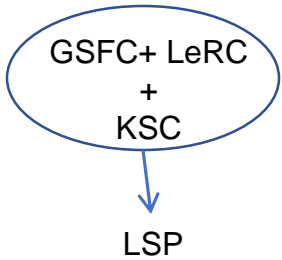


Approaches to Mission Assurance for High Risk Missions

Deciding to reduce mission assurance requires a clear understanding of the current framework for existing mission assurance, the risk posture of the agency stakeholders, and clearly communicated expectations

NASA LSP's Mission Assurance Approach has Evolved Over Time

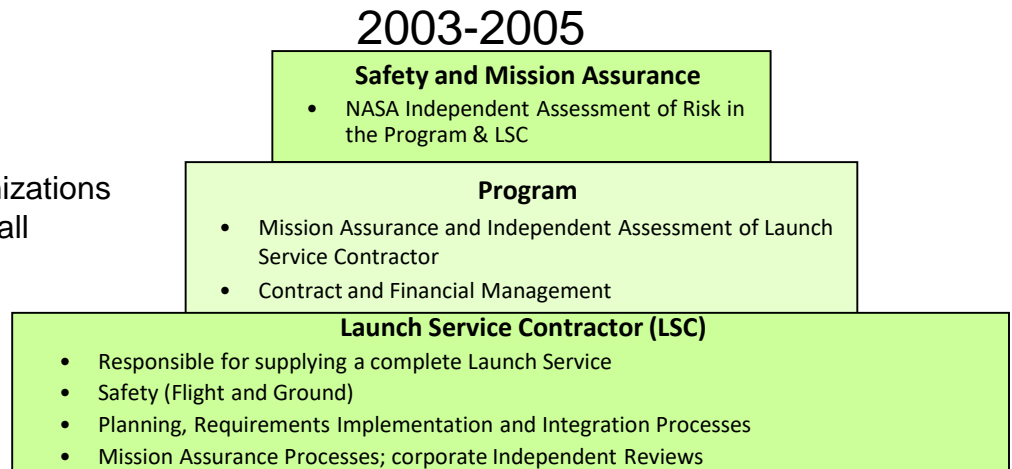


1998-1999
Consolidate and launch "faster, better cheaper"

14 missions in first 15 months

2000-2002
Institutionalize Mission Assurance Practices

- Issue NLS contract
- Created Engineering Review Board Process
- Revised Certification Policy beyond heritage vehicles
- Created Risk management plan

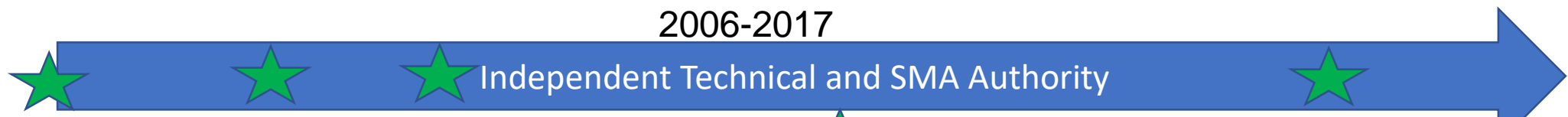


Recognized value of US Government LV organizations Working together for overall Mission Assurance

Completed Certification of Atlas V
 NASA is the first US Government launch of Atlas V

Layered Approach to Mission Assurance

New Leadership



Columbia Investigation Implementation

Advisory Process Formalized

2008 CRS Approach Approved

2011 USAF adopts 2012 NASA framework for Certification

2015 Venture Class Awards

WHAT IS CATEGORY 1 CERTIFICATION?

