Engineering Technical Review Planning Briefing

The general topics covered in the engineering technical planning briefing are 1) overviews of NASA, Marshall Space Flight Center (MSFC), and Engineering, 2) the NASA Systems Engineering (SE) Engine and its implementation, 3) the NASA Project Life Cycle, 4) MSFC Technical Management Branch Services in relation to the SE Engine and the Project Life Cycle, 5) Technical Reviews, 6) NASA Human Factor Design Guidance, and 7) the MSFC Human Factors Team. The engineering technical review portion of the presentation is the primary focus of the overall presentation and will address the definition of a design review, execution guidance, the essential stages of a technical review, and the overall review planning life cycle. Examples of a technical review plan content, review approaches, review schedules, and the review process will be provided and discussed. The human factors portion of the presentation will focus on the NASA guidance for human factors. Human factors definition, categories, design guidance, and human factor specialist roles will be addressed. In addition, the NASA Systems Engineering Engine description, definition, and application will be reviewed as background leading into the NASA Project Life Cycle Overview and technical review planning discussion.
Marshall Space Flight Center (MSFC)
Engineering Technical Review Planning Briefing
Presenter: Terrie Gardner/MSFC

October 22, 2012
Agenda

• NASA Overview
• MSFC Overview
• Engineering Directorate, Spacecraft and Vehicle Systems Department, Systems Engineering and Integration Division Overview
• NASA Systems Engineering Engine
• NASA Project Life Cycle
• Technical Management Branch Overview
• Engineering Planning and Technical Review Team Overview
• Technical Reviews
• Human Factors
• Questions
• Closing
NASA Overview
NASA has a key role in NASA’s mission.
MSFC Overview
A Legacy of Science and Exploration

Marshall continues its legacy of science and exploration.
Marshall Space Flight Center (MSFC)

- Marshall is one of NASA's 10 field centers and works under the direction of headquarters in Washington, D.C.

- The map shows the location and specialty of each center -- each with its own unique role in meeting the agency’s goals.

- Marshall Space Flight Center is providing critical support in space transportation, space operations, and scientific research.

- One of Marshall’s unique roles in the agency is the management of the Michoud Assembly Facility in New Orleans, Louisiana.
  - It’s a major space vehicle manufacturing and assembly facility and among the world’s largest manufacturing sites.
  - Michoud manufactured Saturn components, space shuttle external tanks and is ready to play a role in NASA’s new launch vehicles.
From Exploration to Opportunity

- $2.88 billion (FY2009) impact to Alabama economy
- Nearly 6,000 employees (civil service and contractor, approximate number)
- 3rd largest employer in the Huntsville – Madison County area
- 4.5 million square feet of space occupied in Huntsville
- 2.2 million square feet of manufacturing space at Michoud Assembly Facility

Marshall impacts the community.
Marshall’s Role in Space Exploration

Marshall makes significant contributions to America’s space program.

Living and Working in Space

Understanding Our World and Beyond

Lifting from Earth

Marshall makes significant contributions to America’s space program.
Lifting from Earth – Exploration Program Destinations

Beyond LEO – NASA’s Space Launch System

Mars and Its Moons

Near-Earth Asteroids

Earth’s Moon

Low Earth Orbit (LEO) – Commercial Space Transportation

The need for flexible, evolvable and affordable systems.
Lifting from Earth – The Space Launch System

SLS – America’s Heavy Lift Rocket

• Safe, affordable and sustainable
• Carries the Orion Multi-Purpose Crew Vehicle (MPCV)
• Supports national missions beyond Earth orbit
• Does not preclude back-up for ISS transportation
• Initial lift capacity of 70 metric tons (mt) evolving to 130 mt
• Builds on Saturn, Shuttle and Ares

Marshall’s capabilities and facilities are launching the future of space vehicle development.
Flexible, Modular Configuration for Exploration Missions

- **Lifting from Earth**
  - 70 mt (230 ft.)
  - 130 mt (429 ft.)
  - Orion Multi-Purpose Crew Vehicle
  - Launch Abort System
  - Interstage
  - Solid Rocket Boosters
  - Payload Fairing
  - Upper Stage with J-2X Engine
  - Solid or Liquid Rocket Boosters
  - RS-25 (Space Shuttle Main Engines)

**INITIAL CAPABILITY, 2017–21**

**EVOLVED CAPABILITY, Post-2021**
Engineering Directorate, Spacecraft and Vehicle Systems Department, Systems Engineering and Integration Division
Organization Overview
The Spacecraft and Vehicle Systems Department, Engineering Directorate, plans, performs and directs the technical Design, Analysis, Test, Evaluation, Verification, Integration, and Research & Development of the state of the art Spacecraft and Launch Vehicle Systems.
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Systems Engineering Definitions

• Systems engineering is a methodical, disciplined approach for the design, realization, technical management, operations, and retirement of a system.

