What is the Final Verification of Engineering Requirements?

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"Systems Engineering" Session
Project Management Challenge 2010

Presentation Outline

- Requirements Development
  - Definition
  - Documentation
  - Maintenance
- Implementation
- Requirements Verification
  - Methods
  - Verification Plan
  - Process
- Final Verification Approach

Requirements Definition

- Derived from higher level requirements (example shown next page)
  - Program requirements drive mission requirements
  - Mission requirements drive engineering solutions
  - Engineering solutions drive system requirements
- Requirements should be driven by basic needs
  - Wants or 'desirements' should be treated differently than requirements
  - Requirements should not specify engineering solutions
- Reviewed by both 'supplier' and 'customer'
  - Entity with the need is 'customer'
  - Entity that fulfills the need is 'supplier'
  - Both equally responsible for defining requirements
  - Iterative Process
  - Modifications may drive contractual changes

Requirements Derivation

- Program Goals
  - Science Objectives
    - Mission Requirements
      - Instrument & System Requirements
        - Subsystem & Component Requirements
          - Drawings & Procedures

Requirements Documentation

- Requirements must have formal documentation, such as an Interface Control Document (ICD)
  - For higher level systems, can take years to develop
  - Approved by 'Supplier' and 'Customer'

- Only top level requirements are captured
  - Implementation and derived requirements are tracked internally by the supplier
  - Relevant, but not required, data should be kept out of the control document.

- The control documentation has contractual implications
  - Failure to meet the requirements is a breach of contract
  - Expansion of the requirements is a change in scope

Requirements Maintenance

- Need to agree upon a formal requirement change/deviation/ variance/waiver process
  - Changes to track new direction or to fill in TBDs
  - Waivers, with rationale, to accept deviation from a stated requirement
  - All parties who signed the original document must also review and sign changes/waivers

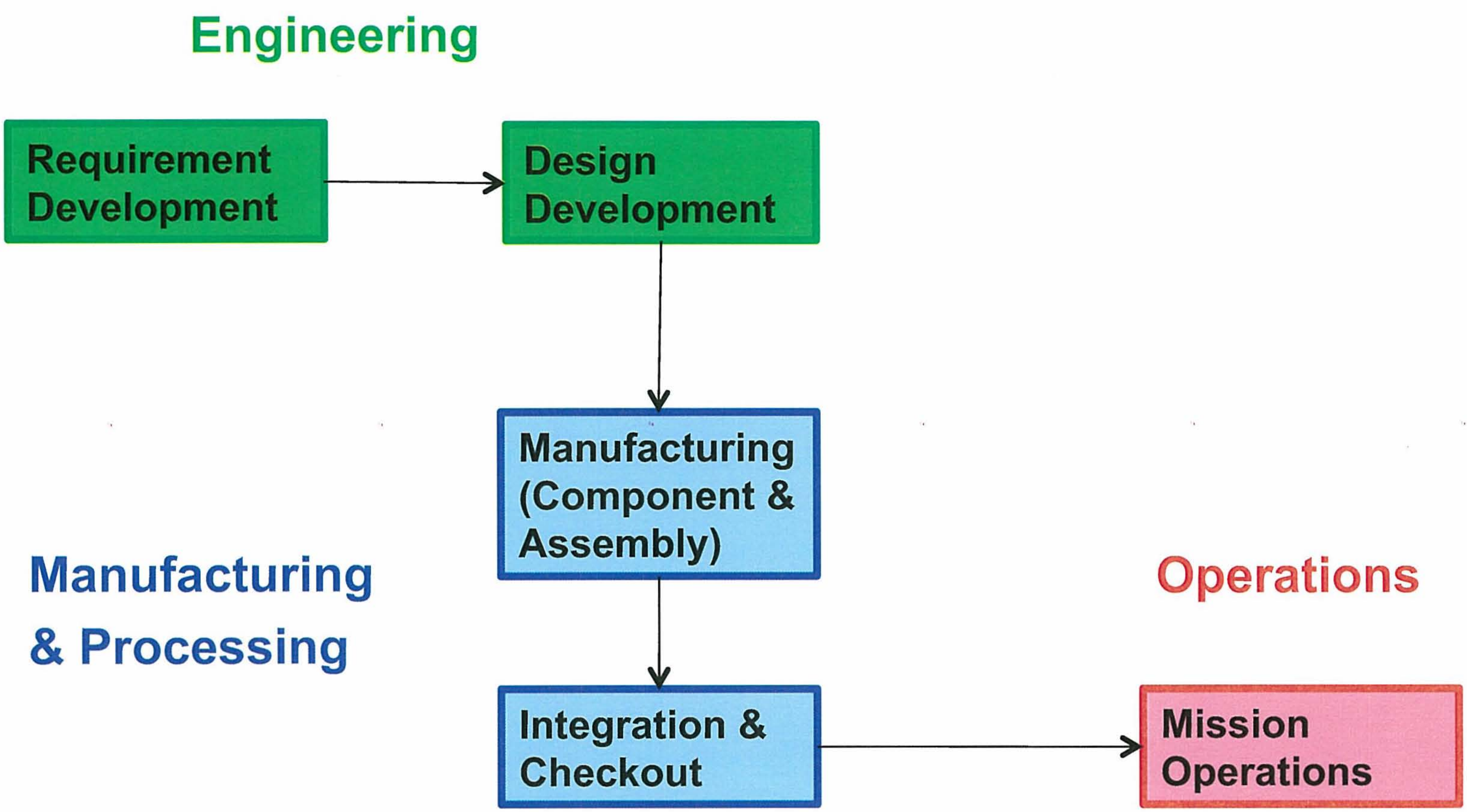
- Contractual and technical issues must have separate decision path
  - Implementation of new requirements may need additional funding
  - If funding is not approved for a new requirement, engineering team should have an avenue to elevate the technical risk incurred