Non Recurring Mission Assurance- High Risk Missions

- LSP recently approved, and tomorrow NASA HQ will be presented with, a Category 1 Certification Strategy
- Allows NASA to be the first flight of a new LV, for Class D missions
 - Requirements in place since the 1999 release of the policy, implementation has not yet been required
 - Since 1988, one third of new vehicles since world wide have had a failure in the first 3 flights
 - Changes to core propulsive stages is key definition of a new LV for any Category
- Purpose is to identify risk areas and provide advice that suppliers may choose to act upon but do not have to mitigate the risk as done for typical NASA LSP missions
 - For a decade my thought was "this is a review of a some documents and a 6 month overall process"
 - Expectation is "high risk" which is translated to 20% or greater possibility for failure if within first 3 launches
 - If risk is unrealistically high for a new LV (e.g. wildly inadequate engine/flight computer/INU qualification, widespread failure to meet suppliers own qualification criteria, reckless ignorance of qualification failures), then do not certify and do not launch
- Tailored approaches, when a Category is not specifically defined, have been used sparingly (ie. Mostly for delivery on orbit; see example)

LV Risk Category	Category 1 (High Risk)	Category 2 (Medium Risk) 90/50 or 80/80 demonstrated	
Vehicle Maturity	No Flight History	Limited Flight History	
		Alternative 3	Alternative 2
Quality Management Systems	AS9100 or ISO 9001 Compliant	AS9100 Compliant	AS9100 Compliant
Flight Experience	No previous flights required, can use the first flight of a common launch vehicle configuration, instrumented to prove design verification and flight performance data Post Flight Operations/Anomaly Resolution Process Flight Data Assessment Process	1 successful flight of a common launch vehicle configuration, instrumented to prove design verification and flight performance data Post Flight Operations/Anomaly Resolution Process NASA Flight Margin Verification	3 (minimum 2 consecutive) successful flights of a common launch vehicle configuration, instrumented to prove design verification and flight performance data Post Flight Operations/Anomaly Resolution Process NASA Flight Margin Verification
System Safety	FMEA for all safety critical components Prelim and Final Hazards Analysis Compliance w/ applicable Range Safety Requirements	Demonstrated Compliance with Applicable Range Safety Requirements	Demonstrated Compliance with Applicable Range Safety Requirements
Design Reliability	NASA evaluation of LSC Design Reliability	NASA evaluation of LSC Design Reliability	NASA evaluation of LSC Design Reliability
Mfg, Ops and Sys Eng	NASA Audits, and Documented ICD Process	NASA Audits	NASA Audits
Quality Systems/Process	NASA Audit	NASA Audit	NASA Audit
Test and Verification	Acceptance Test Plans in Place, Ground and End to End Tests Completed	Comprehensive Acceptance Test Results	NASA Design Certification Review
Flight Hardware & Software Qualification	Space Qualified Hardware for application, testing complete	Series of NASA ERB's on Vehicle Subsystems	
Launch Complex	None	NASA ERB	
Launch Vehicle Analysis	Analysis Plan/Definition	Analysis Plan/Definition and NASA CLA IV&V	NASA IV&V
Integrated Analysis	None	None	None
Risk Management	Risk Plan, Mitigated & Accepted Technical/Safety Risks	Risk Plan, Mitigated & Accepted Technical/Safety Risks	Risk Plan, Mitigated & Accepted Technical/Safety Risks

Significant Differences Exist for Category 1

- Unlike Category 2 (medium risk) and Category 3 (low) risk, will not require NASA engineering agreement on hardware qualification status
 - Supplier will demonstrate to NASA that qualification has been done to supplier's standards
 - 2-3 day review
 - LSP reserves the right to withhold Category 1 Certification if the Contractor defined success criteria has not been met
 - Key systems: Core stage engines and tanks, flight computer and INU, engine actuators, main batteries and payload fairing
- NASA not required to perform any IV&V but could do so if the launch service provider would like an independent analysis performed (no charge to provider)
- Systems Engineering Audit may be accomplished via LSP participation in launch system development reviews (e.g. PDR, CDR and Qualification Data Review)
 - Note that VCLS reviews were required as technical milestones to protect NASA funding, not as a forum to obtain NASA concurrence/approval of design
- VCLS QDR milestone is the pathfinder for Category 1 Hardware Qualification assessment shown in back up (contract already has similar language for QDR)

Governing NASA Policy, NPD 8610.23, gives flexibility for recurring Mission Assurance

