Mission Assurance Implications of Space Vehicle (SV) Thermal Vacuum Retest Product Overview

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Acknowledgements

This document has been produced as a collaborative effort of the Mission Assurance Improvement Workshop. The forum was organized to enhance mission assurance processes and supporting disciplines through collaboration between industry and government across the U.S. Space Program community utilizing an issue-based approach. The process is to engage the appropriate subject matter experts to share best practices across the community in order to produce valuable mission assurance guidance documentation.

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Agenda

- Executive Summary
- Product Traceability
- Product Overview
- Topic Follow-on Recommendations
- Team Membership and Recognition

Space Vehicle Thermal Vacuum Retest Study Executive Summary

Problem Statement

- "In a recent Aerospace internal study conducted on 29 NSS space vehicles (since 2000)—11 of 29 or 38% of the vehicles studied saw 1 to 3 additional space vehicle level retests"

Data Set

- 350 U.S. government civil/DOD and commercial high-reliability vehicles since 2000

Charter

- Investigate alternative approaches across the industry that does not reduce mission assurance
- Develop approach and decision process for addressing retesting
- Identify risks of retesting
- Understand the technical rationale of why space vehicle level thermal vacuum retests occur
- Compare government and commercial space vehicle thermal vacuum retest decision processes
- Measure effectiveness of space vehicle level thermal vacuum retest activities

Key Observations

- SV thermal vacuum retest ratio was found to be 22% for NSS SVs; 12% across 350 SVs in study
- 16 considerations were identified for thermal vacuum retesting decision process
- Retest reasons were split between Unit and System I/F anomalies mostly workmanship related

Key Recommendations

- Sixteen industry topic team-defined considerations should form the basis for SV thermal vacuum retest decision process
  - Informs alternate verification methods to mitigate consideration-defined risks
- Perform assessment integrated with existing board reviews (aka FRBs/PRBs)

FRB – Failure Review Board PRB – Program Review Board

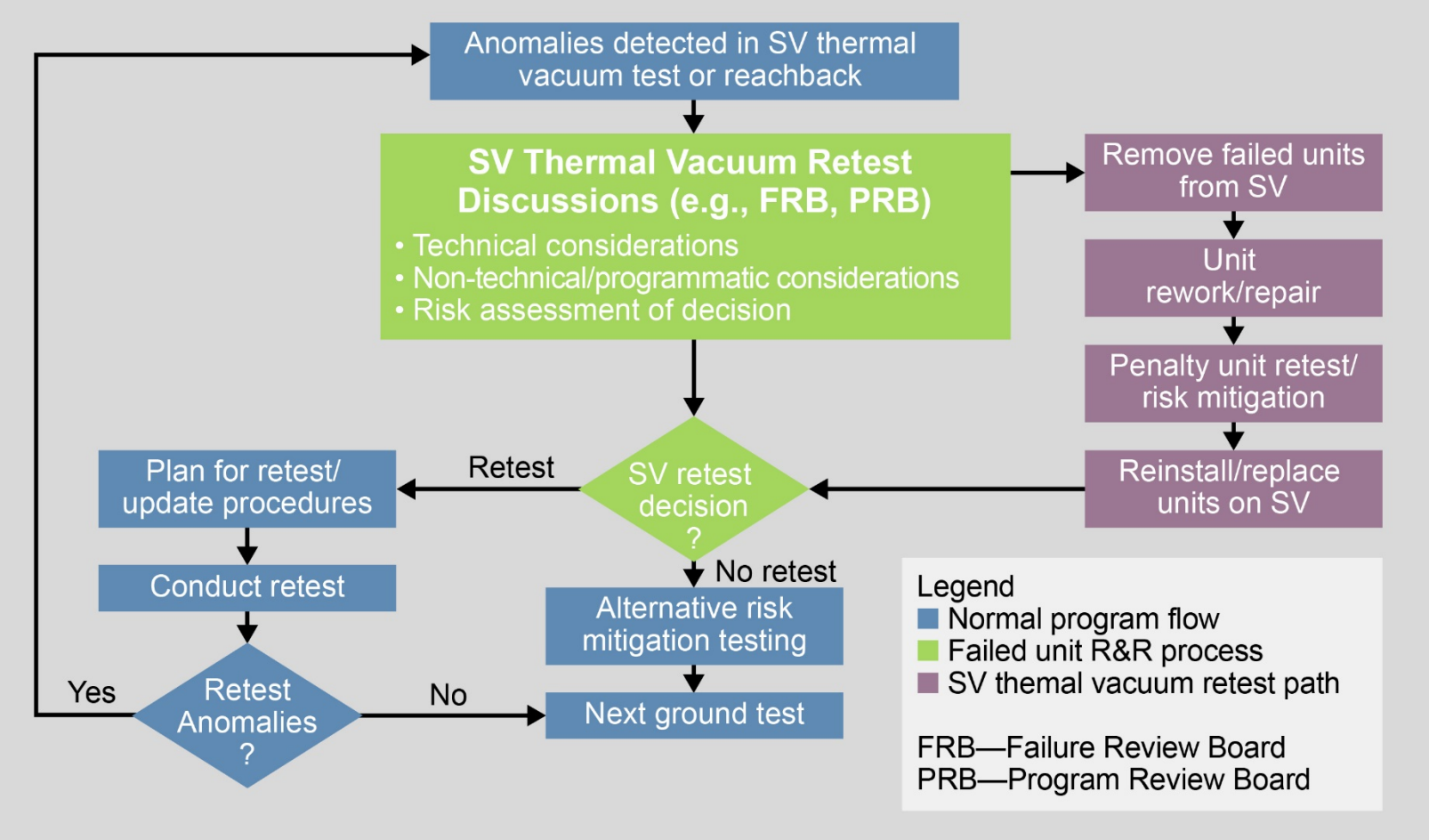
Product Traceability

Deliverable Requested	Location Covered in Product
Recommendations for retest decision process	Section 4.2: Thermal Vacuum Retest Recommendations
Data set of thermal vacuum testing in industry	Chapter 3: Space Vehicle Thermal Vacuum Test Data Collection and Analysis
Comparison of government and commercial processes	Chapter 1.3.1: Retest Philosophy Differences between Government and Commercial Programs
Methods to mitigate risks associated with thermal vacuum retest	Chapter 2.3: Mitigating and Alternative Approaches
Test effectiveness of thermal vacuum retest	Chapter 3.4: Space Vehicle Thermal Vacuum Retest Effectiveness

