Constellation Stretch Goals
Review of Industry Inputs

December 19, 2006

THE AEROSPACE CORPORATION

Study Team

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Outline

"Stretch Goals" Industry Study Background

- Part of multi-pronged approach by ESMD to reducing operational costs for CxP
- What is a "Stretch Goal"?
  - Forces major, discontinuous, global change
  - Spans most or all parts of a system
  - Appears impossible
  - Ultimately is feasible
- Aerospace tasked to collect, summarize, and analyze information

Source: Directorate Integration Office – ESMD "Stretch Goals" Activity Oct 16, 2006

Aerospace Tasks

- Collect Goals from Industry
  - Technical Interchange Meetings (TIMs) and follow-up telecons
  - Develop template for collection
  - Discussions and clarifications
- Organize
  - Consolidate similar goals
  - Summarize
  - Categorize
- Analyze
  - Potential savings
  - Cost of implementation
  - Performance or other impact/penalties
  - Roadblocks
  - Unintended consequences
  - Bottom line

Study Schedule

Event	Date
Industry TIM #1	Oct 16
One-on-One Meetings/Telecons with Industry	Oct 17 – Oct 27
Industry TIM #2	Oct 31
Aerospace Analysis	Nov 1 – Nov 30
Pre-SRR Goals Submittal	Nov 6
Report Delivery	Dec 20

Overview of Industry Inputs

- Overall, good participation and cooperation from all parties
- Total of 89 goals received from Industry by TIM #2
  - Industry submissions attached as appendix to this report
- After consolidation of similar entries, 53 distinct goals were evaluated
  - 54 goals were originally defined; however, the goal pertaining to the use of green propellants was removed from consideration due to extensive studies previously conducted by NASA
- Different ways to organize goals
  - Technical vs. Program Management vs. Business vs. etc.
  - Levels of application/implementation

Categorization by Type

- Design Solutions/Approaches (10)
  - Maximize commonality (5)
  - Specific design/technology solutions (5)
- Business/Contracts (5)
  - Intelligent cost sharing with other agencies and nations (3)
  - Incentivize contractors to reduce costs (fee structure) (1)
  - Flexibility in meeting small business goals (1)
- Program Management (16)
  - Requirements management and control (2)
  - Streamline government oversight (2)
  - Knowledge management (4)
  - Manpower/personnel management (5)
  - Other management (LCC, risk, margin) (3)
- Operations (22)
  - Design for operability (10)
  - Operations flow (8)
  - Define operational end state (4)

Categorization by Level

Level 1 - Program					Level 2 - Project				Level 3 - Element		
(1) Flexibility in Meeting Small Business Goals	(2) Life Cycle Cost Management	(3) International Collaboration	(5) DoD Cooperation	(6) Enforce Commonality	(4) Vehicle Operational Status	(15) Optimize Astronaut Corps Size	(19) Risk Management at Each Element	(21) Ship and Shoot	(20) Built in Test Equipment	(25) Mission Control at Second Stage Separation	(28) Adaptable Surface Systems
(7) Use COTS	(8) Incentivize Contracts for LCC	(9) Commercial Cooperation	(10) Streamline Oversight	(11) Responsibility, Authority, and Accountability	(23) Vertical Integration Timeline	(27) Streamline Testing	(32) Reduce Process Related Testing	(37) Hypergolic Servicing Consideration	(30) Crew Logistics	(31) Launch after Reaching Pad	(33) Hands-off Umbilicals
(12) Margin Management	(13) Modernize Software	(14) Functional Groups More Project Oriented	(16) Challenge Requirements	(17) Predictable Change Insertion	(38) Common Flight Software	(43) Standby Payload	(45) Automate On-orbit Capabilities	(47) On-orbit Servicing	(34) Skill-based Crew Training	(36) Smart Descent Stage	(39) MLP and Launch Pad Refurbishment
(18) Program-wide Uniform Systems	(22) Design for Operability	(24) Project Knowledge	(26) Reduced Sparing	(29) Metric Evaluation	(48) Roll Out and Launch Timeline	(51) Vehicle Transport Timeline	(52) Nuclear Power		(40) Launch Site Verification Accessibility	(42) Hardware Accessibility	(44) Automate Launch and Pre-Launch Control
(35) Asset Based Configuration Management	(41) Implement Lean Manufacturing	(46) Clean Pad	(49) Reliability and Redundancy						(50) Rollback Safety Req	(53) Lightning Protected LAS	

Note: (#) denotes Stretch Goal reference number

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Stretch Goals Analysis

- Top-level look at cost impacts and feasibility
  - Cost savings
  - Cost of implementation
  - Schedule, performance, and safety/reliability impacts
  - Political, cultural, and organizational roadblocks
  - Unintended consequences (both good and bad)
  - Bottom line
- Many of the goals are individually worthy of further study

