Mission Assurance and Residual Risk: The Performance Verification Challenge for Technology Infusion

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RISK IS INTENTIONAL INTERACTION WITH UNCERTAINTY [1]

EXPLORATION MISSIONS ARE RISKY

- Exploration is venturing into unknown environment
- Unknown is uncertain

- NASA's Policy on Mission Assurance [3]
  - Accept residual risk
    - Remaining risk that exists after all mitigation actions have been implemented or exhausted in accordance with the risk management process

NEW FRONTIERS ANNOUNCEMENT OF OPPORTUNITY [2]

- No target is specified for mission residual risk
- *Limited number of less mature technologies and/or advanced engineering developments are permitted*
  - *Must contain a plan for maturing systems to TRL 6 … by no later than Preliminary Design Review (PDR)*

- Proposers will likely concentrate on technology risk vs mission residual risk

TECHNOLOGY DEVELOPMENT IS RISKY

- Development means creating new behavior
- New is uncertain

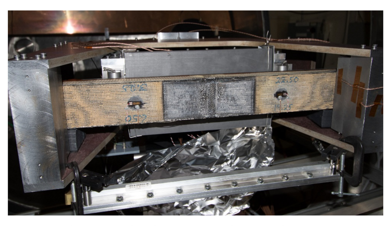
- NASA's Systems Engineering Handbook [4]
  - Technology infusion is
    - Very complex process
    - Ad hoc approaches for different projects have varying degrees of success
    - Failure contributors are related to level of uncertainty at project inception

TRL 6 CAN CORRESPOND TO A WIDE RANGE OF MISSION RISK

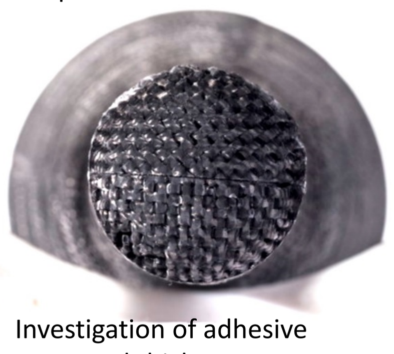
QUALITY OF DEMONSTRATION AND ENVIRONMENT

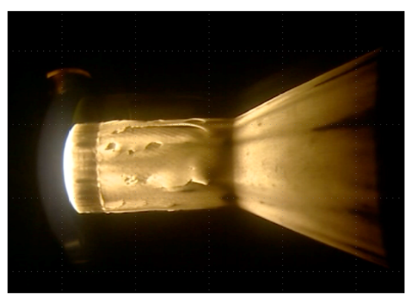
- Nominal vs bounding loads
- Confirming success vs exploring failure
- Individual loads vs combined loading
- Scale of test article
- Gap between demonstration environment and operational environment
  - Thermal Protection System cannot test in fully relevant environment
- Single demonstration vs statistically relevant data set
- Pass/fail vs model correlation
- Attack Unknown and Under-Appreciated Risk [5]
  - Likely a factor of 2-5 higher than estimated risk at start of system operation
  - Affected by
    - Pace of development
    - Prioritization of safety vs cost and schedule