Space Vehicle Thermal Vacuum Retest—Product Overview

- Introduction
  - *Background and problem statement*
  - *Purpose of thermal vacuum testing and retesting*
  - *Current industry practices and processes*
    - Retest philosophy differences between government and commercial programs
  - *Thermal vacuum retest implications*
  - *Defining space vehicle thermal vacuum retest*
  - *Environmental testing definitions*
- Retest assessment process
  - *Thermal vacuum retest considerations*
  - *Mitigating and alternative approaches*
    - Analysis proving minimal risk to design integrity
    - Unit thermal testing
    - Subsystem thermal vacuum testing
    - Alternative vehicle-level testing
    - Non-environmental test assessments
- Space vehicle thermal vacuum data collection and analysis
  - *Discussion of data collection*
  - *Results of data collection*
  - *Reasons for retesting from data collection*
  - *Space vehicle retest effectiveness*
    - Multiple retests
- Conclusions and recommendations
  - *Data Analysis Conclusions*
  - *Thermal Vacuum retest recommendations*
  - *Future work*

Space Vehicle Thermal Vacuum Retest Decision Process



Thermal Vacuum Retest Considerations – 16 Considerations in 5 Categories –

1. Units Removed and Replaced (R&R)
   a. *Number of Units Removed and Replaced*
   b. *Number of Reworks/Repairs*
   c. *Percentage of the SV touched during R&R*
   d. *Type of R&R Unit Thermal Interface*
   e. *Power Dissipation/Density*

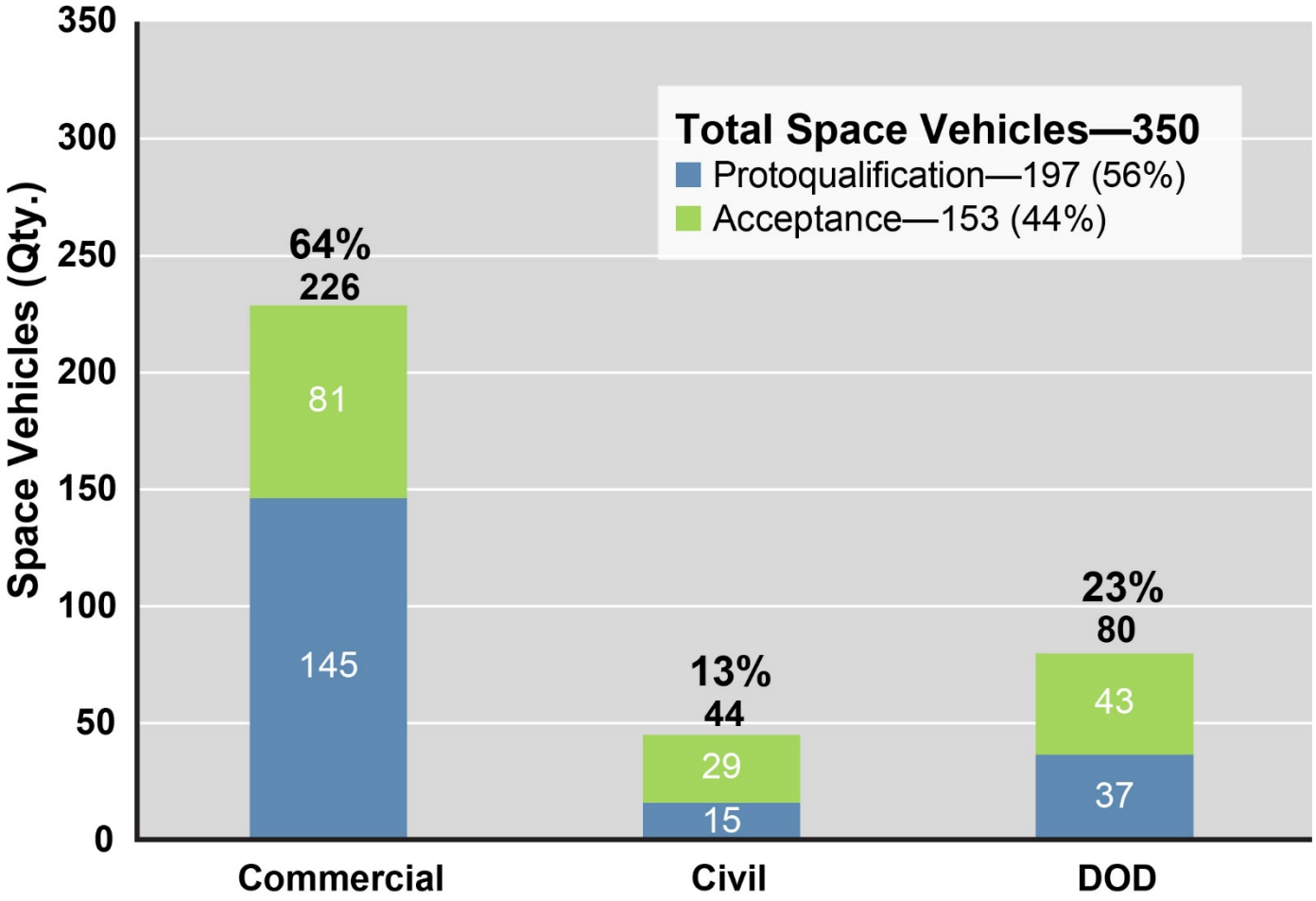
2. Flight Harnesses and Connectors
   a. *Flight Harness Modification/Manipulation /Routing*
   b. *No. of Connector and Conductors Demated /Remated*
   c. *Type of Connectors Demated/Mated for each Unit*
   d. *Type of Signals running through each Demate/Remate Connectors (DC, analog, digital)*
   e. *Number of Blind Mates*