We have requirements, now what?

- Engineering team leads development of the implementation solution
  - Starting from requirements, team designs the system
  - Draws from experience, history of successful systems
  - Seeks input from manufacturing and operations

- Final design is disseminated to other organizations
  - Drawings sent to manufacturing for production of operational units (flight hardware, GSE)
  - Procedures sent to operations for processing

Requirements-to-Operations Flow



Verification

- Final operational system must satisfy original requirements
  - Systematic verification offers good protection against failure
  - Verification of system performance reduces unexpected system behavior
  - A formal process is required to document the methods used

- Many verifications can be performed along the way to reduce schedule risk
  - Waiting until the system is operational to verify requirements is too late
  - Performing incremental verification reduces risk of performing the next step in the process

Verification Strategy

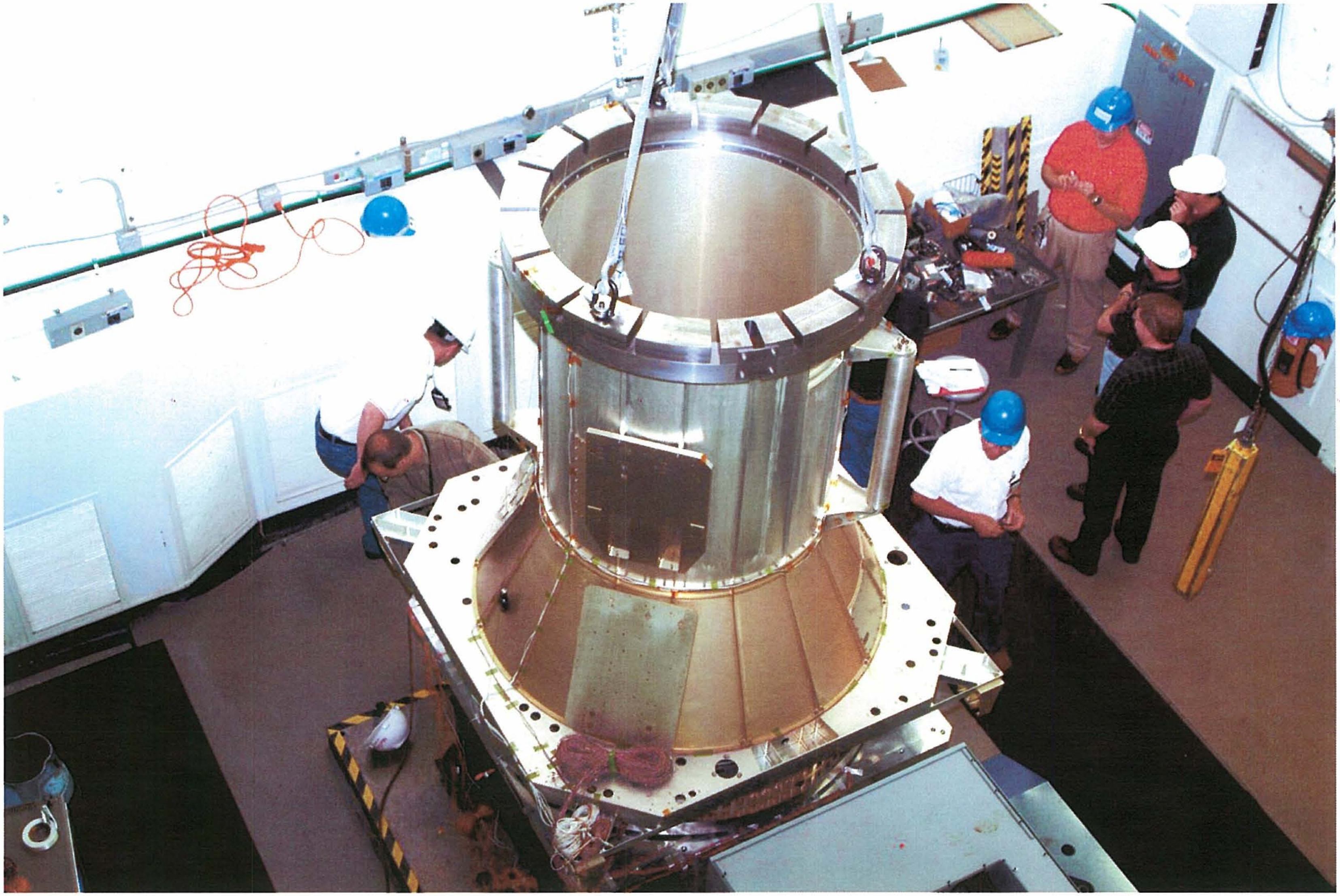
- Program Review
- Data Review
- Integrated Systems Tests
- System Level Testing
- Subsystem & Component Bench Testing
- Drawing & Procedure Reviews