Cost Analysis Methodology

- Potential savings based on idea of fully embracing goal
  - Less than full implementation would reduce cost impact

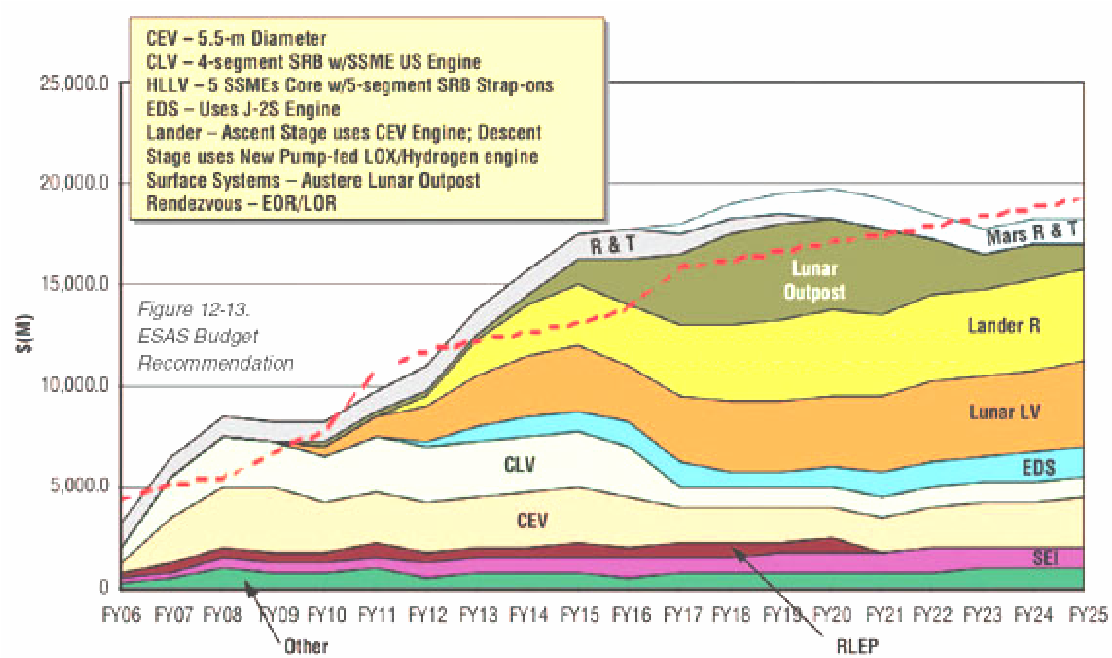
- Coarse quantity
  - Estimate a percentage of savings
  - Estimate size or scope of activity (budget data)
  - Multiply to get potential savings
  - Notional example
    - Reduction of contractor oversight estimated to save 20% of each contract, ~$100B in contracts will be handed out over 20 years, resulting in a potential for ~$20B in savings

- Estimate
  - Using models, examples, engineering build-up
  - Notional example
    - Automated launch umbilicals have the potential of reducing launch operations cost by $5M per launch or $140M over 20 years, which will be offset by increased infrastructure costs

Analysis Assumptions and Scope

- Assumptions
  - 20-year life cycle (2006 - 2025)
  - Constellation flight manifest (as of Fall 2006) assumed through 2020
  - 2 flights/yr for CLV, 2 flights/yr for CaLV assumed after 2020

Notional Scope Example: Cx Budget (from ESAS Report)



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Analysis Criteria

- Cost Implications
  - **Potential Savings** = Approximate maximum cost savings over Cx life cycle
  - **Cost of Implementation** = Approximate cost incurred to implement goal
  - Rating Criteria:

L	M	H
<$100M	$100M - $1,000M	>$1,000M

- Program Impacts
  - **Schedule** = Negative impacts on development and/or mission schedule
  - **Performance** = Negative performance impacts on any Cx vehicles
  - **Safety and Reliability** = Overall impact on mission safety and reliability
- Roadblocks
  - **Political** = Issues concerning Congressional involvement, the Cx Budget, public interest, etc.
  - **Cultural** = Issues challenging the traditional methodologies, practices, etc. of NASA
  - **Organizational** = Issues concerning delegation of work to the NASA centers
- Unintended Consequences
  - Potentially unforeseen consequences (positive and negative) due to implementation of goal

Priority Rating

- Description
  - Subjective “bottom line” summary which combines potential cost savings, cost of implementation, schedule, performance, and safety impacts, roadblocks, and unintended consequences
  - Cross-checked using an objective analysis (e.g. weighting the above criteria and consolidating using a mathematical formula)