3. Handling and Access
   a. *Installation Difficulty/Access Difficulty including Special GSE*
   b. *Potential for Collateral Damage*

4. Design and Test History
   a. *Mission Criticality and Redundancy Architecture for all R&R Units*
   b. *Previous R&R Unit Failure History*

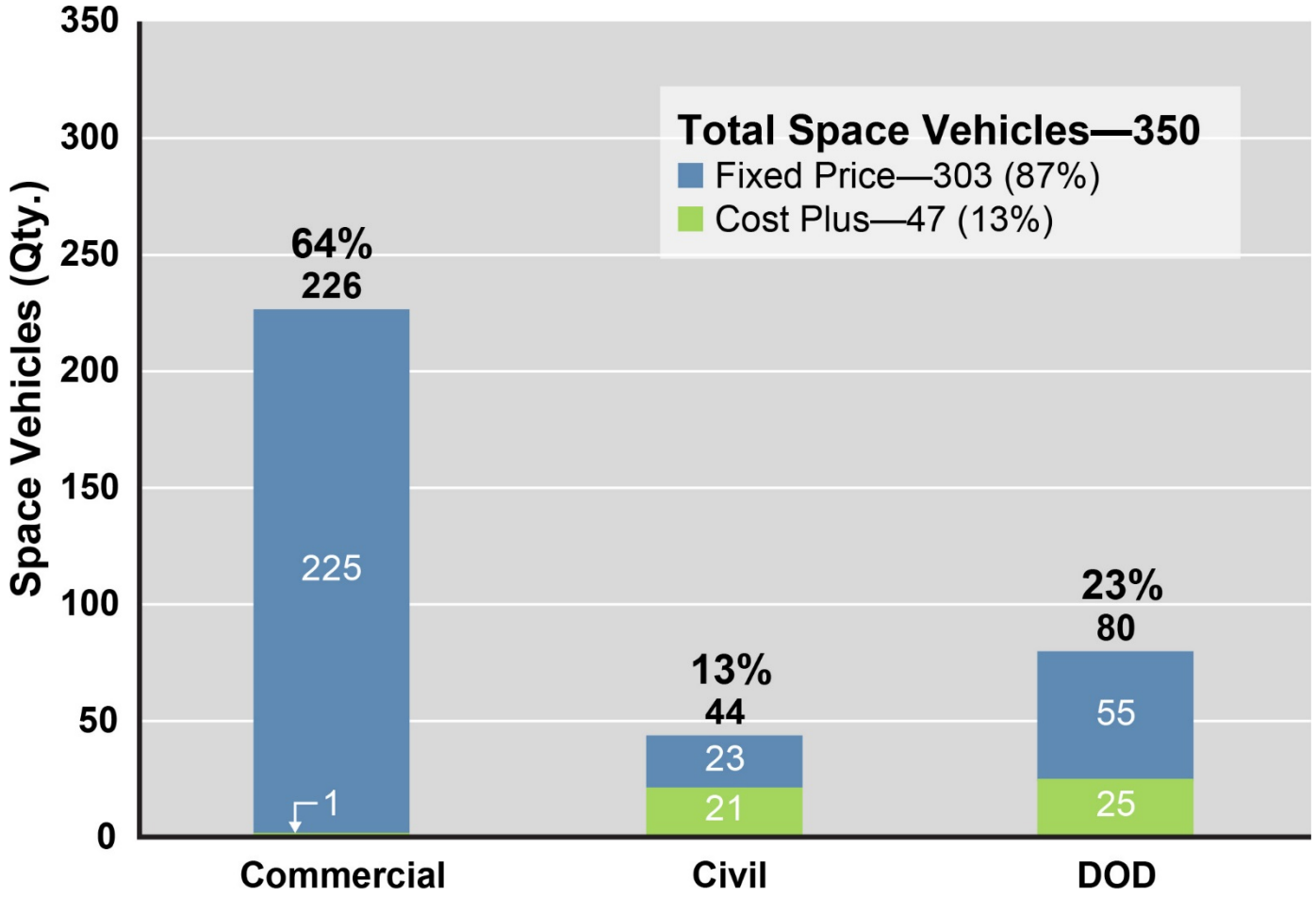
5. Performance Verification
   a. *Degree of Post Rework/Repair Vehicle Performance Testing*
   b. *Confidence Testing Required*

