliability Leads
  - Top Level Management and Program managers
  - Proposal Evaluators
- **Outline is 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**

NASA Handbooks vs Institutional Guidelines

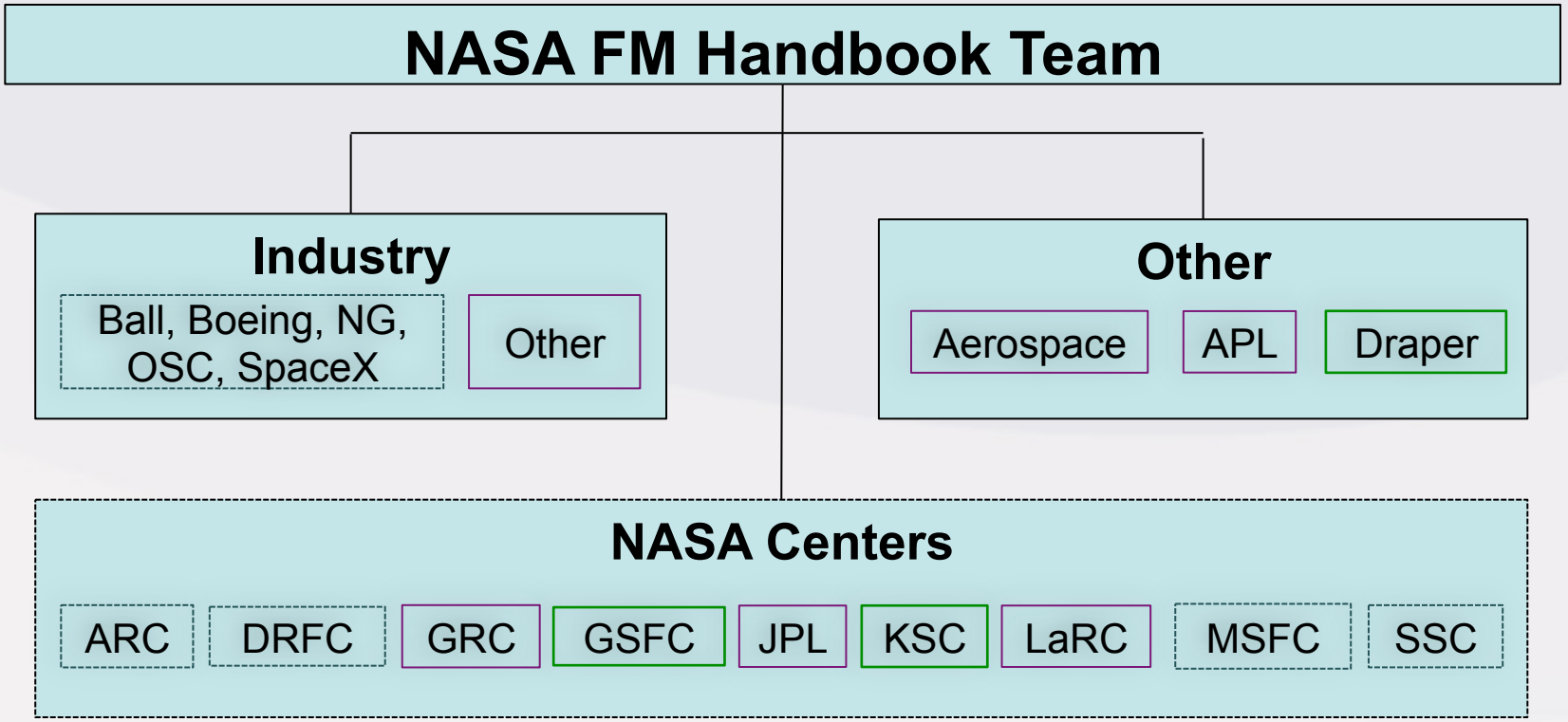
Agency-level guidance and core concepts

Institutional-level practices and guidance



FM Handbook Participants

Goal: To capture expertise across NASA and industry that would respond to needs identified in the FM Workshop Findings/Recommendations, for the benefit future missions