- Rating Criteria
  - 5 = Recommended
  - 4 = Tentatively recommended, but may need further study
  - 3 = Further study required
  - 2 = Tentatively not recommended, but may need further study
  - 1 = Not recommended

Stretch Goals Index

Design		Business/Contracts			Program Management					Operations		
Design for Commonality	Specific Design/Tech Solutions	Cost Sharing	Fee Structure	Small Business Goals	Requirements Management	Government Oversight	Knowledge Management	Personnel Management	Other Management	Design for Operability	Operations Flow	Operational End State
(6) Enforce Commonality	(13) Modernize Software	(3) International Collaboration	(8) Incentivize Contracts for LCC	(1) Flexibility in Meeting Small Business Goals	(11) Responsibility, Authority, and Accountability	(10) Streamline Oversight	(18) Program-wide Uniform Systems	(15) Optimize Astronaut Corps Size	(2) Life Cycle Cost Management	(20) Built in Test Equipment	(21) Ship and Shoot	(4) Vehicle Operational Status
(7) Use COTS	(30) Crew Logistics	(5) DoD Cooperation			(16) Challenge Requirements	(14) Functional Groups More Project Oriented	(24) Project Knowledge	(25) Mission Control at Second Stage Separation	(12) Margin Management	(22) Design for Operability	(23) Vertical Integration Timeline	(17) Predictable Change Insertion
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										(42) Hardware Accessibility	(50) Rollback Safety Req.	
										(46) Clean Pad	(51) Vehicle Transport Timeline	
										(49) Reliability and Redundancy		
										(53) Lightning Protected LAS		

Key:

Stretch Goal Number (#)

Priority Ranking: 5 | 4 | 3 | 2 | 1

1. Flexibility in Meeting Small Business Goals

5 PRIORITY

Stretch Goal Description/Implementation

Allow Primes to account all of their supplier's small business contracts to meet the small business goal. Ensures required percentage of NASA contracted work goes to small businesses with greater flexibility for all Primes.

Cost Implications

	Score	Discussion
Cost Savings	H	5% of all contracted work through 2025.
Cost of Implementation	L	No significant costs.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability	None Expected	

Roadblocks

	Score	Discussion
Political	L-M	Some complaints from small businesses that get phased out.
Cultural	L	None Expected
Organizational	L	None Expected

Unintended Consequences

Source Traceability

ATK 3

Bottom Line - **Potential for large savings with no significant downsides by removing inefficiencies in current small business contracting methods.**

2. Life Cycle Cost Management

5 PRIORITY

Stretch Goal Description/Implementation

Implement life cycle cost management at the Constellation Program level and at each element of Constellation. Establish office responsible for LCC of all Constellation programs and all phases.

Cost Implications

	Score	Discussion
Cost Savings	H	Implementing LCC management can result on the order of 5% LCC savings by allocating funds to manage down risks.
Cost of Implementation	M	May require development of specialized systems/software to keep all apprised of LCC impact due to design changes.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	M	Focus on LCC management implies that performance may be sacrificed for cost savings when necessary.
Safety & Reliability		Minimal impact expected.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	NASA is shifting this direction, but substantial changes still required.
Organizational	M	Putting LCC management tools in hands of engineers may result in resistance from established cost analysis groups.

Unintended Consequences

LCC management tools can involve engineers more thoroughly in the design process (i.e. by knowing LCC impact of any design changes). Cost optimal designs may result in difficulty meeting performance requirements. Inaccuracies in LCC management tools may lead to poor design decisions.

Source Traceability

Boeing 2,4 / USA 23

Bottom Line - **LCC management is a good way to manage the balance between designing for LCC and optimal performance. Boeing commercial aircraft example demonstrates the utility of thoroughly implementing this technique.**

3. International Collaboration

PRIORITY 4

Stretch Goal Description/Implementation

Optimize international collaboration by early planning and minimizing development overlap.

Cost Implications

	Score	Discussion
Cost Savings	H	Optimize international collaboration by getting international partners (IPs) to develop 20% of the required surface systems (e.g. ISRU test experiment).
Cost of Implementation	L	Some overhead of dealing with IPs (e.g. review boards, IP offices, etc.). Increased cost of hardware interfaces.

Program Impacts

	Score	Discussion
Schedule	L	None Expected. Surface systems development not in near term.
Performance	L	None Expected
Safety & Reliability	None Expected	

Roadblocks

	Score	Discussion
Political	M	Could be good or bad impact, depending on government opinions and/or amount of savings projected.
Cultural	M	Some disagreement on IP roles may be present (due to ISS experiences).
Organizational	M	Moving projects (even minor ones) from NASA to IPs could face resistance.

Unintended Consequences

If mismanaged, could result in ISS-like situation where IP projects are canceled or sit on the ground for 5+ years before launch. Could result in non-monetary obligations to NASA (e.g. sending a foreign astronaut to the Moon as compensation).