Examined 350 Space Vehicles that underwent Thermal Vacuum Test from 2000–2016



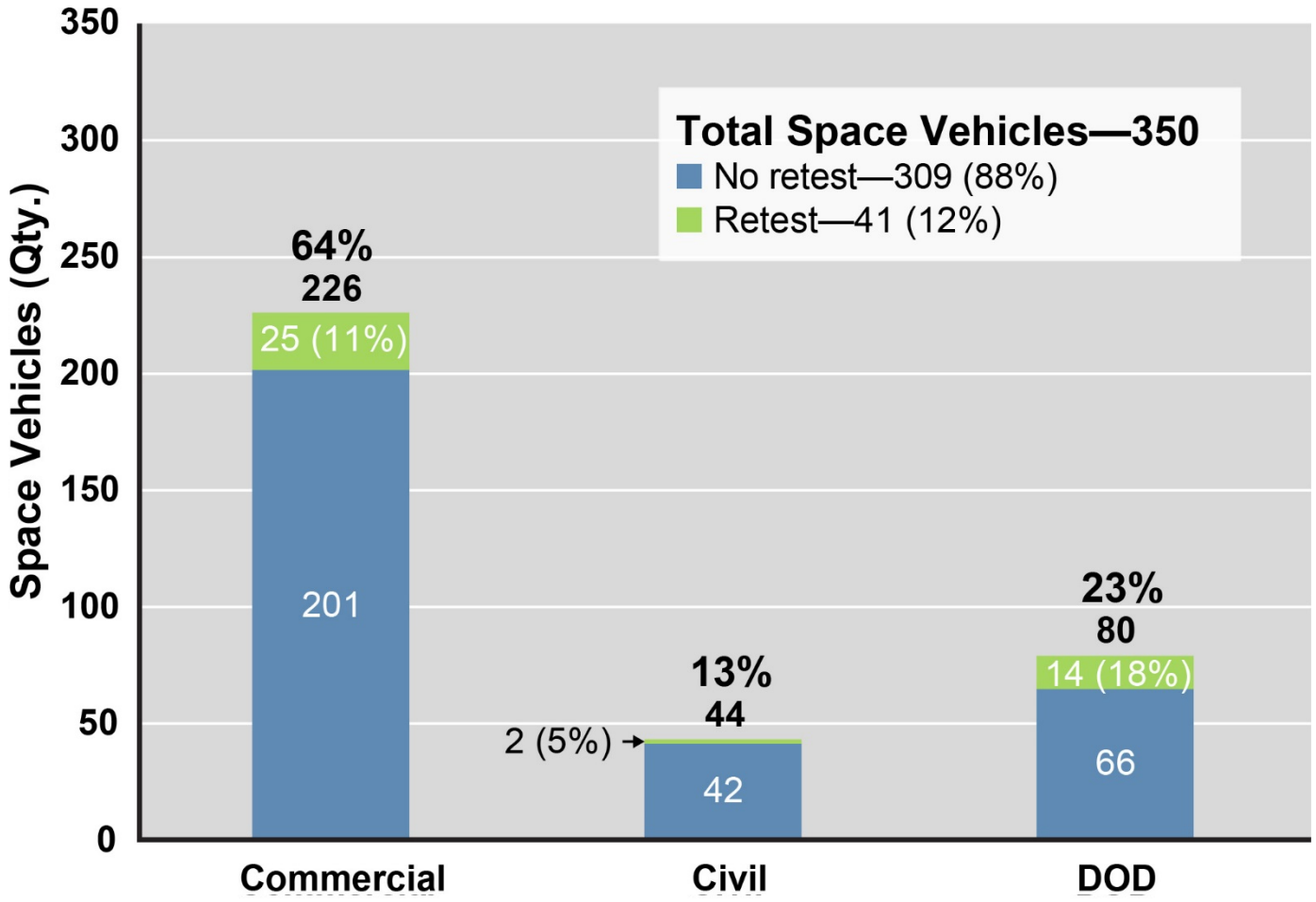
Representative Dataset Spanning Six Contractors