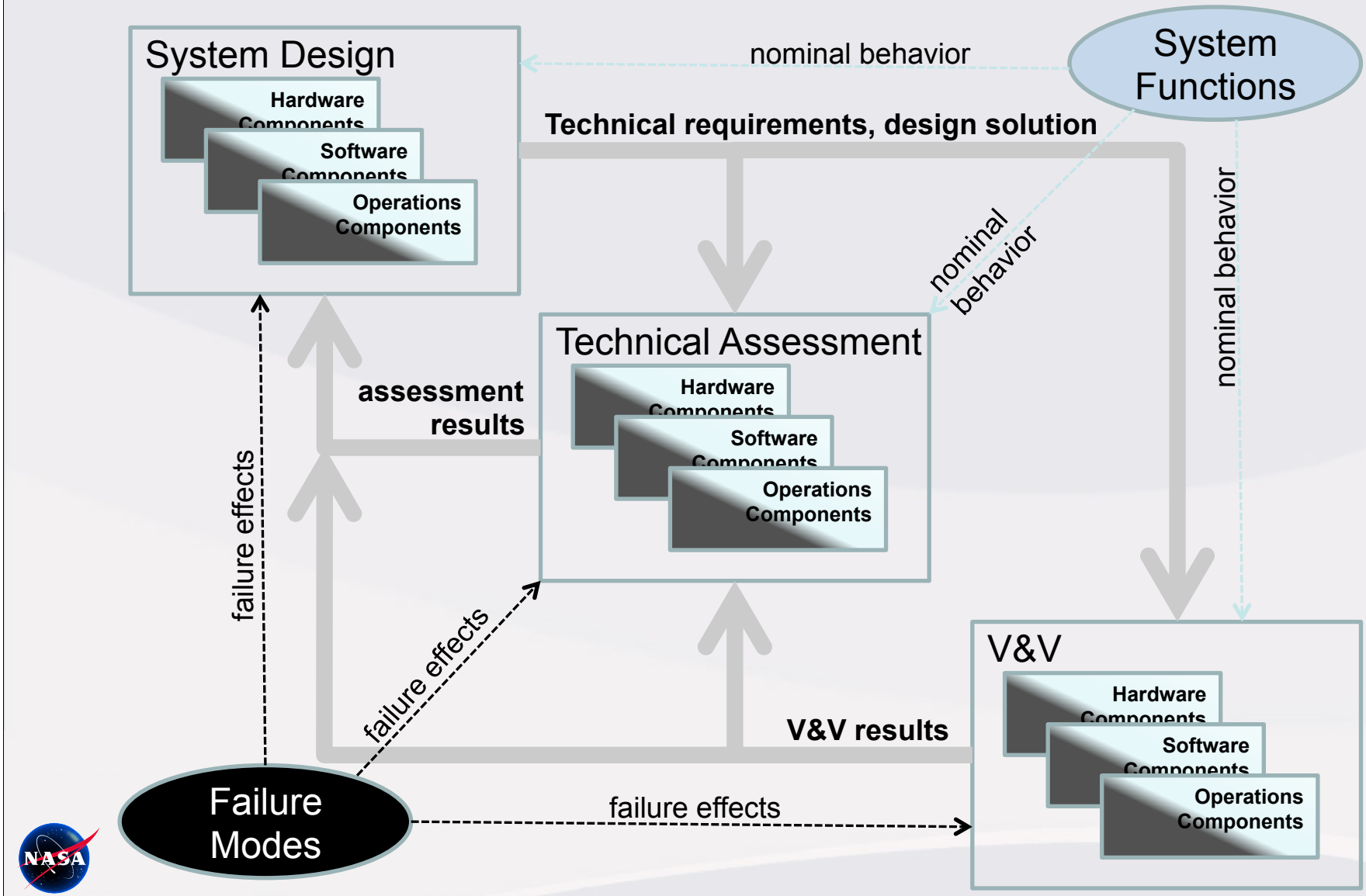


FM Handbook Outline

Section	%*	Summary	Accomplishments/Challenges
Foreward	100	What does this Handbook provide? Why does NASA need a FM Handbook?	Fairly stable. Still debating whether FM includes Prognosis, and if FM = ISHM (or VSHM).
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	Team did not completely concur on definitions and concepts. Also, need to coordinate with OSMA (NASA-STD 8709.22) & Aerospace/DoD

* 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 Domain


System Design
Hardware Components
Software Components
Operations Components
nominal behavior
System Functions
Technical requirements, design solution
nominal behavior
nominal behavior
Technical Assessment
Hardware Components
Software Components
Operations Components
assessment results
failure effects
failure effects
V&V
Hardware Components
Software Components
Operations Components
V&V results
Failure Modes
failure effects

FM Handbook Outline – cont.

