Requirements and Verification (R&V) Streamlining for NASA's Space Launch System (SLS)

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Outline

- Classical approaches to R&V
- Tenets of SLS
- Implementation of SLS R&V
- Snapshot of Results
- *Backup: Terms and Definitions*

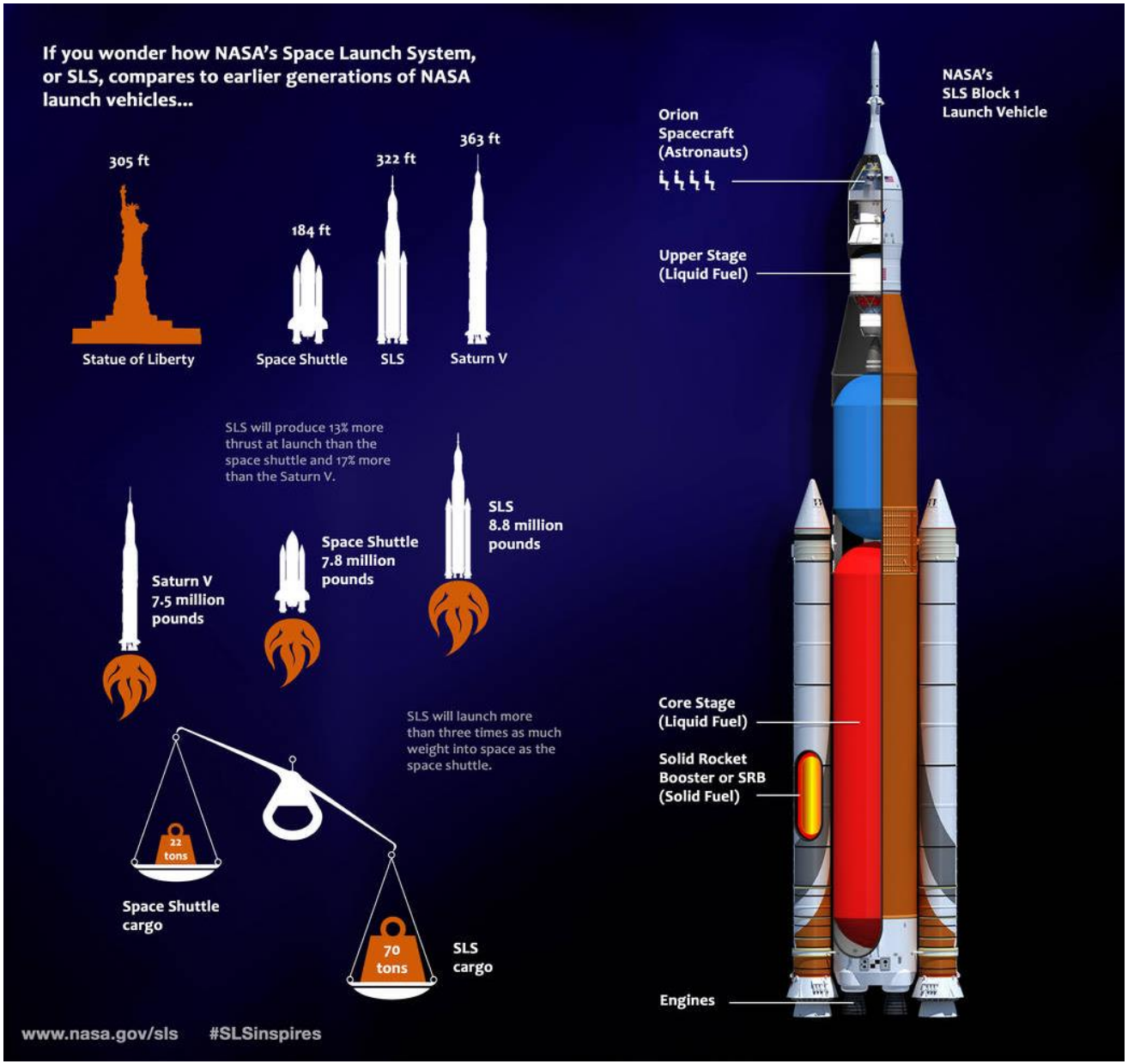
Classical Approaches to R&V

- **Highly detailed and overly-prescriptive R&V**
  - ‘Fat’ requirement sets
    - Specifications written with extensive amount of ‘shall’ statements
    - Standards applied as directives
    - Design solutions included as part of requirement set
    - Multi-dimensioning of requirements through parent/child allocations
  - ‘Multiplexed’ and ‘over-tested’ verification planning
    - Verification planning (events) often overly conservative due to excessive redundancy (overlapping test and analysis activities)
    - ‘Test is best’ mental model often drives additional cost/schedule without commensurate reduction in risk for today’s development

Classical Approaches to R&V (cont'd)

- **Oversight/insight balance tends towards high control level**
  - Multi-dimensioned requirements leads to multi-dimensioned verification closure approvals (same requirement exists at two architecture levels)
  - Additional redundant technical reviews drive large cost/schedule impact with minimal risk reduction to project
  - Opportunities to 'compact' verification compliance assessments into shared compliance events and shared compliance reporting may not be explored

NASA's Space Launch System (SLS)



Tenets of SLS

- **Cost- and schedule-constrained program**
  - SLS Program is based on a model of affordability
  - Program structure and operating model target efficient utilization of taxpayer investments to maximize return on investment in the design of a new heavy lift launch vehicle
  - This requires focus on cost and schedule performance of the program
- **Insight/oversight balance**
  - Oversight is tactically applied at major design reviews (SRR, PDR, CDR, DCR, etc.) and based upon risk between milestones
  - Matrix engineering model for SE&I used to continually administer vertical and horizontal integration, including insight into lower levels of the system

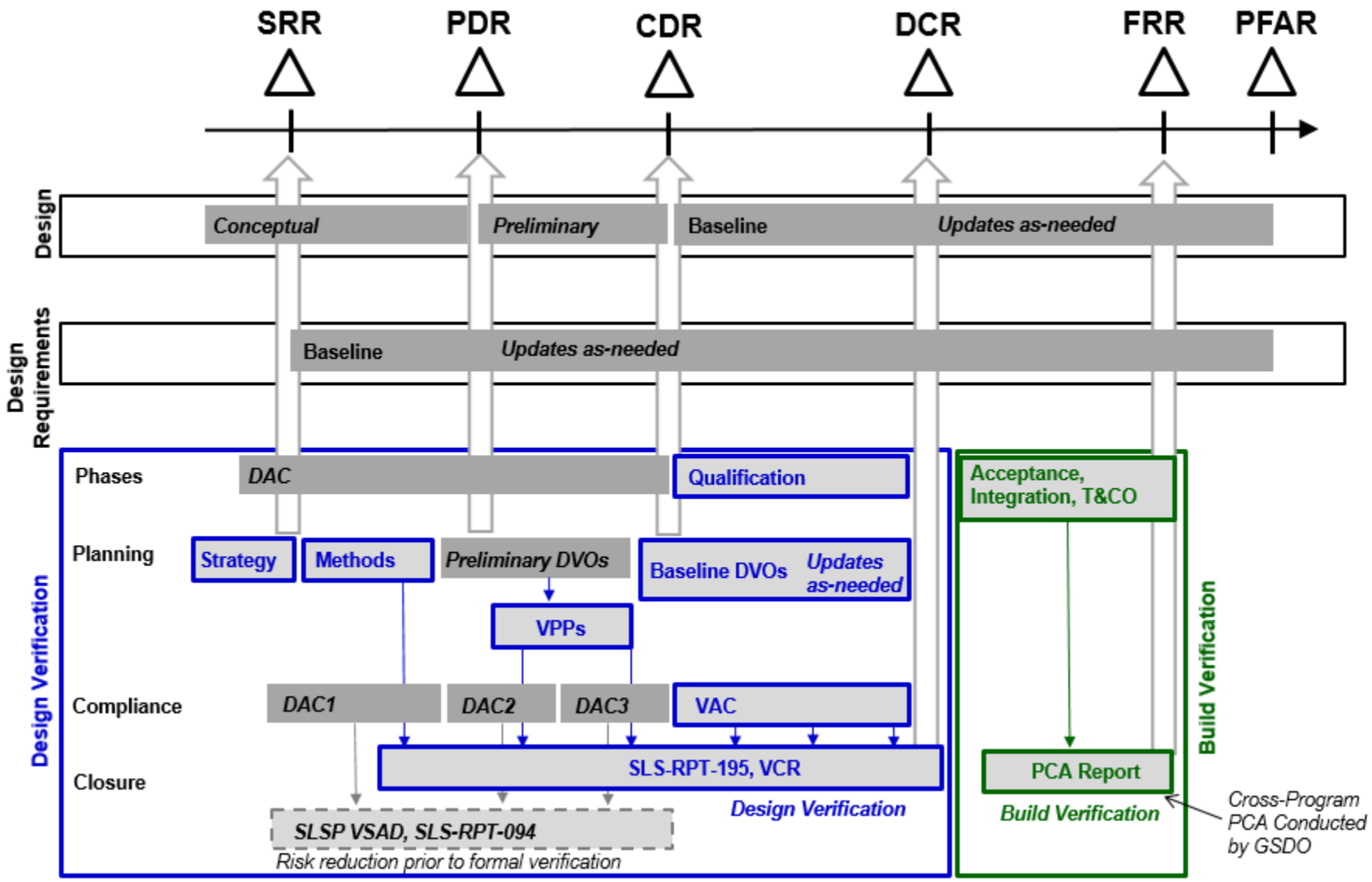
Tenets of SLS (cont'd)

- **Risk-based management**
  - Technical decisions (including R&V considerations) are informed decisions based on risk assessments for safety, technical, cost, and schedule
- **Delegation of technical authority and tailoring**
  - In response to key parent requirements, detailed requirement sets are derived by the technical authority at the level of implementation in the architecture
  - Design and construction standards are applied as requirements with a clearly defined, risk-based process for tailoring:
    - Delegated to technical authority at the system-element level of the architecture
    - Allows system-elements to meet the intent of allocated standards with equivalent or modified standards
    - Elevation criteria defined for cases where intent is not met

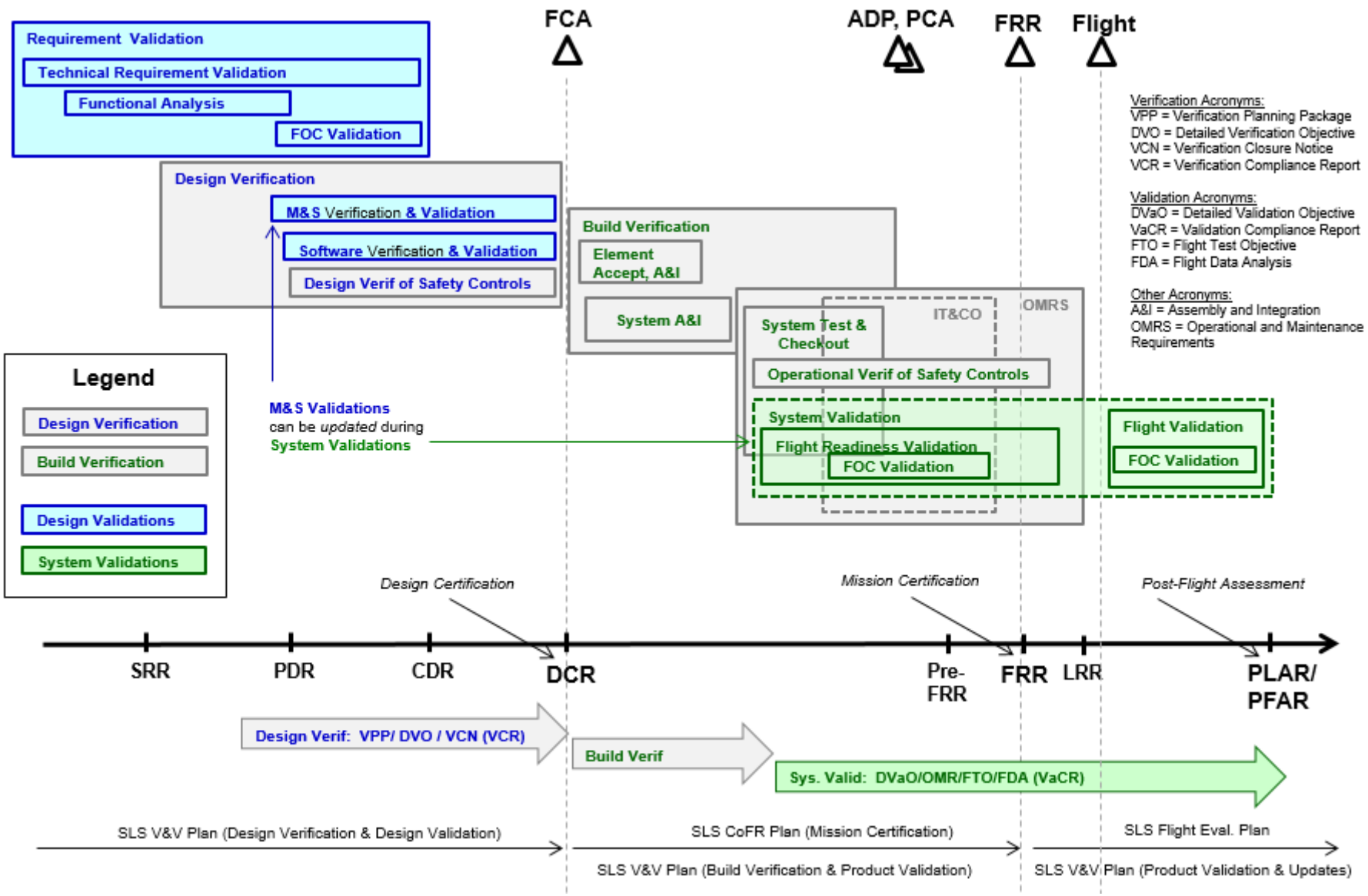
Implementation of SLS R&V

- **Implementation of SLS R&V**
  - Lean R&V
    - ‘Skinny’ requirement set developed to define key safety, performance, functional, interface, and design standard requirements
    - Tactical verifications applied to ensure technical adequacy without forcing unneeded costs into the overall program
  - Model-based R&V
    - Novel analytical approaches in lieu of classical requirement-to-analysis verifications
    - ‘Heritage’ hardware affordability maximized using controlled models
  - ‘Design constraints’ used to formalize design agreements
  - Removal of ‘waste’
    - Redundant approvals removed from the overall process by delegating technical review, approval, and responsibility to the lowest level of the system
    - A subset of the verification method ‘Inspection’ was defined (called ‘Validation of Records’) to enable risk-based approval of delegated verification closures
  - *Clear communication of definitions, process, and implementation facilitated consistency and effectiveness of the overall R&V program*

SLS Design Verification Lifecycle



SLS V&V Lifecycle



Snapshot of Results

- **Risk-based process enables informed decisions**
  - Maintains technical rigor while allowing trade with cost and schedule
- **Improved program momentum (schedule)**
  - Increased schedule performance during critical early program timeframe
  - Allowed for reduced ‘churn’ in program that results from defining overly constricting requirements, which allowed designers to swiftly proceed with preliminary and detailed design activities
- **Improved cost performance**
  - Significant reduction in non-value-added activities
  - Reduced processes and removed redundancy in verification compliance and verification closure approvals
  - Tailoring of standards replaces need for costly waivers/deviations that would have been identified late in the program development lifecycle
  - Use of model-based R&V significantly reduces R&V overhead in areas where approach is risk-appropriate

Backup

Terms and Definitions

- Build verification – a verification conducted against a released engineering requirement
- Compliance activity – an analysis, test, inspection, demonstration, or other 'compliance' event where objective evidence is generated for comparison against applicable verification requirements
- Compliance report – a report that documents the results of a compliance activity
- Design verification – verification conducted against a design (specification) requirement
- Requirement – a 'shall' statement that must be verified
- Validation – the act of generating and approving objective evidence that a product meets stakeholder expectations
- Verification – the act of generating and approving objective evidence that a requirement has been successfully satisfied
- Verification closure – approval of the successful completion of all the necessary verification compliance activities by a technical and/or program authority
- Verification requirement – a binding requirement that defines the conduct and measure(s) of success for verification closure, including verification objectives and verification success criteria for necessary compliance activities associated with a requirement