Distribution of Space Vehicles by Contract Type

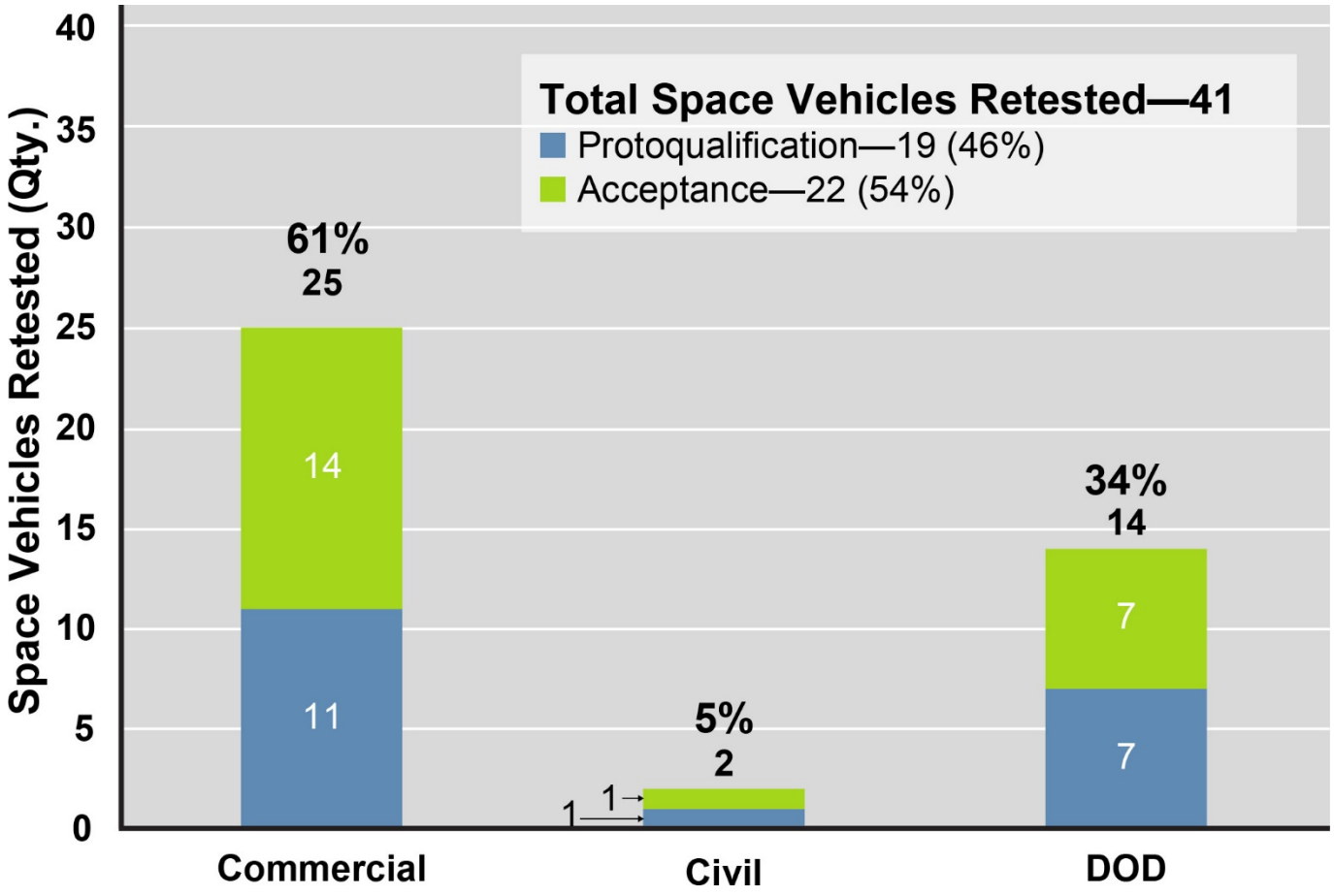


Fixed price contracts do not affect retest rates

Number of Space Vehicles TV Retested

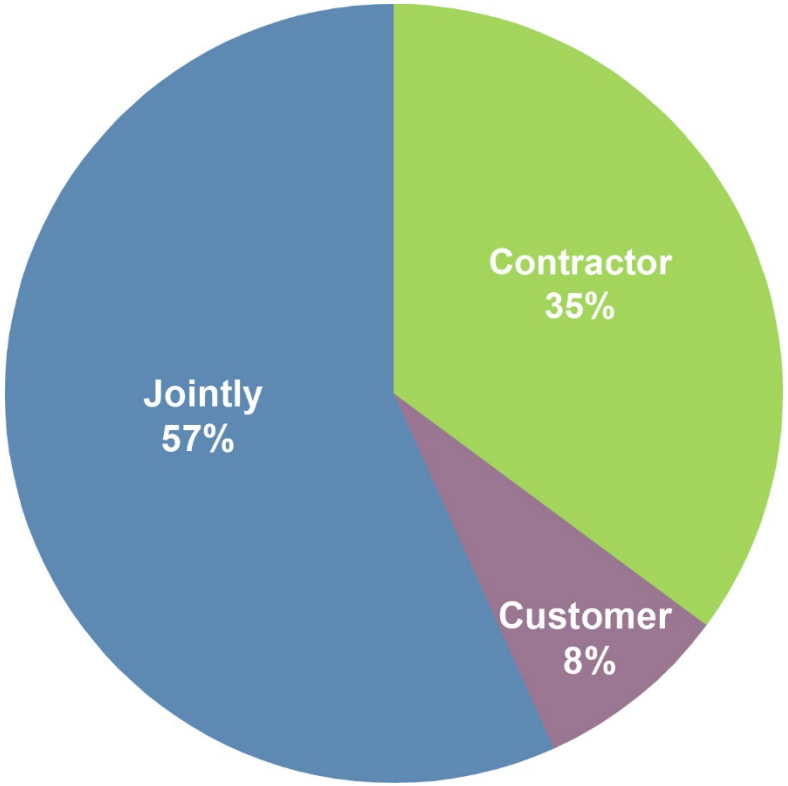


Retested Space Vehicles by Test Type



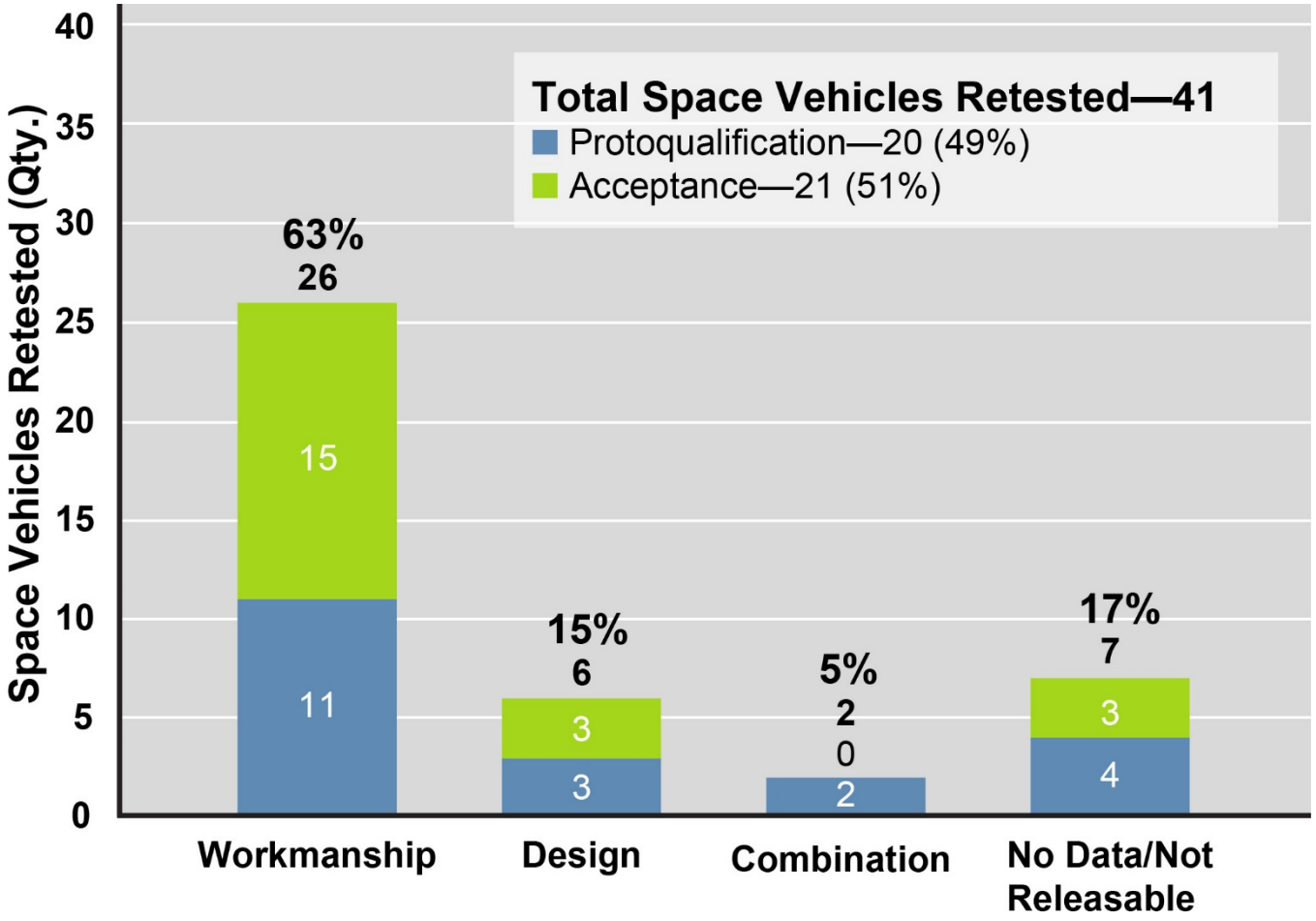
Close to even-split for Protoqualification vs. Acceptance tests