Verification Methods

- Test
  - Qualification testing – verification of the design through testing to extremes of use environment
  - Acceptance testing – verification that a unit has been built per the design
  - Lot Acceptance Test – testing of a sampling of units to verify the entire lot is acceptable (ordnance)

- Inspection
  - Review of documentation (drawings, procedures) to verify that requirements have been properly disseminated, or "flowed down"
  - Review of hardware to verify implementation is correct
    - Connectors
    - Tubing
    - Etc.

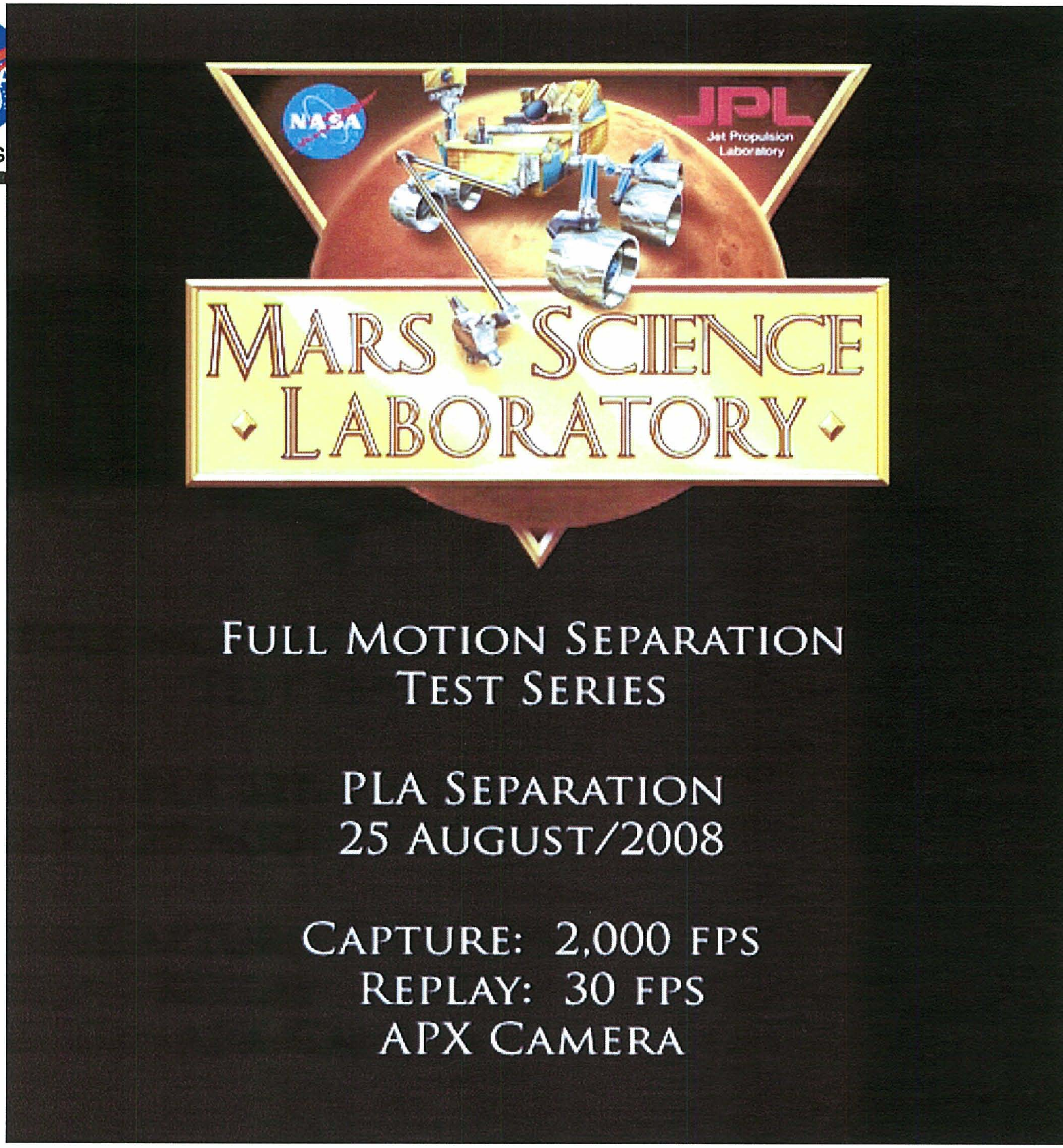
Spacecraft Bus Vibration Testing



Verification Methods (continued)

- Analysis
  - Calculation of predicted performance based on worst case scenario
  - Not a preferred method, but necessary in some cases (e.g. rocket flight trajectory)

- Demonstration
  - Operation of an item to show that the item is capable of fulfilling its intended purpose
  - Can be used to verify hardware, software or procedures


NASA
JPL
Jet Propulsion Laboratory
MARS SCIENCE LABORATORY
FULL MOTION SEPARATION
TEST SERIES
PLA SEPARATION
25 AUGUST/2008
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REPLAY: 30 FPS
APX CAMERA

Verification Plan

- Once the requirements are documented, a plan for the specifics of verification is needed
  - Every requirement must be formally verified
  - Methods specified
  - Responsible organization specified.
  - Multiple verifications for one requirement is common
  - Incremental verifications can be documented, but one final verification is sufficient.

- Verification plan is reviewed by all parties
  - One party responsible for maintaining the plan
  - Changes must be reviewed by all and documented

Verification Process

- The responsible party performs the verification
- A summary of the verification performed, along with supporting documentation, is distributed to all parties
- Reviewers clarify any questions
- Final verification documented and closed by each party

Midpoint Review

- In the beginning, there is an engineering team that develops a design solution
  - Team primarily composed of specialized, highly trained (expensive) personnel
  - The end product of this team is a paper (electronic?) design
  - The design gets passed on to other teams who are expert at the tasks of manufacturing and processing
  - The completed system gets passed on to another team, tasked with operating the system

- In the end, we want a system that meets the mission objectives, and was completed on time and within the given budget

Cradle-to-Grave Engineering

vs.