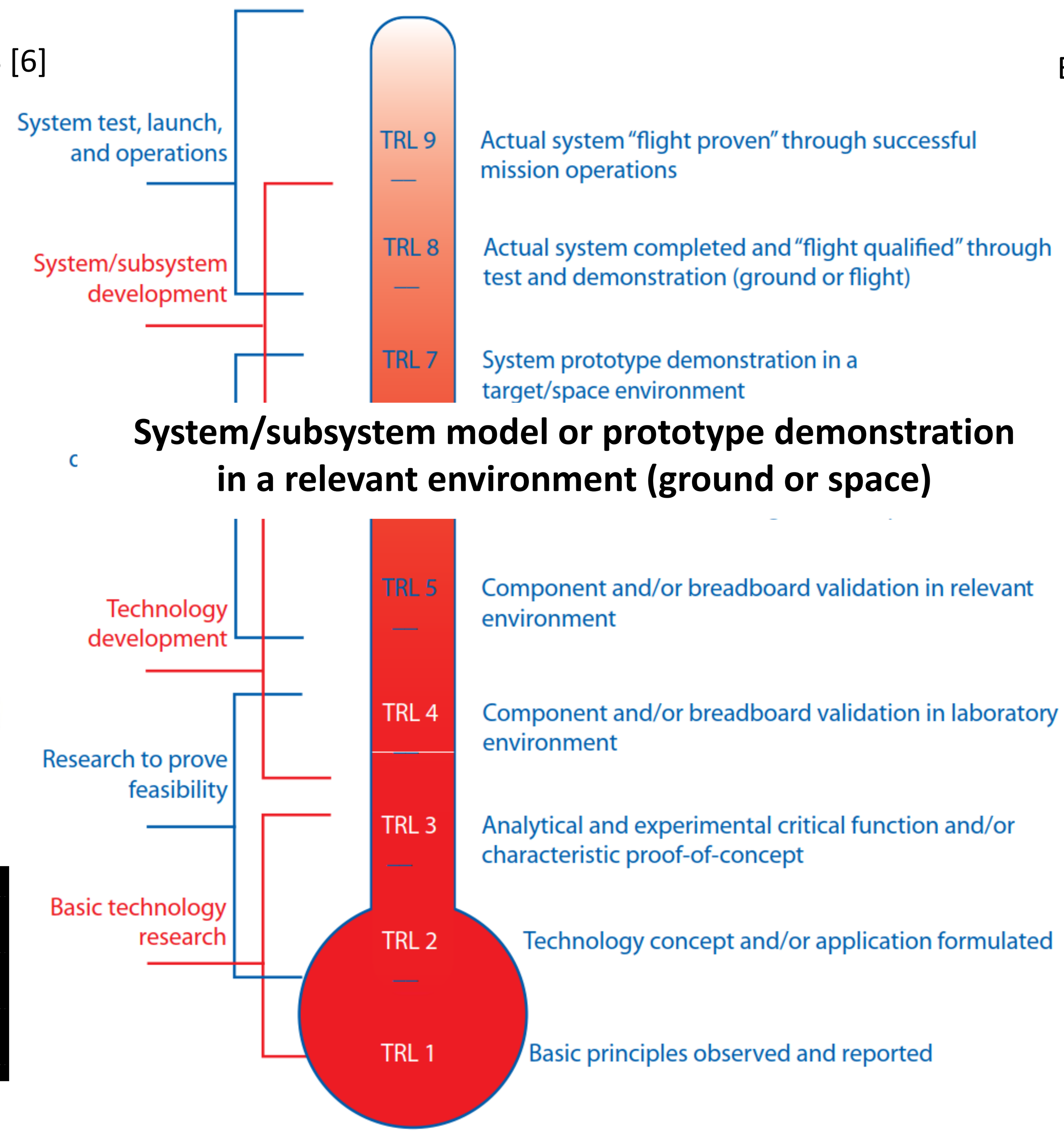
Example: HEEET TPS [6]


Combined thermal and mechanical loading of seams

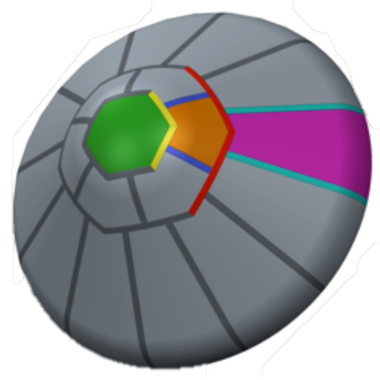

High shear testing of complete seam


Investigation of adhesive types and thicknesses


Extreme environment testing of acreage material

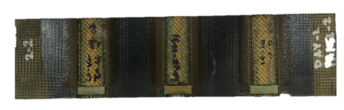


Example: HEEET TPS [6]


Complete heatshield


Assembly


Seam interfaces


Seam assembly

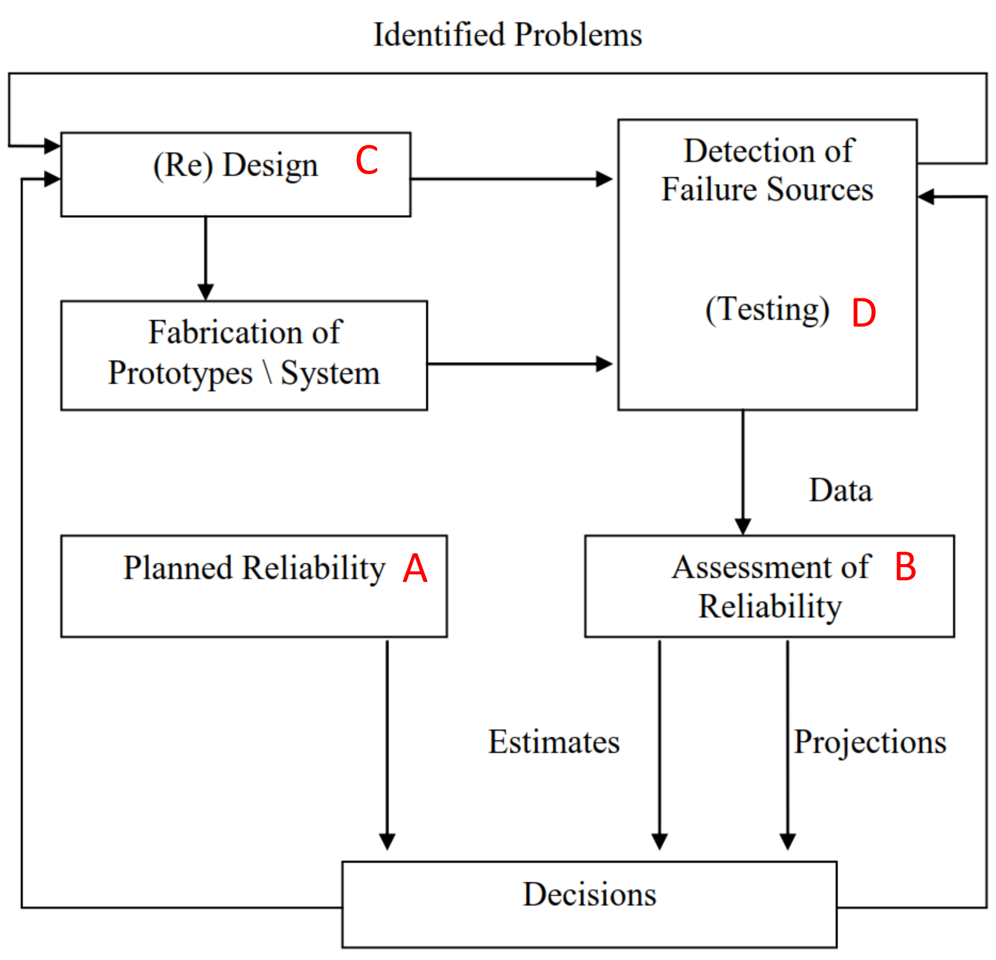

Component

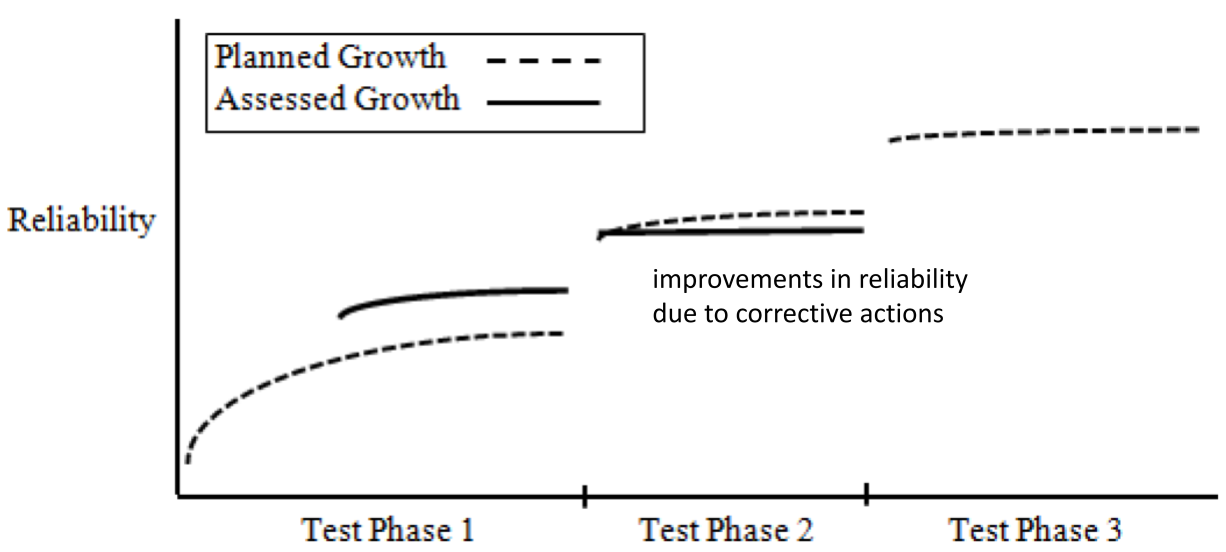
QUALITY OF PROTOTYPE

- Who built it?
  - Technologist vs industry
  - Experienced personnel available for flight build?
  - Same manufacturing infrastructure for flight build?
- When was it built?
  - Obsolescence of components or processes [7]
- Are the processes mature and repeatable?
  - Verification and acceptance criteria
- Are there raw material procurement issues?
- Is the supply chain complex?
- Sole source or intellectual property issues?
- Any scale changes required for flight?

RECOMMENDATIONS FOR MISSION RESIDUAL RISK REDUCTION

Reliability growth [8] is improvement in reliability over time due to corrective actions to system design, operation… or the associated manufacturing process





A. Assign reliability goal for system in Announcement of Opportunity [9]
   - Facilitates comparison of Expected Value from competing mission proposals
   - Proposers can allocate reliability requirements to subsystems
     - Balance new technology reliability against capability of other subsystems
B. Assess reliability of subsystems and integrated system
   - Avoid costly reliability improvement for subsystems that do not drive integrated mission risk [10]
   - Search for unanticipated failure modes
     - Drive down Unknown Risks [5]
   - Concentrate on failure modes that dominate risk [11]
   - Monitor remaining opportunity for reliability growth
C. Provide flexibility for TRL advances in mission development schedule
   - Different technologies have different design cycle duration
     - Short cycle time permits later design freeze in mission development timeline
     - Technology already transferred to industry can have shorter delivery schedule
   - New technologies are likely early in the reliability growth curve
     - Expect significant reliability improvement from an additional design cycle
D. Test hard
   - Develop insight into technology capability limits
   - Vary test environments to assess sensitivity of response
   - Collect data to validate predictive models
   - Study failure phenomenology, including precursors [12]

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