• Systems engineering is the art and science of developing an operable system capable of meeting requirements within often opposed constraints.

• Systems engineering is a holistic, integrative discipline, wherein the contributions of structural engineers, electrical engineers, mechanism designers, power engineers, human factors engineers, and many more disciplines are evaluated and balanced, one against another, to produce a coherent whole that is not dominated by the perspective of a single discipline.

Systems Engineering Engine
Figure 3-1 – SE Engine

NID 7123.69, NASA Systems Engineering Processes and Requirements
SE Engine Description

- Contains core set of common technical processes and requirements to be used by NASA projects in engineering system products during the product life cycle.

- The 17 common technical processes are enumerated according to their description in the NASA Interim Directive 7123_69, NASA Systems Engineering Processes and Requirements.

- SE common technical processes model illustrates the use of:

  1. The system design processes for —top down design of each product in the system structure
  2. The product realization processes for —bottom up realization of each product in the system structure
  3. The technical management processes for planning, assessing, and controlling the implementation of the system design and product realization processes.
  4. Guide technical decision making (decision analysis)
The SE common technical processes model is referred to as an —SE engine:

- To stress that these common technical processes are used to drive the development of the system products

- To stress that these common technical processes are used to drive the development of associated work products required by management to satisfy the applicable product-line life-cycle phase exit criteria

- While meeting stakeholder expectations within cost, schedule, and risk constraints.
Application of SE Engine Processes within System Functions

Figure 3-2 – Application of SE Engine Processes within System Structure

NID 7123.69, NASA Systems Engineering Processes and Requirements
The common technical processes are used to define the WBS models of the system structure in each applicable phase of the relevant product-line life cycle to generate work products and system products needed to satisfy the exit criteria of the applicable phase. System engineering continues well into the operations and maintenance phase of a project, i.e., after the system products are delivered.
NASA Project Life Cycle

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<td>KDP B</td>
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<td>Flight Project Life</td>
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<td>Other Reviews</td>
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<td>Supporting Reviews</td>
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Re-enters appropriate life-cycle phase if modifications are needed between flights

FOOTNOTES
1. Flexibility is allowed as to the timing, number, and content of reviews as long as the equivalent information is provided at each KDP and the approach is fully documented in the Project Plan.
2. Life-cycle review objectives and expected maturity states for these reviews and the attendant KDPs are contained in Table 2-5.
3. PRR is needed only when there are multiple copies of systems. It does not require an SRB. Timing is notional.
4. CERRs are established at the discretion of program offices.
5. For robotic missions, the SRR and the MDR may be combined.
6. SAR generally applies to human space flight.
7. Timing of the ASM is determined by the MDAA. It may take place at any time during Phase A.

ACRONYMS
- ASM: Acquisition Strategy Meeting
- CDR: Critical Design Review
- CERR: Critical Events Readiness Review
- DR: Decommissioning Review
- DRR: Disposal Readiness Review
- FA: Formulation Agreement
- FAD: Formulation Authorization Document
- FRR: Flight Readiness Review
- KDP: Key Decision Point
- LRR: Launch Readiness Review
- LV: Launch Vehicle
- MCR: Mission Concept Review
- MDR: Mission Definition Review
- MDAA: Mission Design and Analysis Team
- MRR: Mission Readiness Review
- PDR: Preliminary Design Review
- PRR: Production Readiness Review
- SAR: System Acceptance Review
- SMSR: Safety and Mission Success Review
- SRB: Standing Review Board
- SRR: System Readiness Review

Red triangles represent life-cycle reviews that require SRBs. The Decision Authority, Administrator, MDAA, or Center Director may request the SRB to conduct other reviews.