Passing the Baton

Continuous Involvement

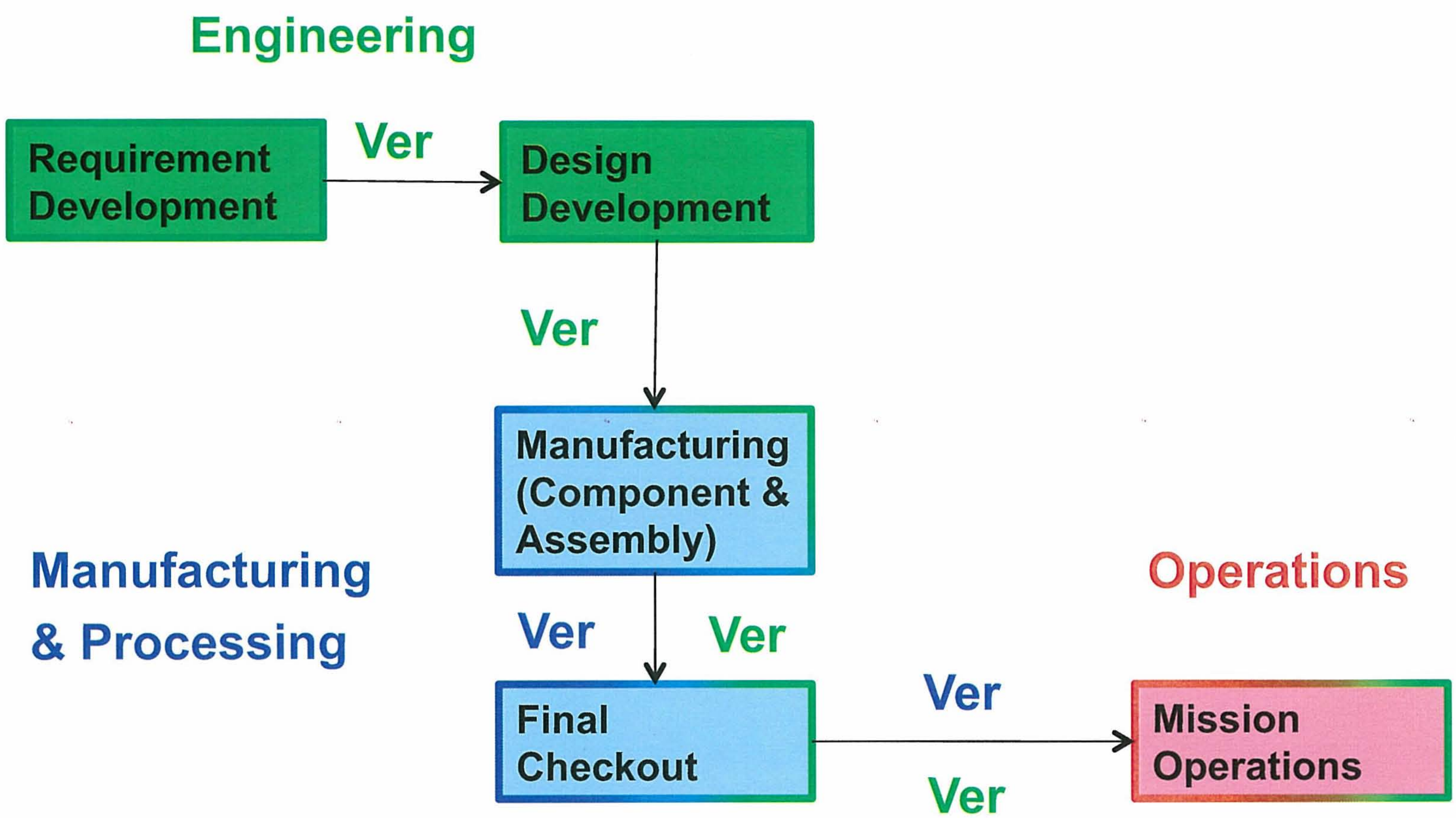
- Engineering team determines requirements, develops design solution

- When manufacturing begins, engineering team continues to follow the process
  - Ensures parts are built as intended
  - Allows engineers to spot unforeseen flaws in the design

- During final processing flow, engineering team follows the operations
  - Ensures system operates as intended
  - Aides trouble shooting if problems arise during check-out

- During mission operations, engineering team on hand to help trouble-shooting

Continuous Involvement Flow



Continuous Involvement Responsibility Table

Event	Verification	Responsibility
Requirement Documentation	Documentation Review	Engineering
Implementation Design	Drawing, Procedure Review	Engineering
Component Manufacture	Receiving Inspection	M&P, Engineering
Systems Integration	As-run procedure	M&P, Engineering
System Test	Test results	M&P, Engineering

Mission Relay

- Engineering team determines requirements, develops design solution

- When manufacturing begins, engineering team hands off to the manufacturing center
  - Parts built per drawing
  - If questions arise, engineering team can be consulted