Primary Decision-maker for Retesting



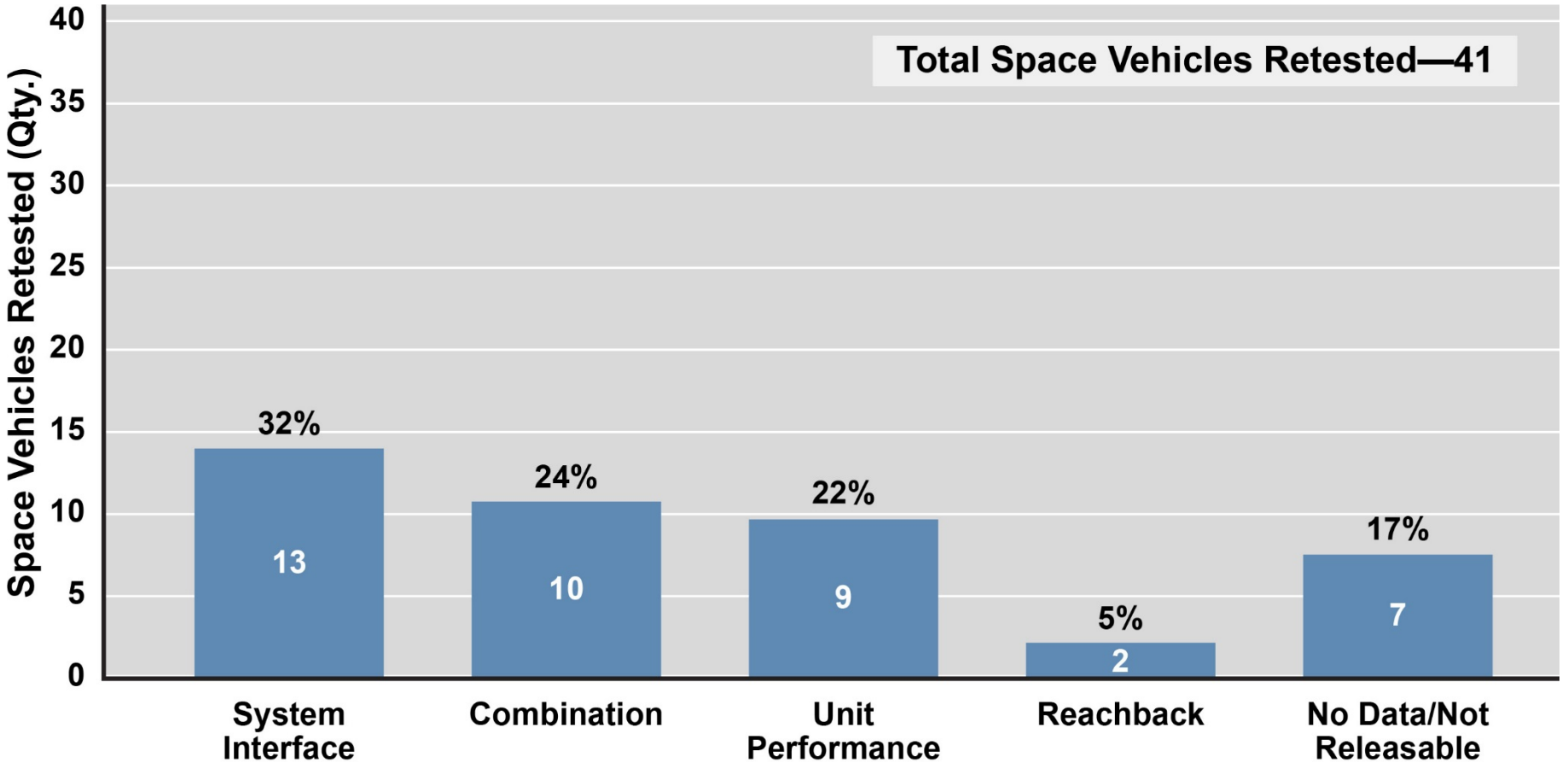
For most SVs, the retest decision maker was the company or jointly decided