NPR 7120.5E, NASA Space Flight Program and Project Management Requirements
Technical Management Branch Organization

Technical Management Branch

- Risk Team
- Engineering Planning and Review Team
- Cross Cutting Team
• The Technical Management Branch provides systems design with the following products and services:

• Multidiscipline leadership

• Technical Guidance

• Technical Planning
  • Production and maintenance of technical plans such as the SEMP and Development Plans for the program/projects
  • Management of communication across interfaces
  • Technical Plan Implementation Assessments

• Milestone Technical Review Planning

• Decision Process Support

• Risk Management

• Technical Performance Metrics
Engineering Planning and Review Team Services

• Expertise
  o Technical and Review Plan Development and Maintenance
  o Drafting, negotiating, and baselining of technical plans such as a program or project’s Systems Engineering Management Plan (SEMP)
  o Mission Concept Review (MCR) Plan
  o Other Review plans (i.e., SRR, SDR, PDR, CDR, DCR, etc.).

• Implementation of Plans
  o Review Plan direction, implementation, and coordination
  o Technical Plan Implementation Assessment

• Administrative
  o RID Tool Support
  o Review and RID Tool Training
  o RID Tool Account maintenance during program reviews
  o Track and monitor RID review process to assure closure of open RIDs
Technical Reviews
A technical review is an evaluation of the project, or element thereof, by a knowledgeable group for the purposes of:

a. Assessing the status of and progress toward accomplishing the planned activities.

b. Validating the technical tradeoffs explored and design solutions proposed.

c. Identifying technical weaknesses or marginal design and potential problems (risks) and recommending improvements and corrective actions.

d. Making judgments on the activities’ readiness for the follow-on events, including additional future evaluation milestones to improve the likelihood of a successful outcome.

e. Making assessments and recommendations to the project team, Center, and Agency management.

f. Providing a historical record that can be referenced of decisions that were made during these formal reviews.

g. Assessing the technical risk status and current risk profile.

Reference: NID 7123.69, NASA Systems Engineering Processes and Requirements
Technical Review Execution Guidance

• The technical team shall execute the required technical review in accordance with the review entry and success criteria guidance in governing documentation.

• Reviews are considered complete when the following are accomplished:
  a. Agreement exists for the disposition of all Review Item Discrepancies (RIDs) and Request for Actions (RFA).
  b. The review board report and minutes are complete and distributed.
  c. Agreement exists on a plan to address the issues and concerns in the review board’s report.
  d. Agreement exists on a plan for addressing the actions identified out of the review.
  e. Liens against the review results are closed, or an adequate and timely plan exists for their closure.
  f. Differences of opinion between the project under review and the review board(s) have been resolved, or a timely plan exists to resolve the issues.
  g. A report is given by the review board chairperson to the appropriate management and governing program management committees (PMCs) charged with oversight of the project.
  h. Appropriate procedures and controls are instituted to ensure that all actions from reviews are followed and verified through implementation to closure.

Reference: NID 7123.69, NASA Systems Engineering Processes and Requirements
Table G-7 – PDR Entrance and Success Criteria