Section	%*	Summary	Accomplishments/Challenges
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	Made some progress, but it was challenging to agree on terminology and guiding principles. This Section tended to generate lengthy academic/ philosophical discussions. Still no unanimous agreement, and we expect more divergence before convergence, once we bring on additional practitioners and hear their definitions/ viewpoints. But we now have a basic FM framework that we can use across NASA and with industry partners.
5. Organization, Roles, and Responsibilities	75	Project organizational structure to support FM; interfaces; tasks	Fairly stable. Need to address different Mission classes (A, B, C, D).
6. Process	90	Follows SE Process but focuses on FM products – Concept design, requirements, architecture, analysis, V&V, Ops and Maintenance	Came together nicely, once we adopted NASA SE Process as foundation. Agreement at a high level; further discussions still required to mature details.

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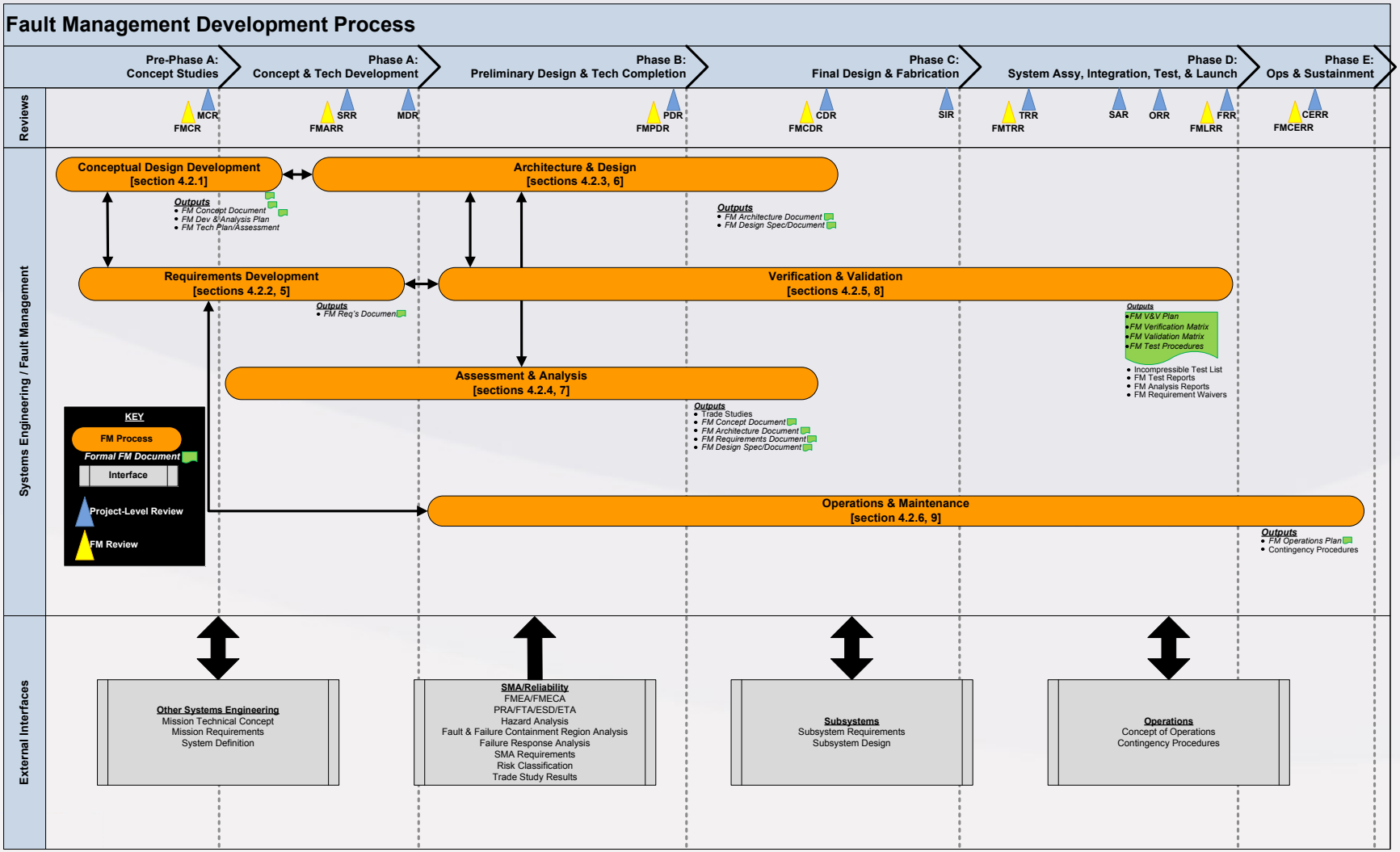
FM Process as Part of SE Process