Primary Reasons for SV Thermal Vacuum Retest



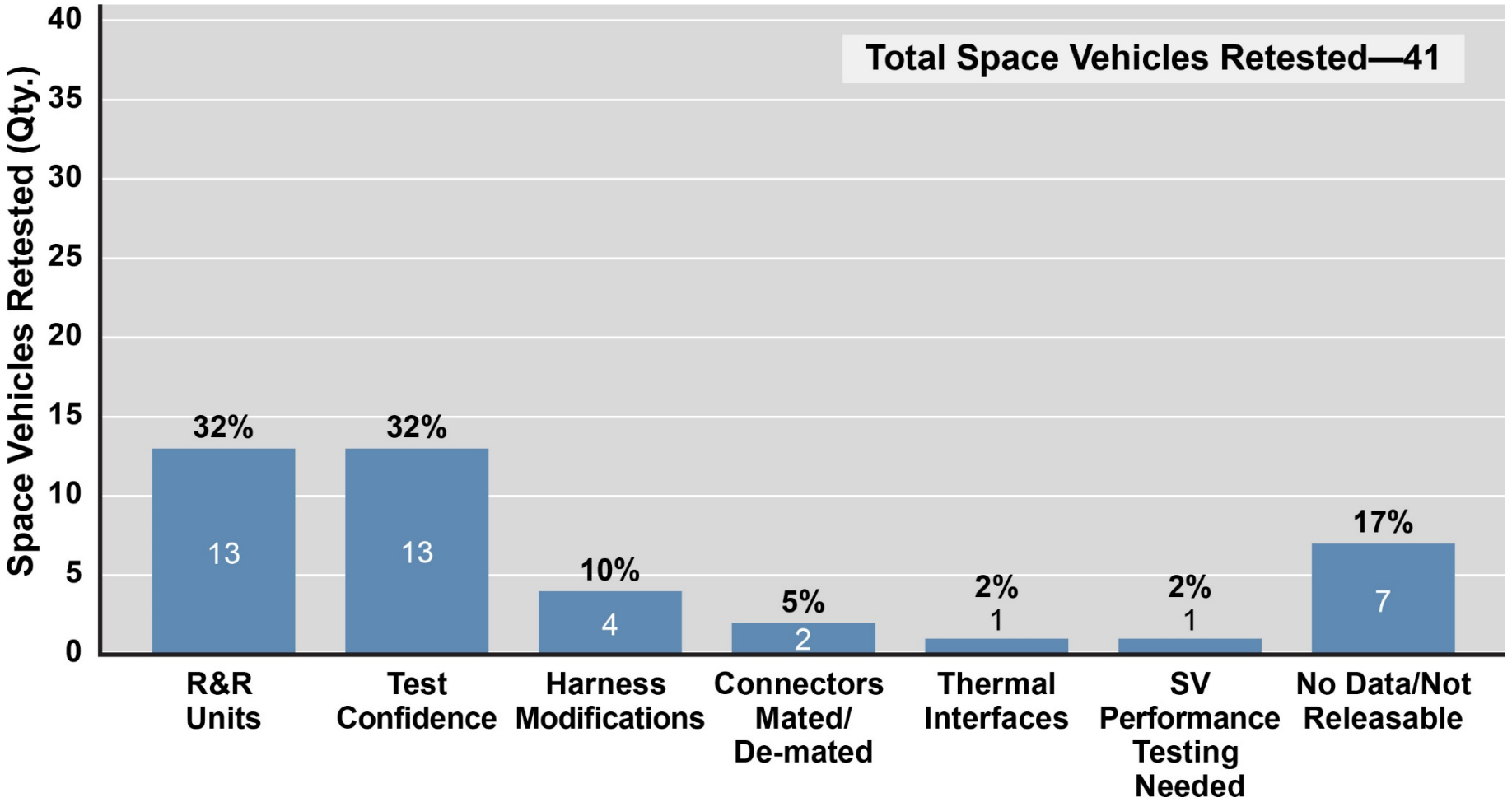
Workmanship issues were leading retest reason