<table>
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<tr>
<th>Entrance Criteria</th>
<th>Preliminary Design Review</th>
<th>Success Criteria</th>
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<tbody>
<tr>
<td>1. Successful completion of the SDR or MDR and responses made to all SDR or MDR RFAs and RIDs, or a timely closure plan exists for those remaining open.</td>
<td>1. The top-level requirements—including mission success criteria, TPMs, and any sponsor-imposed constraints—are agreed upon, finalized, stated clearly, and consistent with the preliminary design.</td>
<td>2. The flowdown of verifiable requirements is complete and proper or, if not, an adequate plan exists for timely resolution of open items. Requirements are traceable to mission goals and objectives.</td>
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<tr>
<td>2. A preliminary PDR agenda, success criteria, and charge to the board have been agreed to by the technical team, project manager, and review chair prior to the PDR.</td>
<td>3. The preliminary design is expected to meet the requirements at an acceptable level of risk.</td>
<td>3. The preliminary design is expected to meet the requirements at an acceptable level of risk.</td>
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<td>3. PDR technical products listed below for both hardware and software system elements have been made available to the cognizant participants prior to the review:</td>
<td>4. Definition of the technical interfaces is consistent with the overall technical maturity and provides an acceptable level of risk.</td>
<td>4. Definition of the technical interfaces is consistent with the overall technical maturity and provides an acceptable level of risk.</td>
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<td>a. Updated baseline documentation, as required.</td>
<td>5. Adequate technical interfaces are consistent with the overall technical maturity and provide an acceptable level of risk.</td>
<td>5. Adequate technical interfaces are consistent with the overall technical maturity and provide an acceptable level of risk.</td>
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<td>b. Preliminary subsystem design specifications for each configuration item (hardware and software), with supporting trade-off analyses and data, as required.</td>
<td>6. Adequate technical margins exist with respect to TPMs.</td>
<td>6. Adequate technical margins exist with respect to TPMs.</td>
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<td>c. Updated technology development maturity assessment plan.</td>
<td>7. Any required new technology has been developed to an adequate state of readiness, or back-up options exist and are supported to make them a viable alternative.</td>
<td>7. Any required new technology has been developed to an adequate state of readiness, or back-up options exist and are supported to make them a viable alternative.</td>
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<td>d. Updated risk assessment and mitigation.</td>
<td>8. The project risks are understood and have been credibly assessed, and plans, a process, and resources exist to effectively manage them.</td>
<td>8. The project risks are understood and have been credibly assessed, and plans, a process, and resources exist to effectively manage them.</td>
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<tr>
<td>e. Updated cost and schedule data.</td>
<td>9. Safety and mission assurance (e.g., safety, reliability, maintainability, quality, and EEE parts) have been adequately addressed in preliminary designs and any applicable S&amp;MA products (e.g., PRA, system safety analysis, and failure modes and effects analysis) have been approved.</td>
<td>9. Safety and mission assurance (e.g., safety, reliability, maintainability, quality, and EEE parts) have been adequately addressed in preliminary designs and any applicable S&amp;MA products (e.g., PRA, system safety analysis, and failure modes and effects analysis) have been approved.</td>
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<td>f. Updated logistics documentation, as required.</td>
<td>10. The operational concept is technically sound, includes (where appropriate) human factors, and includes the flowdown of requirements for its execution.</td>
<td>10. The operational concept is technically sound, includes (where appropriate) human factors, and includes the flowdown of requirements for its execution.</td>
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<tr>
<td>g. Applicable technical plans (e.g., technical performance measurement plan, contamination control plan, parts management plan, environments control plan, EMI/EMC control plan, payload-to-carryover integration plan, producibility/manufacturability program plan, reliability program plan, quality assurance plan).</td>
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<td>h. Applicable standards.</td>
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<td>i. Safety analyses and plans.</td>
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<td>j. Engineering drawing tree.</td>
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<td>k. Interface control documents.</td>
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<td>l. Verification/validation plan.</td>
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<td>m. Plans to respond to regulatory requirements (e.g., Environmental Impact Statement), as required.</td>
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<td>n. Disposal plan.</td>
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<tr>
<td>o. Technical resource utilization estimates and margins.</td>
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<td>q. Preliminary limited life items list (LLIL).</td>
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Technical Review Stages

• Review Planning

• Checkpoint

• Review Logistics and Preparation (Includes Training)

• Kickoff

• Review Execution

• Reporting to Management

• Review Item Discrepancy (RID) Burndown/RID Dispositioning Process

• Review Complete
Review Planning Life Cycle
Example Table of Contents for a Technical Review

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Example Review Approach

• Review is focused on the adequacy of the technical approach focused on the program and vehicle integration

• MPR 7123.2A milestone success criteria and safety criteria are used to guide the assessment

• Review teams addressed program and vehicle integration of the system requirements, design definition and safety by assessing each of the success criteria from their perspective

• RIDs written against not meeting criteria – not against documents
Example Team Approach

• **Discipline Review Teams**
  - Organized by functional teams
  - Review teams to represent the implementation of the program, technical and safety organizations
  - Review Team Leads and team members are independent of the program or project being reviewed
  - Review teams served as dispositioning team for RIDs originating or assigned to their team

• **Screening Committee**
  - Led by Lead System Engineer
  - Membership included the review team leads

• **Pre-Board**
  - Chaired by the Chief Engineer
  - Membership defined in Program/Project Review Plan or in a memorandum

• **Board**
  - Chaired by the Program Manager
  - Membership defined in Program/Project Review Plan or in a memorandum
## Example Review Schedule

<table>
<thead>
<tr>
<th>Description</th>
<th>Start</th>
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<tr>
<td>Data Package Delivered</td>
<td>2/1/2012</td>
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<td>Pre-declared RID Cutoff</td>
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<tr>
<td>Data Package Available</td>
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<tr>
<td>Kickoff Meeting</td>
<td>2/15/2012</td>
<td>2/16/2012</td>
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<td>Tabletop Meetings (discuss Pre-RIDs)</td>
<td>2/27/2012</td>
<td>3/6/2012</td>
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<tr>
<td>RID Integrated Screening</td>
<td>2/29/2012</td>
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<td>3/27/2012</td>
</tr>
<tr>
<td>Board</td>
<td>3/29/2012</td>
<td>3/29/2012</td>
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Example Review Process