FM Handbook Outline – cont.

Section	%*	Summary	Accomplishments & Challenges
7. Requirements Development	90	FM requirements categories; driving requirements; flow-down	Nice baseline identifying how to write FM requirements, with many examples and lessons learned provided. Currently deep-space-centric.
8. Design and Architecture	60	Impacts of mission risk posture, goals, characteristics and FM priorities; FM architectures, design features and approaches; mission-specific considerations	Hardest Section to write. It experienced many painful re-orgs/re-writes, so final version did not receive as much review as the other Sections. All practitioners know how to design, and agreed that it must be architected from the beginning since it permeates all levels of design; but no one approach is appropriate for all missions. Final incarnation in Version 1 expresses our realization that design is driven by mission requirements, and we then identified basic building blocks and guidance on how/when to use them. Open issues include establishing balance between distributed vs centralized, and between sub-system/low-level vs system-level. Trade space of mission characteristics and system design characteristics.

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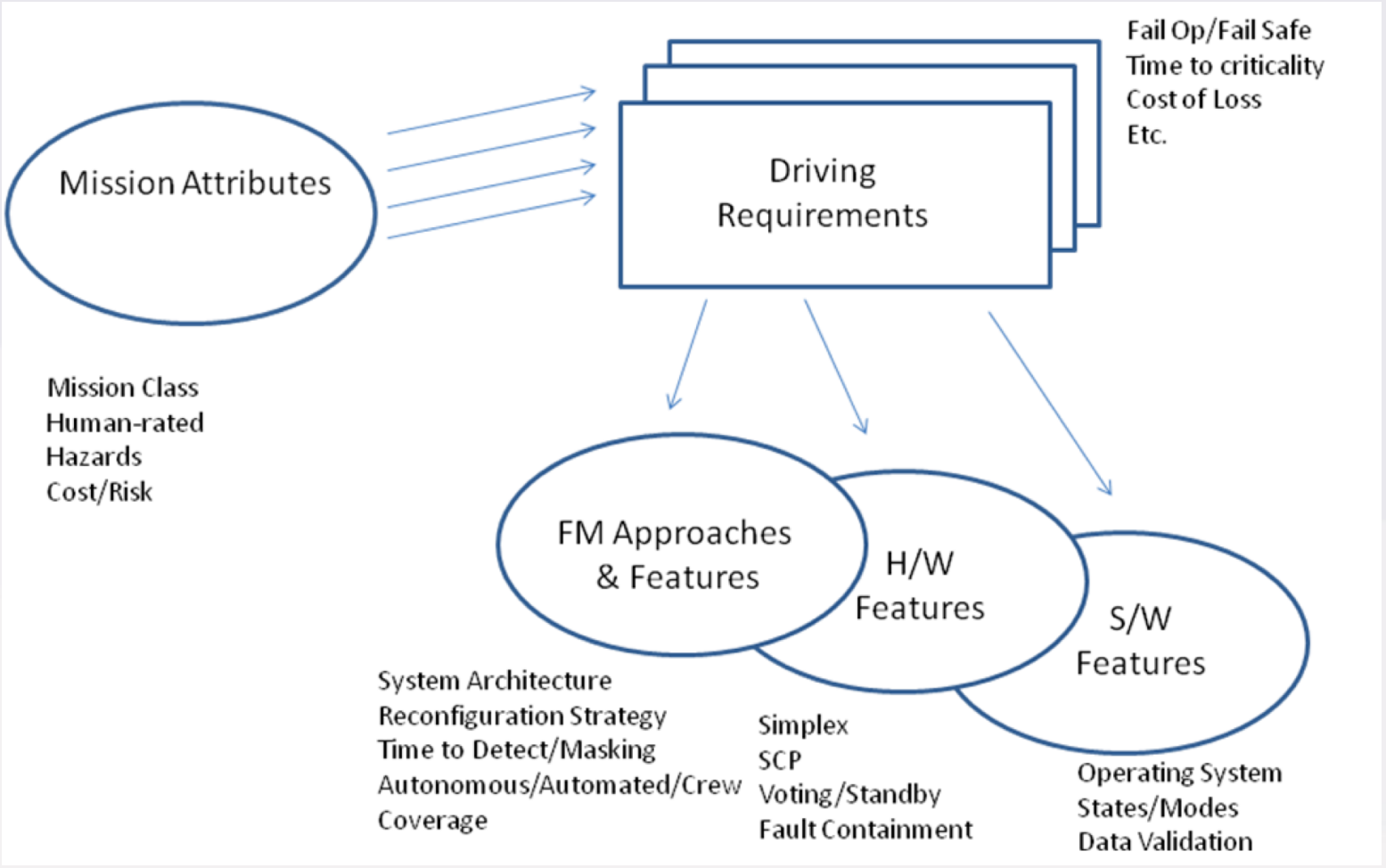
Mission Requirements Drive FM Design



FM Handbook Outline – cont.

Section	%*	Summary	Accomplishments/Challenges
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	Fairly stable -- did not generate much controversy. Needs to address more Workshop Recommendations, like Design for Testability. Consider including Formal Methods.
11. Operations and Maintenance	0	To be expanded in later releases	

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FM Handbook Outline – cont.

Section	%*	Summary	Accomplishments/Challenges
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	Can be used stand-alone by any Review Team, for reviewing FM material at major milestone reviews and during FM-focused reviews. Need to scrub entrance/success criteria to make more FM-specific. Provide underlying mishap or motivation that led to questions.
13. Conclusion	0	To be expanded in future releases	
14. Future Directions	0	Where this field is headed – new technology being developed that would offer technical solutions	Still debating if this Section should be included.

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FM Handbook Outline – cont.

Section	%*	Summary	Accomplishments/Challenges
Appendix A	100	References	
Appendix B	0	Work Product Templates (TBS)	
Appendix C	95	Relevant NASA Lessons Learned	GSFC Gold Rules contain a number of FM-related rules. If these are based on Lessons Learned, capture them here. Suggest mining the Aerospace LL database.
Appendix D	100	Acknowledgements, historical background	