Nature of Failure that led to SV Thermal Vacuum Retest

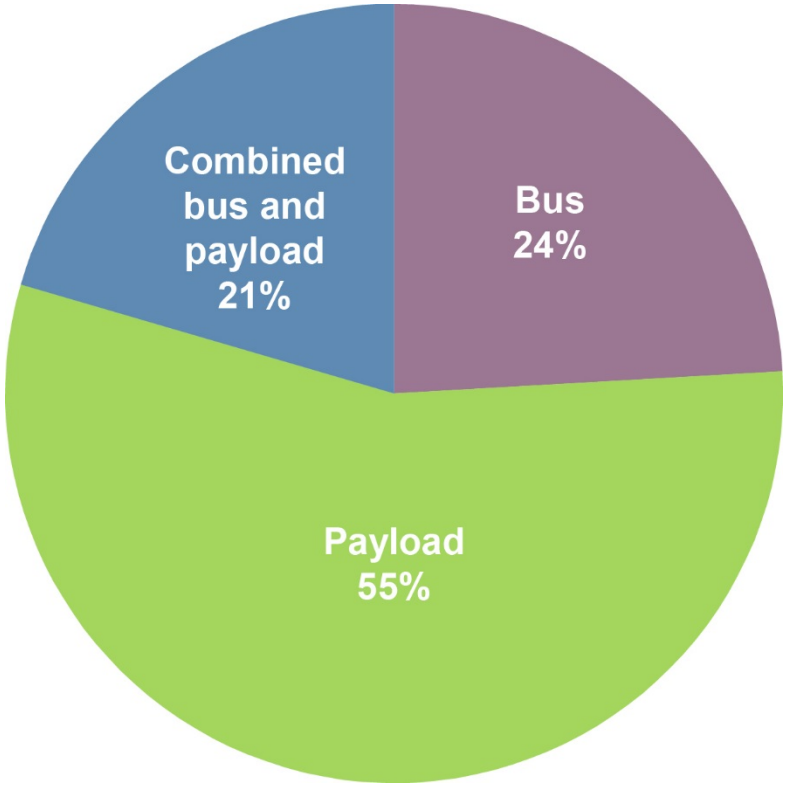


System I/F, Unit Performance, and the combination of—were leading failure causes

Contributing Considerations for Retesting

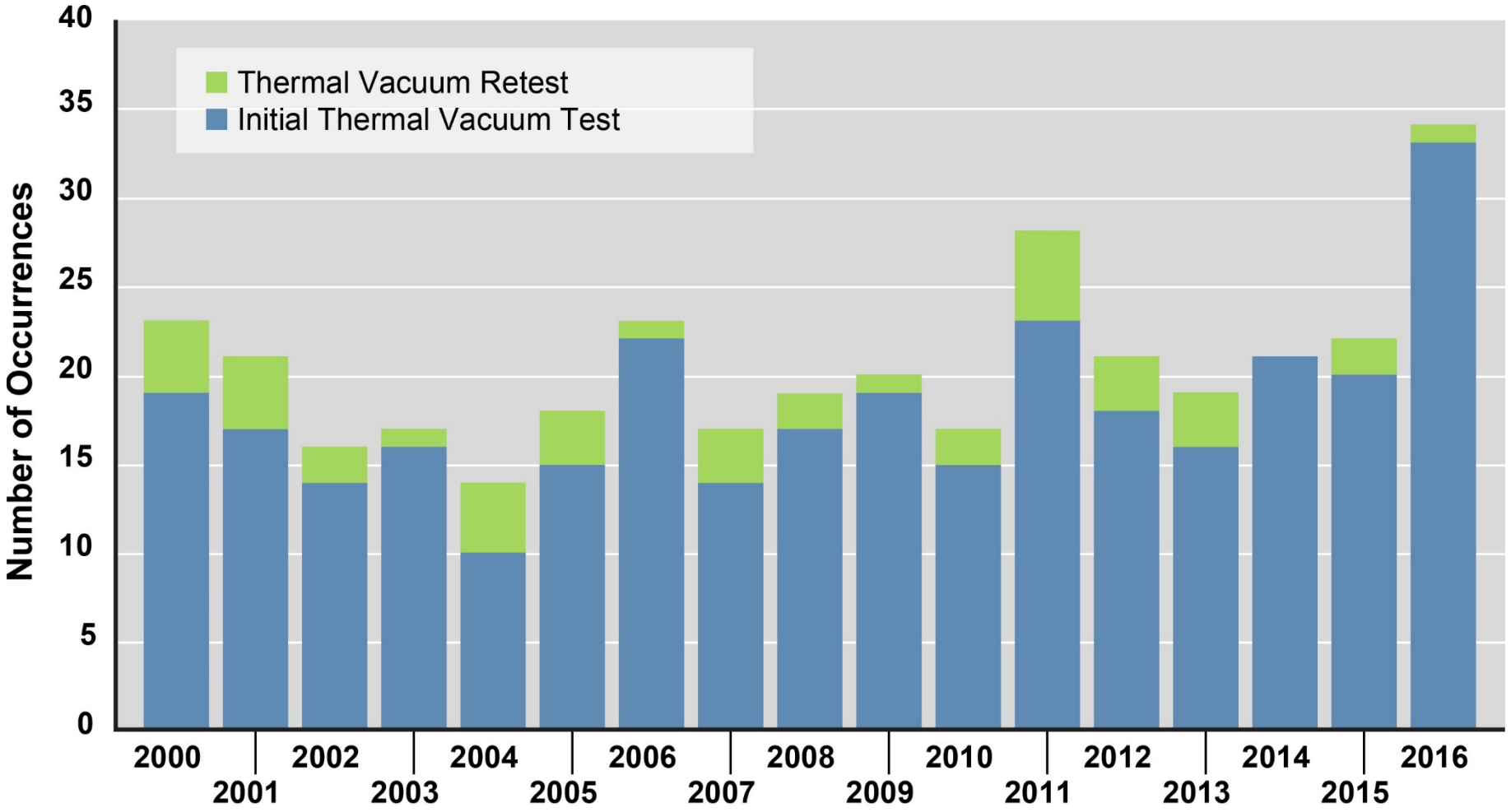


Failures That Lead to Retesting by Hardware Type



Payload issues higher retest factor than Bus

Historical Trend for Retesting



No real trend, higher amount of retest in first than last 3 years

Comparison of Protoqualification vs. Acceptance and Commercial vs. Government Failure Rates

Vehicles	Initial SV TV Test Results		SV TV Retest Results
	Retested Vehicles	Failures/Test	Failures/Test
Protoqualification	16	4.6	0.7
Acceptance	18	2.0	0.3
	Total = 34	Average = 3.3	Average = 0.6

Vehicles	Initial SV TV Test Results		SV TV Retest Results
	Retested Vehicles	Failures/Test	Failures/Test
Commercial	24	3.4	0.2
Government	10	3.1	1.7
	Total = 34	Average = 3.3	Average = 0.6

Thermal Vacuum Retest Recommendations

- Center retest decision process on technical risk using existing review boards (e.g., Failure Review Board and Program Review Board)
- Use the industry-developed 16 considerations to form the basis of the SV thermal vacuum retest process
- Consider alternative verification methods in lieu of SV thermal retest to mitigate assessed risks
- Ensure rigorous unit-level testing to eliminate/minimize unit defect escapes
- Revise SMC-S-016 (2014) to reflect the current industry practices and recommendations as documented in this report (TOR-2017-01693)

Team Membership and Recognition

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