1. KICK-OFF
2. DATA PACKAGE REVIEW
3. REVIEW TEAM MEETINGS
4. CRITERIA TABLE TOP MEETINGS
5. RID IMPACT ASSESSMENT MEETINGS
6. SCREENING MEETINGS
7. RID CLOSURE
8. BOARD
9. RID DISPOSITION MEETINGS
Human Factors
Human factors engineering is the discipline that studies the human-system interfaces and provides requirements, standards, and guidelines to ensure the human component of the integrated system is able to function as intended.
Four Categories of Human Factors

• The first is anthropometry and biomechanics—the physical size, shape, and strength of the humans.

• The second is sensation and perception—primarily vision and hearing, but senses such as touch are also important.

• The environment is a third factor—ambient noise and lighting, vibration, temperature and humidity, atmospheric composition, and contaminants.

• Psychological factors comprise memory; information processing component such as pattern recognition, decisionmaking, and signal detection; and affective factors—e.g., emotions, cultural patterns.

Reference: NASA/SP-2007-6105
Human Factors Engineering in the System Design Process

• Stakeholder Expectations

• Requirements Definition

  - NASA-STD-3001, NASA SPACE FLIGHT HUMAN SYSTEM STANDARD VOLUME 1: CREW HEALTH


  - NASA/SP-2010-3407, HUMAN INTEGRATION DESIGN HANDBOOK (HIDH)

• Technical Solution

• Usability Evaluations of Design Concepts

• Verification

Reference: NASA/SP-2007-6105
What does a Human Factors Specialist do at NASA?

The human factors specialist supports the systems engineering process by representing the users’ and maintainers’ requirements and capabilities throughout the design, production, and operations stages.

Reference: NASA/SP-2007-6105
Human Factor Specialist Roles

- Identify applicable requirements based on Agency standards for human-system integration during the requirements definition phase.

- Support development of mission concepts by providing information on human performance capabilities and limitations.

- Support task analysis and function allocation with information on human capabilities and limitations.

- Identify system design features that enhance usability. This integrates knowledge of human performance capabilities and design features.

- Support trade studies by providing data on effects of alternative designs on time to complete tasks, workload, and error rates.

- Support trade studies by providing data on effects of alternative designs on skills and training required to operate the system.

- Support design reviews to ensure compliance with human-systems integration requirements.

- Conduct evaluations using mockups and prototypes to provide detailed data on user performance.

- Support development of training and maintenance procedures in conjunction with hardware designers and mission planners.

- Collect data on human-system integration issues during operations to inform future designs.

Reference: NASA/SP-2007-6105
MSFC Human Factors Team

• This team is the discipline center of expertise at Marshall.

• The team's specialties are worksite design, usability, and human modeling.

• The team has mockup development and use expertise, as well as CAD-based simulation.

• We create human:systems interaction requirements, identify verification methods, and complete verification.
• MSFC HFE deals with a broad range of human interface design considerations

• Worksite design
  • Work, reach, & visual envelopes
  • Lighting
  • Tools & support equipment
• Human:Computer Interaction
  • Displays design
  • Usability testing
• Human:Robotic Interaction
• Effects of special space environments
  • Vibration (during launch)
  • Weightlessness
    • Ability to perform work tasks
• Habitability; not strictly HFE, but is system-level HF
• Tools

• Mockups
  • Wood, foamcore, plastic, metal
  • Fidelity appropriate to information needed
    • Typically, higher as design matures

• Human modeling

• Motion capture

• Neutral buoyancy
• **History**

• **Skylab (first American Station) Crew systems**
  - Life support
  - Crew quarters
  - Deconditioning mitigation
  - Displays and controls
  - Maintenance
  - Procedures & training
  - Skylab design:
    - Tektite underwater lab for habitability studies

• **Shuttle**
  - Payloads (science)
    - Procedures & training
    - Displays & controls
    - Maintenance
  - Hubble EVA
    - Maintenance
Recent

- International Space Station
  - Module design for crew use: similar to Skylab design work
  - Physical design for experiments (payloads) and subsystems, such as life support
    - For operation and maintenance
  - EVA design
- Constellation (moon program)
  - Worksite design for ground crews assembling Ares rocket
  - Vibration effects on astronaut task performance
- Deep-space habitability studies
- Single-person spacecraft studies
Questions
Closing Remarks