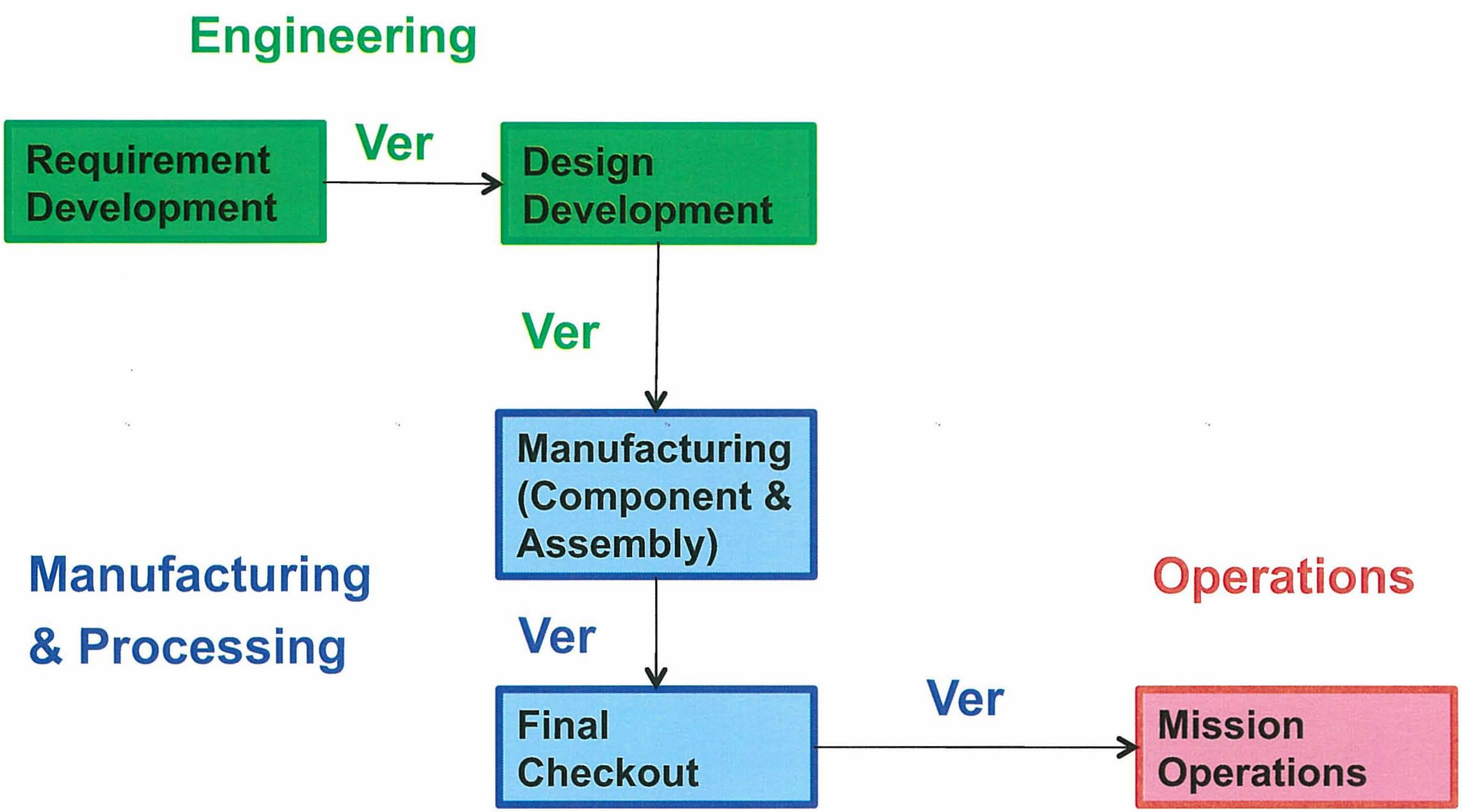
- During final processing flow, manufacturing center hands off to operations team
  - Assembly and check out done per procedure
  - If questions arise, engineering team can be consulted

- During mission operations, any of the above groups can be consulted for trouble shooting

John F. Kennedy Space Center

LAUNCH SERVICES PROGRAM

Mission Relay Flow



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Final Verification

- Final verification of the mission system occurs as an integrated system test, just before deploying the system in to the operations phase
  - There is little disagreement that an integrated, system-level test should be performed
  - Exercising the system significantly reduces implementation risk and often finds errors

- Debate is really over who performs the verification – Should the original development team continue to follow process all the way through to operations?

Closing

- Mission Success is the main objective
  - NASA missions are typically one-of-a-kind, never-been-done-before operations
  - There is plenty of room for error and misunderstanding when passing off designs
  - Personnel continuity through the phases increases the probability of mission success

- High cost is a major obstacle to receiving approval for missions
  - Mission costs are strongly influenced by labor hours
  - Many aspects of space operations have been done before
  - Experienced manufacturing and operations personnel can mitigate risk of misunderstanding

As Always, the Answer is . . .