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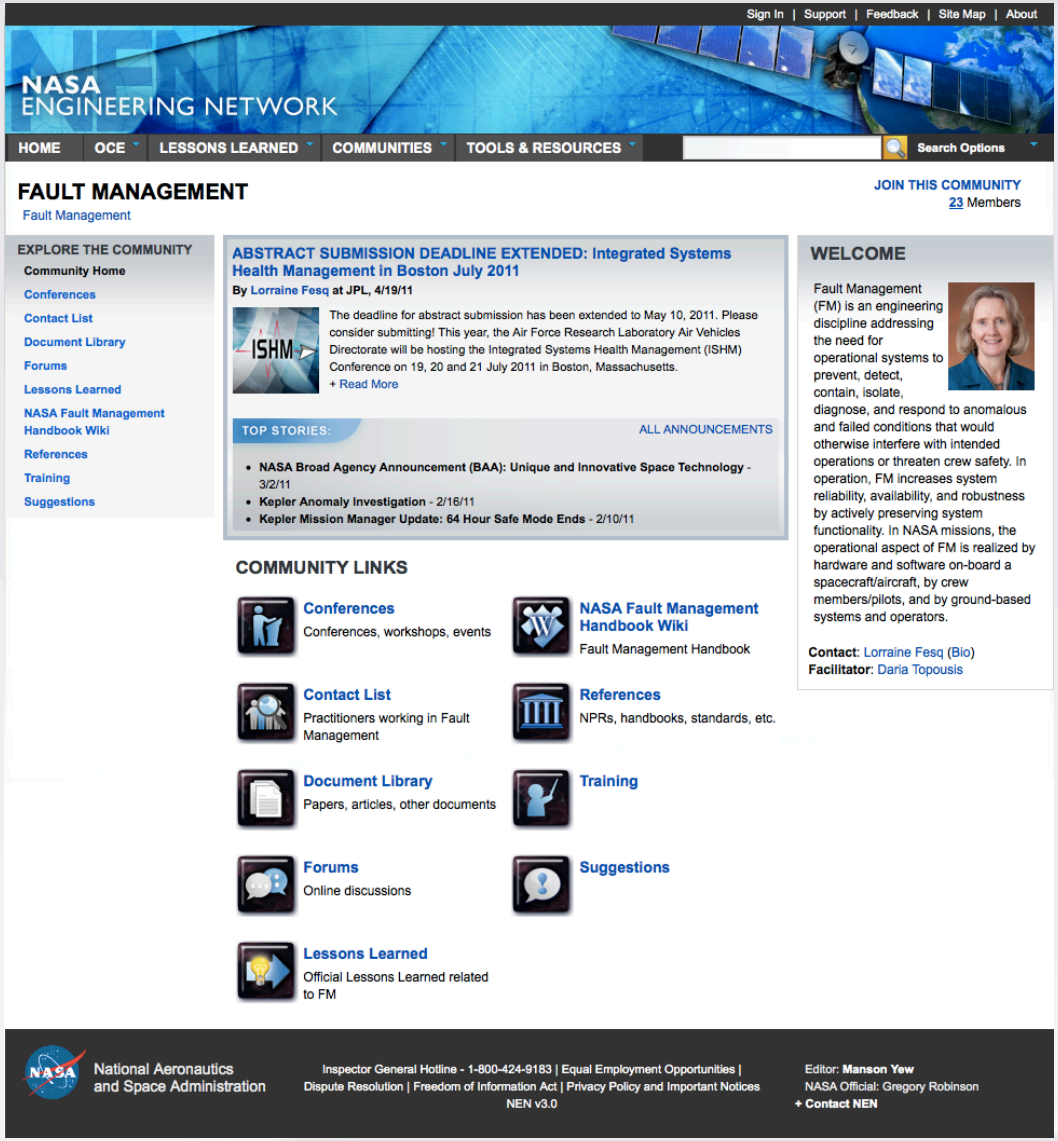
Longer Term Vision

1. **Develop agency-wide FM Handbook -- Version 2**
   - Engage Human Spaceflight Programs, Mission/Ground Systems, Aeronautics, OSMA.
   - Address more Workshop Recommendations (e.g., representation techniques)
2. **Hold another FM Workshop** to focus on Solution Space – **SPRING 2012!**
3. **Establish Agency-wide FM Board/WG/whatever to work through more Recommendations (e.g., FM architecture trade space, metrics)**
4. **Integrate/coordinate FM concepts with other organizations** (e.g., DoD, NRO) and with other documents (e.g., NASA Systems Engineering Handbook, NPRs)
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

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**



Final Thoughts

- **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
- **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.**
- **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 Office of the Chief Technologist: FM identified in 7 of NASA's 14 Space Technology Roadmaps – opportunity to coalesce and establish thrust area to progressively develop new FM techniques

Planning a 2nd NASA FM Workshop in Spring 2012, in New Orleans, LA. Look for announcements on the FM CoP Website!

Acknowedgements

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