- Technical Oversight: Combination of focused approvals and technical insight of contractor launch activities
 - NASA retains the right to non-concur w/ contractor's proposed actions based on knowledge through insight
 - NASA uses a combination of specified approvals and targeted insight in order to establish, apply, and modify mission technical requirements, identify technical issues and resolve disputes, and assess the competency and adequacy of the technical work performed by the commercial launch service providers
 - Consistent with the responsibility to ensure the highest practicable probability of launch success, NASA will retain involvement in and control of the launch through a technical oversight approach, which combines focused approvals and technical insight of contractor launch activities
 - Policy applies to all NASA managed launches. Launches identified at the Flight Planning Board (FPB) as able to tolerate higher risk may utilize a modified technical oversight approach.
 - On orbit delivery is also a special consideration allowing a modified technical approach
- It seems inappropriate to have Technical Oversight as defined in this policy for Class D missions with "high risk" LVs that have had limited non recurring evaluation during certification
 - If Technical Authorities and Program Management have same expectations put upon them, then there is no chance for reduced mission assurance
 - Believe we should give up the Launch Vehicle "Go/No-Go for launch but retain Spacecraft Readiness Go/No-Go

NPD 8610.23

Thoughts on Recurring Mission Assurance for High Risk Missions

- As written, specific areas requiring government approval are focused on the interface with the spacecraft
 - Contemplating that any reduced recurring mission assurance would still have approval of following
 - S/C to LV Interface Control Documents (ICD's) and drawings
 - Mission Unique hardware design, analysis manufacture, test and anomaly resolution
 - Resolution/closeout of Mission Integration Working Group (MIWG), Mission Readiness Review (MRR) and Flight Readiness Review (FRR) action items
 - Spacecraft Handling Procedures
- Contemplating that some items would be deleted and a few moved from approval to insight (e.g.)
 - Mission Unique Software
 - Integrated spacecraft/launch vehicle test (portions that relate to spacecraft unique requirements)

NPD 8610.23

Thoughts on Recurring Mission Assurance for High Risk Missions

- As written, areas open to government insight are widespread
- 21 items as written with intent being essentially everything
 - Baseline vehicle design, analyses and configuration management
 - Production: Including reviews, plans, schedules, tests, post-test data, MRB's and critical flight hardware pedigree
 - Major system and integrated systems tests
 - Post-test data, anomaly resolution/closeout, failure analysis
 - Launch Site schedules, plans, vehicle preparation, closeout data, walkdowns, operations and procedure discipline
 - Post-launch data and anomaly investigations/closeouts
- Contemplating that reduced recurring mission assurance would have much less insight
- 7 or 8 specific items possible
 - Consider milestone based insight used to protect the investment rather than “retaining control of the launch”
 - Believe that 4 or 5 of the items listed in the NPD would remain as insight in addition to the items moved from approval to insight

AN EXAMPLE OF REDUCED MISSION ASSURANCE (previously approved by NASA Stakeholders for a specific mission)

- With the guiding principle being the commercial provider, not NASA, will be responsible for the launch success of the service, identified key areas that will provide the the best evaluation of the contractor's launch vehicle performance and technical risk
 - Non Recurring work is centered around key hardware systems with contributions to world wide failure history as a subset of the Hardware Qualification assessments made for Category 2 or 3 Cert
 - Recurring work is focused on build processes and insight into the specific vehicle anomalies, without ERB's
 - LSP Chief Engineer is not the NASA Technical Authority for the mission
 -
- Test Like You Fly Assessment (non-recurring)
 - System and component qualification based on vehicle design, analyses, test
 - Launch vehicle systems limited to propulsion, flight controls (Computer, INU, actuators), and separation
- GN&C and Flight Software Simulation and Recurring Software Development Practices (non-recurring)

A NASA APPROVED EXAMPLE OF REDUCED MISSION ASSURANCE

- Mission Reviews (recurring)
 - Provide an “advisory” assessment, at mission reviews (eg. Mission PDR, CDR, FRR) under the contract
- Post Flight Data Review launch vehicle, tracking and range data, launch vehicle anomaly investigations and closeouts
 - Flight Margin Verification ERB on 1 successful flight of common launch vehicle planned before first NASA launch (non recurring), Engineering Review on all subsequent flights of common launch vehicle (recurring)
- Quality, Reliability, Systems Engineering and Risk Management
 - Anomaly resolutions for the integrated assembly (recurring)
 - Major/critical problems, anomaly resolutions and failure analysis (recurring)
 - Production and systems test and Material Review Boards (recurring)- In factory
 - First Flight items

VCLS Key Provisions- More risk tolerant than Class D payloads

- Obtain an FAA license
- No LV Technical Oversight Clause in the Contract
- Only 9 CDRL's of which 3 require approval
- Conduct launch vehicle program reviews that provide evidence of launch vehicle maturity towards the contracted launch window and to provide the Government with appropriate evidence needed to satisfy milestone payments to the Contractor (9 milestones)
- Provide resolution of critical problem areas to minimize or eliminate schedule impacts.
- A report on the performance of subcontractors shall be included as part of any program reviews.
- Analysis required to validate the launch vehicle design shall be documented to the launch vehicle Contractor's standards
- Identify launch vehicle ground and flight safety launch constraints
- The Contractor shall provide access for up to three Government personnel at the launch site for familiarization and communication of launch status. Support should be consistent with the Contractor's day of launch available information, which may include access to real-time telemetry (RF and hardwire), voice communication channels with listen capabilities, video and telephones.

ADDITIONAL INFORMATION

Post Challenger LV Initial Launch Success 1988 thru December 31, 2016

- Common Launch Vehicle Configurations (CLVCs) use NPD 8610.7 definition as utilized by NASA LSP since approximately 1999
- 42 New US CLVCs with 33 failures out of 509 launches = 93.5%
 - Dominated by flights 1 thru 3 = 83.0%
 - 19 failures out of 112 (93/112)
 - 15 different vehicles of 42 had a failure ~ 36%
 - Flights 1 thru 14 (273/302) = 90.4%
 - Flights 14+ (203/207) = 98.1%
- 39 New Foreign CLVCs w/ 33 failures out of 652 launches = 94.9%
 - Dominated by flights 1 thru 3 = 84.4%
 - 15 failures out of 96 (81/96)
 - 12 different vehicles of 38 had a failure ~ 32%
 - Flights 1 thru 14 (285/311) = 91.6%
 - Flights 14+ (334/341) = 97.9%

* Partial failures = failure here but could count as certification success

Hardware Qualification Remains the Key Assessment for Category 1 Certification

- The LSC shall demonstrate the functional performance of launch vehicle components and systems/subsystems, with margin above maximum predicted environments encompassing the entire component life-cycle
- A Qualification Data Review (2-3 days duration) shall be presented by the LSC to provide NASA confidence in the LSC's ability to successfully deliver the launch service.
- Qualification is required to be accomplished against the Contractor's internal standards and is subject to LSP review; however, this review does not require or constitute NASA verification or agreement that the qualification meets NASA's definition
-
- LSP reserves the right to withhold Category 1 Certification if the Contractor defined success criteria has not been met or if there is other reasonable evidence to suggest the Qualification Test of a defined major/key item is unsuccessful
 - Core stage engines and tanks, flight computer and INU, engine actuators, main batteries and payload fairing
- For Category 1 Certification to be issued, completed qualification testing shall include major key systems proposed by the LSC and agreed to by LSP; however, must include new propulsion systems if applicable.

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- A Qualification Data Review (2-3 days duration) shall be presented by the LSC to provide NASA confidence in the LSC's ability to successfully deliver the launch service.
 - The LSC will present rationale to LSP showing that components and subsystems are "qualified" to contractor's satisfaction (i.e. meet contractor's internal standards deviation/waiver process and risk management practices).
 - The QDR shall include the as-built and qualified implementation/fabrication, component qualification, and system level qualification/compatibility. The presentation material of the QDR will cover all elements of the hardware's entire life cycle
 - Qualification rationale shall include the qualification and acceptance test and/or analysis levels, the environments derivation methodology and examples.
 - The rationale shall be clear on the use of analysis, test and/or similarity. All anomalies and deviations from the LSC test plans, with associated resolutions and rationale shall be identified.
 - While not held as an ERB, the LSP Chief Engineer, or designee, will chair the QDR with a small, multifunctional technical team that includes a mission assurance representative from SMA.
 - Qualification is required to be accomplished against the Contractor's internal standards and is subject to LSP review; however, this review does not require or constitute NASA verification or agreement that the qualification meets NASA's definition.
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 - The core stage engines and tanks, flight computer and INU, engine actuators, main batteries and payload fairing

Governing NASA Policy, NPD 8610.23, gives flexibility for recurring Mission Assurance

- Technical Oversight: Combination of focused approvals and technical insight of contractor launch activities
 - Insight: Acquiring knowledge and understanding of contractor's actions by monitoring of selected metrics and/or milestones through watchful observation, documentation review, meeting attendance, reviews, tests, and compliance evaluations
 - Approval: Providing the contractor authority to proceed and/or formal acceptance of requirements, plans, tests, or success criteria in specified areas
- NASA retains the right to non-concur with the contractor's proposed actions based on knowledge obtained through insight
- Policy applies to all NASA managed launches. Launches identified at the Flight Planning Board (FPB) as able to tolerate higher risk may utilize a modified technical oversight approach.
 - On orbit delivery is also a special consideration allowing a modified technical approach

It seems inappropriate to have Technical Oversight as defined in this policy for Class D missions with "high risk" LVs that have had limited non recurring evaluation during certification

VCLS Milestones and CDRLs

Event	Typical Payment Months Before/After Milestones*	Payment Amount Percentage
Kick Off Meeting	NET Award	5
System Requirements Review (SRR)	NET Award + 2 Weeks	5
Preliminary Design Review (PDR)	NET SRR + 3 Months	10
Critical Design Review (CDR)	NET PDR + 6 Months	15
Qualification Testing (QT)	CDR + 3 Months	20
Qualification Data Review (QDR)	NET QT + 3 Months	10
Launch Vehicle Readiness Review (LVRR)	NLT L- 3 Months	10
Flight Readiness Review (FRR)/Launch Readiness Review (LRR) & Launch	NLT L-0	5
Post-Launch Assessment Report	NLT Launch + 2 months	20

Item	Document	Approval/ Review/Submit	Initial Submittal Date	Subsequent Submittal Date	No. of Copies
1: Documentation					
VCLS-1 (C1-1)	Formal Meeting & Review Documentation	Submit	At Each Review	As Required (A/R)	A/R
VCLS-2 (C1-2)	Countdown Documentation	Review	L-1W	As Changed	3
2: Mission Integration					
VCLS-3 (C2-1.1)	Interface Control Document (ICD)	Approval	Preliminary ICD at PDR	Baseline ICD at CDR and A/R	3
VCLS-4 (C2-1.2)	Interface Control Document (ICD) Requirements Verification Matrix	Approval	NLT 3 months after Preliminary ICD CDRL approval	A/R or with each ICD revision	3
3: Reserved					
4: Analysis					
VCLS-5 (C4-1)	Performance and Guidance Accuracy Analysis (PGAA)	Initial Submittal = Review, Subsequent Submittals = Approval	PDR	QDR, A/R	3
VCLS-6 (C4-7)	Coupled Dynamic Loads Analysis	Review	PDR	QDR, A/R	3
VCLS-7 (C4-13)	Final Flight Report	Review	L+2 Months	A/R	3
5: Engineering					
VCLS-8 (C5-5)	Spacecraft Integrated Procedures	Approval	45D Prior to Use (for review and comment)	1W Prior to Use (for approval)	3
6: Telemetry and Communications					
VCLS-9 (C6-1)	Vehicle and GSE Telemetry Formats	Review	L+1 Months	As Changed with Configuration	3