Source Traceability

H-S 4

Bottom Line - **Should be investigated to see if savings are possible. Planning and management are key to avoiding problems facing ISS international collaboration.**

4. Vehicle Operational Status

4 PRIORITY

Stretch Goal Description/Implementation

Create clearly defined approach for declaring vehicles operational. During the DDT&E flight test phase establish and certify a flight envelope. Clear and operate a vehicle only within said flight envelope. Implement flight element block upgrades. Envelope expansion-certification to accommodate system growth when required.

Cost Implications

	Score	Discussion
Cost Savings	H	If vehicle is certified operational sooner, then reduction in tests per flight. Assume 20% reduction in operational flight costs through 2025.
Cost of Implementation	L	Additional studies required to determine flight envelopes. Studies/boards needed to determine pre-launch testing.

Roadblocks

	Score	Discussion
Political	M	Reduced testing may be seen by Congress as a reduction in safety.
Cultural	M	Shift towards operational concept requires large cultural shift. Managers need to accept less testing during ops.
Organizational	L-M	Could result in shifting of responsibilities to different groups/organizations.

Program Impacts

	Score	Discussion
Schedule	L-M	More studies on determining correct flight envelope could lengthen DDT&E.
Performance	H	Could result in increased flight margins depending on flight envelope.
Safety & Reliability	Ops phase test reductions may be negative (i.e. not finding potential failures) or positive (i.e. less chance to cause problems by over-testing).	

Unintended Consequences

Low flight rate may make it difficult to see savings -- especially since there are only 5 ISS flights (with 2? manned missions) before doing lunar missions. Taking into account "operational" status may cause vehicles to be designed for larger flight envelopes, and may increase margins/capabilities.

Source Traceability

Boeing 8 / USA 3 / NGC 5 / ATK 1

Bottom Line - **Potential for large savings, but studies must be performed to determine level of applicability to low flight rate, human-rated systems. This is one area where Shuttle shows how the opposite case can significantly increase the amount of testing required.**

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5. DoD Cooperation

4 PRIORITY

Stretch Goal Description/Implementation

25% funding from military programs technology or hardware sharing or leverage investment.

Cost Implications

	Score	Discussion
Cost Savings	H	25% savings in DDT&E costs for major Cx components with common uses across both agencies (e.g. RS-68).
Cost of Implementation	L	Establish board or process to coordinate with DoD. May require investment in DoD capabilities not essential to NASA.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	Reduced performance due to non-optimal designs.
Safety & Reliability		None Expected

Roadblocks

	Score	Discussion
Political	L	None Expected. My be encouraged by Congress for cost savings.
Cultural	H	Requires NASA to share development with DoD. Shuttle experience may make DoD extra cautious to cooperate.
Organizational	H	NASA and DoD often have very different systems requirements. Resistance to moving development to DoD.

Unintended Consequences

Could end up in Shuttle-like scenario where cost-sharing is originally agreed to, but later removed due to DoD losing interest. As a nation, reduction in overall technology development.

Source Traceability

H-S 8

Bottom Line - **Good method to save some money (e.g. RS-68 in particular). May be difficult on scale of stated goal, but further investigation is warranted. This has been a goal in many previous programs but savings have never been realized.**

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6. Enforce Commonality

PRIORITY 4

Stretch Goal Description/Implementation

Commonality of Cx elements enforced by minimize development of unique (element-specific) components to the greatest extent possible.

Cost Implications

	Score	Discussion
Cost Savings	H	Assume 10% overall LCC savings. 5-50% DDT&E & production reduction for applicable components, and may use of cheaper/standardized items.
Cost of Implementation	L-M	Will require trade studies and coordination among different subsystem and system teams to determine areas to take advantage of commonality.

Roadblocks

	Score	Discussion
Political	M	Contracts rewritten to ensure common component usage across contractors.
Cultural	M	Focus on less optimization and more use of common systems.
Organizational	M	Possible responsibility conflicts among different groups for common components used in different systems.

Program Impacts

	Score	Discussion
Schedule	L	None Expected. May actually improve schedule if due to less development required in later years (due to use of common components).
Performance	H	Could result in less-optimized designs depending on level of commonality enforced.
Safety & Reliability		More testing can be done on a per-component basis (i.e. less unique testing required). But, may increase use of non-ideal components.

Unintended Consequences

Non-optimal designs may reduce performance and create difficulties in closing performance margins for various Cx vehicles. Poor implementation could result in low margins or use of common components in non-ideal situations.

Source Traceability

Boeing 9 / USA 1 / H-S 2 / NGC 7

Bottom Line - **Multi-$B cost savings range over the life cycle of the program. Proper implementation early in the design process is essential to realizing large cost savings with minimal negative impacts. Further study to determine appropriate areas to enforce.**

7. Use COTS

4 PRIORITY

Stretch Goal Description/Implementation

Develop a design philosophy which uses COTS systems as first choice.

Cost Implications

	Score	Discussion
Cost Savings	H	Assuming a 5% reduction to CEV, CLV, CaLV, Lander and Mission Ops DDT&E costs. Further, recurring costs savings may also result.
Cost of Implementation	M	Increased procurement, qualification and testing costs. Glueware and hardware modifications/integration costs. Cx program may be in too small a market to reap most of COTS benefits.

Roadblocks

	Score	Discussion
Political	L	Possible industry lobbying against adopting a greater reliance in COTS.
Cultural	M	Resistance on producing a non-optimal design.
Organizational	L	Possible resistance to commercializing formerly NASA functions.

Program Impacts

	Score	Discussion
Schedule	L	Theoretically schedule acceleration is possible, but COTS implementation has not consistently led to significant schedule gains.
Performance	L-M	Increased weight due to non-optimal design to incorporate COTS.
Safety & Reliability		There may be pressure to make non-optimal choices to make COTS work. COTS products generally have support for 5 to 7 years.

Unintended Consequences

Requirements creep forces COTS product to no longer be viable. Insight to COTS source code, may be unavailable. May aid private space entrepreneurship. May increase greater compatibility with DOD and NOAA space systems.

Source Traceability

USA 6, 19

Bottom Line - **Large cost savings if appropriate commercially available systems available, but uniqueness of Cx may COTS gains as there is not a wide market to drive incentives for COTS development, improvement and maintenance. Further study would be needed.**

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8. Incentivize Contracts for LCC

PRIORITY 4

Stretch Goal Description/Implementation

Implement Cx Contracts which directly incentivizes industry to contain and reduce program LCC. Could do the job at lower cost with the right contract structure/incentives.

Cost Implications

	Score	Discussion
Cost Savings	H	Assume up to 10% overall LCC savings vs. standard contracting procedures. Cost reduction may occur primarily in DDT&E, but some production savings may also be realized.
Cost of Implementation	L	Investigation into proper ways to structure contracts (on a per-element and per-contractor basis) is required.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability		Incentivizing contractors could result in safer systems if safety is used as a contract incentive. However, cost-cutting by contractors (to meet goals and bonuses) may result in cutting corners on reliability.

Roadblocks

	Score	Discussion
Political	H	Large paradigm shift in government contracting methods.
Cultural	H	Large paradigm shift in government contracting methods.
Organizational	L-M	Will require different ways of doing things.

Unintended Consequences

High risk in new contracting methods has potential to result in large cost overruns. (e.g. 1990's AF Acquisition Reform).

Source Traceability

ATK 2 / Boeing 34 / USA 24 / NGC 1

Bottom Line - **Has potential to induce multi-$B savings, but will require a large change in contracting methods. Further studies required.**

9. Commercial Cooperation

4 PRIORITY

Stretch Goal Description/Implementation

Establish a less adverse role with contractors by implementing commercially supportable business plans; 25% funding through commercial means. Encourage contractor participation/cost sharing and other creative business arrangements.

Cost Implications

	Score	Discussion
Cost Savings	H	Realize 25% savings in DDT&E costs for major Cx elements (Orion, Ares I, Ares V, and Lander) by motivating industry investment through ownership.
Cost of Implementation	L	Cost incurred for studies on which ownerships (e.g. EDS technologies, etc.) can be transferred to industry.

Roadblocks

	Score	Discussion
Political	H	Large paradigm shift in government contracting methods.
Cultural	H	NASA typically maintains ownership of major components.
Organizational	H	Current administration wants to increase NASA's role in development.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability		None Expected

Unintended Consequences

May increase difficulty/cost of leveraging technology developments in future programs (e.g. may require additional cost given to contractors). Could lessen NASA's role in technology development. High risk in new contracting methods has potential to result in large cost overruns. (e.g. 1990's AF Acquisition Reform)

Source Traceability

H-S 7

Bottom Line - **Has potential to induce multi-$B savings, but will require substantial shift in culture and development methodology. Further studies required.**

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10. Streamline Oversight

4 PRIORITY

Stretch Goal Description/Implementation

Modify government oversight of contractor operations. Reduce the number of civil servants assigned to contracted work. Reduce the reporting requirements for contracted work.

Cost Implications

	Score	Discussion
Cost Savings	H	20% reduction in all contracted costs through 2025
Cost of Implementation	L	Cost of implementation will include the reassignment and training of civil servants to other programs.

Roadblocks

	Score	Discussion
Political	M	Due to reduced government auditing of contracting work.
Cultural	H	This would require a large paradigm shift in way NASA deals with contractors.
Organizational	H	Reassigning civil servants to other programs will probably meet heavy resistance.

Program Impacts

	Score	Discussion
Schedule	M	Potential for increased schedule risk due to decreased oversight.
Performance	L	None Expected
Safety & Reliability	Reducing the number of civil servants overseeing contractor activities may have a negative impact on safety and reliability.	

Unintended Consequences

May result in reduced contractor performance due to reduced oversight.

Source Traceability

Boeing 33 / PWR 1, 3 / ATK 1

Bottom Line - **Reducing government oversight of contractors is a good way for NASA to cut costs, however, this will take a large shift in the way NASA currently does business. Less oversight will increase development risk.**

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11. Responsibility, Authority, and Accountability

4 PRIORITY

Stretch Goal Description/Implementation

Establish criteria and clear RAA for development and operations organizations and their contractors during each phase. Define clear roles (RAA) for operators, developing/sustaining engineering organizations during mission execution. Create joint DDT&E/Ops team to define philosophy criteria and roles. Delegate decision making to the lowest level possible.

Cost Implications

	Score	Discussion
Cost Savings	H	Simplify management and reporting. Potential savings of up to 5% for all LCC.
Cost of Implementation	L-M	Studies required to clearly define RAA.

Program Impacts

	Score	Discussion
Schedule	L	Should improve schedule.
Performance	L	Little impact seen.
Safety & Reliability	Streamline RAA may result in reduction in review that catch potential safety and reliability issues.	

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Will require cultural shift away from program oversight to program support
Organizational	H	Will results in major power shifts across all centers

Unintended Consequences

While reporting may be streamlined, care must be taken that systems engineering and safety oversight is not marginalized by lower level review boards that do not see the larger picture.

Source Traceability

USA 3, 8

Bottom Line - **Streamlining the management and reporting chain could potentially increase efficiency, but it will be challenging and must be done with care to not over-compartmentalize organizations.**

12. Margin Management

4 PRIORITY

Stretch Goal Description/Implementation

Margin management shall be implemented during the development phase of each new system.

Cost Implications

	Score	Discussion
Cost Savings	**H**	50% reduction in cost overruns (taken from allocated reserves in Cx budget) less the increased baseline cost.
Cost of Implementation	**L-M**	Will require increased overhead for board reviews, systems margin management tools, etc.

Program Impacts

	Score	Discussion
Schedule	**L**	None Expected
Performance	**M-H**	Maintaining higher margins will directly impact performance capabilities.
Safety & Reliability		Higher margins will result in higher factors of safety.

Roadblocks

	Score	Discussion
Political	**L**	None Expected
Cultural	**H**	Historically, NASA has encountered overruns due to tight margins during development. Realizing the full benefit of margin management will take a shift in current design methods.
Organizational	**M**	Implementing margin management will take a cohesive effort by multiple centers.

Unintended Consequences

Increased margins early in development will drive the design to meet performance requirements and may result in larger, simpler vehicles. Use of heritage systems leaves less flexibility to implement margin management.

Source Traceability

Boeing 1

Bottom Line - **Margin management may be a good way to reduce cost overruns, but will require a change in NASA's design approach. Further studies required.**

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13. Modernize Software

PRIORITY 4

Stretch Goal Description/Implementation

Adopt state-based modeling to drive software design; allow auto coding.

Cost Implications

	Score	Discussion
Cost Savings	M-H	Reduced cost of software development and maintenance. S/W development for Cx maintenance costs are expected to be significant. Savings potential estimated to 10-25% of cost.
Cost of Implementation	M	Certifying new methods will be a significant undertaking. Cost to make modern work with legacy code.

Program Impacts

	Score	Discussion
Schedule	M	Simplified development may accelerate timelines, but certifying methods will be a significant endeavor.
Performance	L	None Expected
Safety & Reliability		Will require certification of new methods to keep current levels of reliability for critical operations.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Opposition expected due to significant shift away from legacy methods.
Organizational	L	Some commonality will need to be maintained across centers and projects. Will require hiring new or retraining staff.

Unintended Consequences

Modern coding techniques may allow usage of identical code blocks among different Cx elements.

Source Traceability

Boeing 27

Bottom Line - **Cx represents an opportunity to change NASA software away from legacy systems that are difficult to maintain. Modernized software is highly desirable, but caution must be used in its implementation.**

14. Make Functional Groups More Project Oriented

PRIORITY 4

Stretch Goal Description/Implementation

Define the success criteria for functional organizations in NASA (engineering) to partially include meeting project goals and deadlines.

Cost Implications

	Score	Discussion
Cost Savings	M-H	Will result in more success-driven oversight and reduced requirements creep. Up to 10% reduction in all developments through reduced cost overruns.
Cost of Implementation	L	Change in culture and philosophy.

Program Impacts

	Score	Discussion
Schedule	L	Should improve schedule.
Performance	L	Little impact seen.
Safety & Reliability	Success-driven oversight and schedule pressures may lead to reduced emphasis on safety and reliability.	

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M-H	Will require major cultural shift away from program oversight to program support.
Organizational	L	None Expected

Unintended Consequences

Less adversarial relationship should develop between civil servants and contractors leading to improved communications. Pendulum may swing too far toward goals of meeting deadlines and away from mission assurance.

Source Traceability

PWR 2

Bottom Line - **Will reduce schedule slips and requirements creep. It will be difficult to balance success goals with oversight requirements. Care must be made to insure the pendulum doesn't swing too far.**

15. Optimize Astronaut Corps Size

4 PRIORITY

Stretch Goal Description/Implementation

Develop crew cadre sizing model such that size of astronaut corps is optimized and crew support infrastructure is reduced. Create independent study team to define criteria/approach.

Cost Implications

	Score	Discussion
Cost Savings	M-H	Reduce current corps size by 50-100, over 20 yrs.
Cost of Implementation	L	Implementing this goal would take very little upfront investment.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	H	Astronauts have significant influence within NASA. Reducing the size of the astronaut corps would meet major resistance within this group.
Organizational	M	JSC would not like this at all.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability		Increased flight rate per astronaut will increase experience.

Unintended Consequences

Reducing the astronaut corps may potentially result in a reduction in skills/capabilities.

Source Traceability

USA 11

Bottom Line - **Optimizing the size of the astronaut corps shows a potential of significant savings, but implementing this may meet with heavy resistance.**

16. Challenge Requirements

4 PRIORITY

Stretch Goal Description/Implementation

Challenge new requirements before they are incorporated and periodically challenge the need for requirements already in spec.

Cost Implications

	Score	Discussion
Cost Savings	M-H	Will result in reduced requirements creep. Up to 10% reduction in all developments through reduced cost overruns.
Cost of Implementation	L	Change in culture and philosophy.

Program Impacts

	Score	Discussion
Schedule	L	Should improve schedule.
Performance	L	Little impact seen.
Safety & Reliability		May lead to reduced emphasis on safety and reliability, but relaxing some requirements may actually increase safety by removing conflicts.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	H	Will require major cultural shift away from program oversight to program support.
Organizational	L	None Expected

Unintended Consequences

Pendulum may swing too far toward goals of meeting deadlines and away from mission assurance. Increased challenge in adding requirements may just increase bureaucracy while maintaining equal number of requirements.

Source Traceability

Aerospace via industry discussions.

Bottom Line - **Will reduce schedule slips and requirements creep, but will require a major cultural shift within NASA.**

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17. Predictable Change Insertion

PRIORITY 4

Stretch Goal Description/Implementation

Exclude all significant vehicle modifications or configuration changes from ground processing flow. Implement as block updates by OEM at predetermined intervals and prior to KSC processing.

Cost Implications

	Score	Discussion
Cost Savings	M	Reduced testing/staffing required to adjust for configuration changes due to no significant modifications between block updates. 5% reduction in recurring operations cost.
Cost of Implementation	L	May require more considerations of operations during design process.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Not allowing configuration changes between block updates requires changes in operational methods.
Organizational	M	May result in less work for KSC, etc.

Program Impacts

	Score	Discussion
Schedule	L-M	Will require more coordination and investigation into proper interfaces to incorporate.
Performance	L-M	May cause increased margins to future-proof block design.
Safety & Reliability		Could inhibit reliability/safety changes between block upgrades. Would increase confidence due to use of flight-proven configurations.

Unintended Consequences

Prohibiting configuration changes lowers chances of using vehicles for special missions. Larger importance of determining the "right" interfaces/etc during development implies that mistakes or poor decisions could lead to large cost growths later.

Source Traceability

USA 10

Bottom Line - **Similar to Vehicle Operation Status, designing for less ground ops due to less mission-specific changes implies potential for cost savings and streamlined operations. Further investigation required to better determine benefits.**

18. Program-wide Uniform Systems

4 PRIORITY

Stretch Goal Description/Implementation

Implement single, program-wide processes and systems for key areas including: management systems, requirements management, simulation and flight verification math models.

Cost Implications

	Score	Discussion
Cost Savings	H	Cost savings due to combination of RAA, commonality, and project knowledge.
Cost of Implementation	M-H	Majority of costs incurred by standardizing tools and systems.

Roadblocks

	Score	Discussion
Political	L	Reduced number of tool contracts.
Cultural	M	Will change the current practices.
Organizational	H	Will require major changes in tool and management system usage between individual organizations.

Program Impacts

	Score	Discussion
Schedule	L	Potential schedule slip due to implementation of common systems.
Performance	L	None Expected
Safety & Reliability		Improved common data formatting and management systems will result in reduced errors.

Unintended Consequences

Will facilitate greater understanding between centers and allow easier transition for personnel between centers and from contractors to civil service. Uniform systems will encourage reduction in redundant groups across centers. Will reduce ability to perform independent verification of model results.

Source Traceability

USA 2, 5

Bottom Line - **Potential to streamline NASA operations significantly, but will be a major challenge to implement. Will encourage the realization of "One NASA."**

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19. Risk Management at Each Element

PRIORITY 4

Stretch Goal Description/Implementation

Probability based risk management program should be implemented at each element .

Cost Implications

	Score	Discussion
Cost Savings	M-H	Optimize effort of meeting risk requirements by not pursuing requirements that have diminishing returns. 10% reduction in manned systems and 5% reduction in unmanned DDT&E cost.
Cost of Implementation	L-M	Early detailed analysis of failure modes is required.

Program Impacts

	Score	Discussion
Schedule	L	Any lengthening due to increased initial analysis should be offset by less stringent requirements.
Performance	L	Reduced requirements should allow for increased performance.
Safety & Reliability		Potential for overall system improvement through improved probabilistic risk analysis.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	H	All safety and human-rating guides will need to be rewritten. Subsystems will have reduced safety requirements.
Organizational	L	None Expected

Unintended Consequences

Inaccurate analysis may result in poor allocation of funds and increased safety risk.

Source Traceability

Boeing 3

Bottom Line - Will create a more analysis-based method of setting optimal requirements leading to significant cost savings. Full implementation will require difficult analysis and a major cultural change.

20. Built in Test Equipment

4 PRIORITY

Stretch Goal Description/Implementation

Require Built in Test (BIT) equipment for all avionics.

Cost Implications

	Score	Discussion
Cost Savings	L	Savings will come from reduction in labor required to test avionics systems. May also help reduce launch delays.
Cost of Implementation	L	BIT has been around for awhile especially in aircraft.

Program Impacts

	Score	Discussion
Schedule	L	Minor impact on development schedule.
Performance	L	Should be minimal.
Safety & Reliability		Impact on reliability not clear.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	Less likely to open systems and investigate with built-in test present.
Organizational	L	Higher initial costs in development.

Unintended Consequences

False positives/negatives. Will provide more mission data, which could be useful in event of an anomaly.

Source Traceability

Boeing 17 / USA 20

Bottom Line - **Mature technology that should be investigated for use in Cx elements.**

21. Ship and Shoot

PRIORITY 4

Stretch Goal Description/Implementation

Stage and element verification prior to shipping to launch site. Maximize activities at manufacturing site to minimize launch site processing.

Cost Implications

	Score	Discussion
Cost Savings	M	Savings in Ground Flight Integration. Assume net 20% savings for CEV, LV and LSAM ground operations and 5% for Integrated Operations.
Cost of Implementation	L	Possibility for small cost increased due to DDT&E for pre-assembly, personnel training, and logistics for pre-assembly.

Program Impacts

	Score	Discussion
Schedule	L	Changes in delivery system may require additional development actions.
Performance	L	None Expected
Safety & Reliability	None Expected	

Roadblocks

	Score	Discussion
Political	M	Would result in shift in center responsibility away from KSC.
Cultural	M-H	Engineering shift toward pre-assembly mind frame. Lack of testing after delivery will reduce confidence.
Organizational	L	Possibility of work/responsibility from KSC to other centers.

Unintended Consequences

Reduced sparing at launch site, difficult logistics

Source Traceability

Boeing 14 / USA 19

Bottom Line - **Requires further investigation, but looks like a beneficial stretch goal with a high probability of cost savings.**

22. Design for Operability

4 PRIORITY

Stretch Goal Description/Implementation

Involve manufacturing and launch operations in the design process.

Cost Implications

	Score	Discussion
Cost Savings	H	Assume 20% savings in total Cx operations budget due to inclusion of operability considerations during vehicle designs.
Cost of Implementation	M-H	Will require greater coordination of ground design team with Orion/Ares/Lander teams. Designing for operability may require further trade studies to be performed.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M-H	Designing less-than-optimal systems may be difficult -- goes against what's been done in the past.
Organizational	M	Greater focus on operability may increase conflict among different centers

Program Impacts

	Score	Discussion
Schedule	M	Development time may be increased due to greater coordination/design required.
Performance	H	Designing for operability may result in less-optimal designs, which will increase mass.
Safety & Reliability	May increase safety depending on design changes made, but could also decrease reliability if margins are cut too close.	

Unintended Consequences

Depending on magnitude of any mass increase, