NASA Space Flight Vehicle Fault Isolation Challenges

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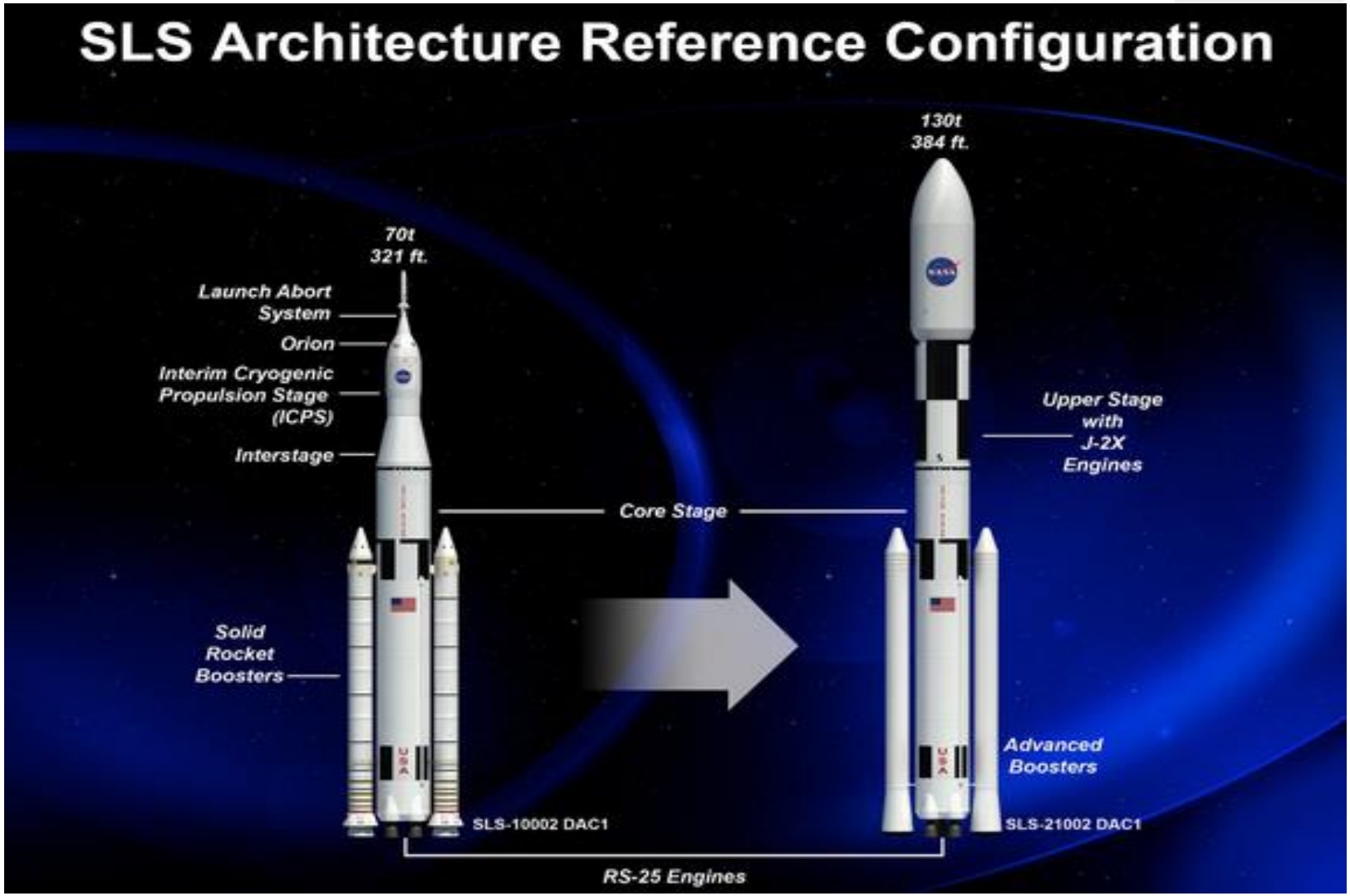
Abstract

- The Space Launch System (SLS) is the new NASA heavy lift launch vehicle in development and is scheduled for its first mission in 2018.
- SLS has many of the same logistics challenges as any other large scale program. However, SLS also faces unique challenges related to testability.
- This presentation will address the SLS challenges for diagnostics and fault isolation, along with the analyses and decisions to mitigate risk.

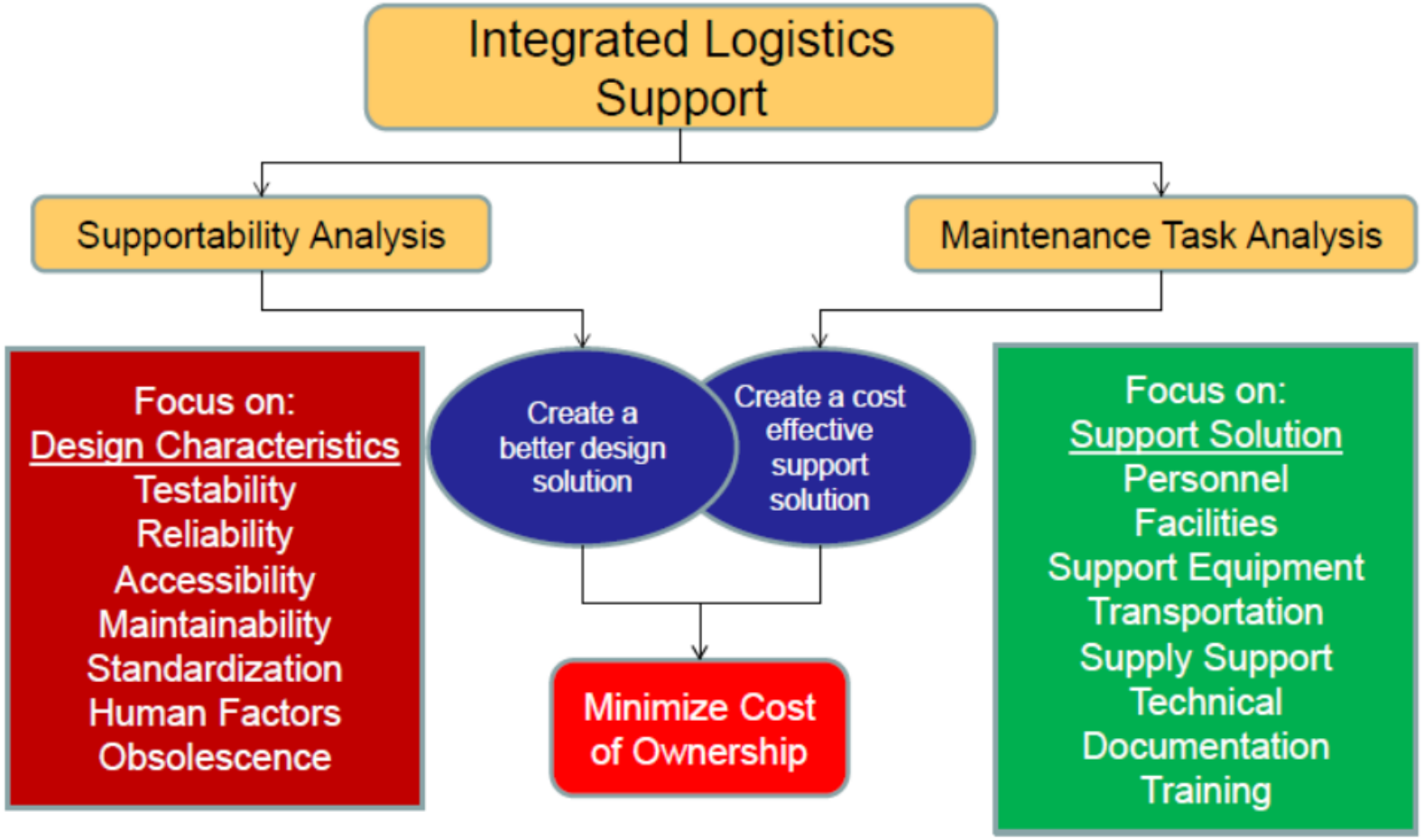
Design Architecture



Supportability in Traditional Integrated Logistics

- Concepts and processes of Integrated Logistics Support (ILS) provide a significant opportunity for applying supportability in the design of the system.
- Traditional application of ILS during the design, development, test and evaluation (DDT&E) of a system typically consists of two different, but highly related processes:
  - Designing a supportable system.
  - Developing a reasonable, responsive and cost effective support solution.

ILS During System Development



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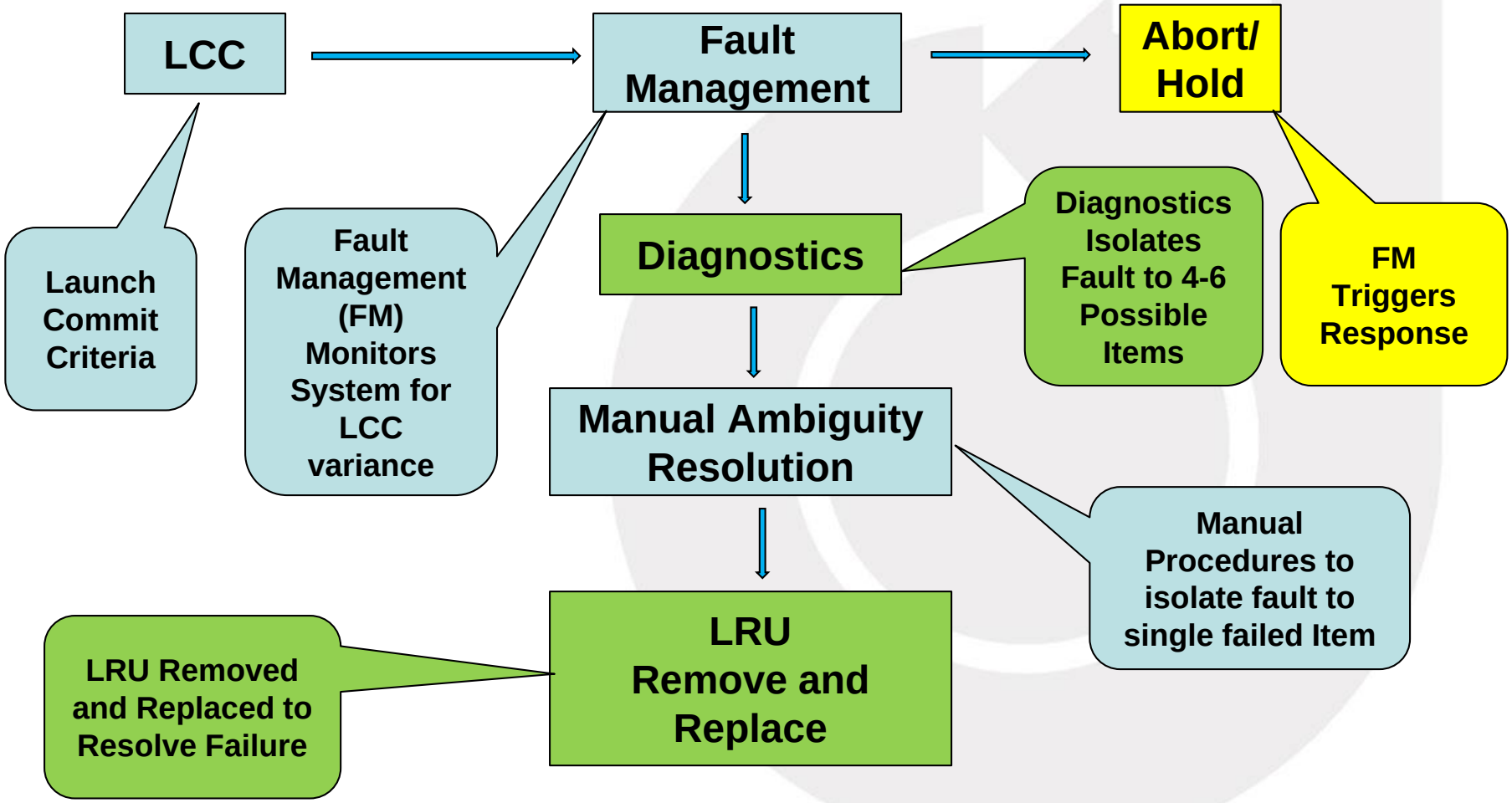
Tailoring ILS

- A simple comparison of traditional ILS concepts and processes with the unique circumstances of the SLS Program (SLSP) indicates that application of ILS must be drastically different to be effective.
- SLSP unique circumstances include:
  - Initial low launch frequency several years apart.
  - Different technology and hardware configurations.
- Supportability characteristic of testability is impacted, particularly fault isolation.

Supportable Design Attributes

- Fault Detection: At least 99% of failure modes.
- Fault isolation: Using automated features to detect failed items 95 – 99% of the time.
- Access: Unimpeded access to failed item.
- Replacement: Rapid removal & replacement (R&R).
- Confidence Test: Test the system after R&R.
- Any Item that meets these five attributes typically referred to as a Line Replaceable Unit (LRU).

How Fault Isolation Should Work



Restoring Operability

- Time to rectify failures is directly related to attributes and characteristics of the design.
- When the system design allows rapid fault isolation, access and R&R of the failed items, then the time penalty is fairly short.
- Otherwise, the resulting time penalty can be severe translating into increased cost and schedule delays, also intangible impacts to reputation and credibility when successive launch attempts are unsuccessful.

Options for Diagnostics and Related Challenges

Diagnostic Option	Challenge
No Diagnostics	Rollback from launch pad to Vehicle Assembly Building for likely vehicle disassembly and reassembly to resolve failure. Significant schedule delay.
Automated	Develop automated capability to extract fault data and input to a FM model to perform diagnostics. Increased cost for vehicle software design.
Manual	Develop manual capability to extract fault data from telemetry and manual input to FM model to perform diagnostics.
Ambiguity Resolution	Manual ambiguity resolution procedures will be required for any option to determine failed LRU.

Relationship of Ground Based Diagnostics

- Ground launch management system at the launch site will determine which FM capabilities will be executed on the vehicle and which will be performed by the ground systems during pre-launch operations, as well as determining the proper response actions in the event of a detected failure.
- Advanced Ground Systems Maintenance (AGSM) concept analyzes data and health status published by the Launch Control System. Video follows.

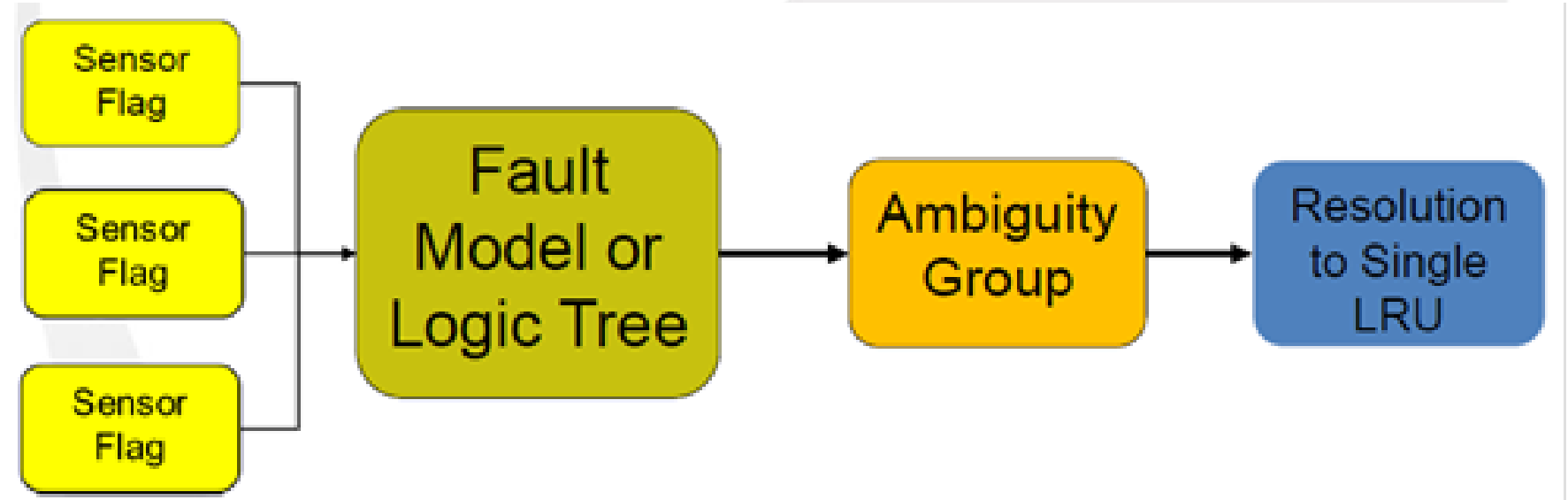
SLS Assessment

- SLS Operations team performed an assessment of supportability attributes and measures, including launch availability & maintenance downtime, to determine best option for diagnostics capability.
- Also considered SLS unique circumstances of low quantity of launch vehicles, short service life, and flight hardware disposability whereby no flight hardware returns.
- Results led to a manual diagnostics capability.

SLS Methodology

- SLSP decision to develop a manual diagnostic capability that is non-intrusive and near real-time drove establishment of a task team.
- The Manual Diagnostics Task Team included the design team and ground launch organizations.
  - Focus on basic fault isolation concept, next figure, to mitigate off-nominal conditions during launch processing.
  - This capability will support quick response to LCC violations and support efficient troubleshooting.

Fault Isolation Concept



Task Team Activities

- Assessment of number and coverage of sensors contained in design to assure adequate coverage of all failure modes with linkage to LRUs.
- Identification of ambiguity resolution procedures necessary to complete fault isolation to single LRU.
- Plan/prepare for use of Testability Engineering and Maintenance System (TEAMS) designer model for manual fault monitoring and isolation, shown next.

Manual Diagnostics Implementation Process Concept

Test & R/R LRU

Resources

Ambiguity Group

Responsibility evolves to launch site after design maturity.

Telemetry Data

Sensor Data

Conclusion

- SLSP has taken a measured approach in applying design considerations for vehicle diagnostics capabilities to aid in fault isolation of failed components during launch processing activities.
- Path Forward: Develop a manual diagnostics capability with a focus on crewed missions, the first of which is scheduled to be Exploration Mission (EM)-2 currently planned for 2021.

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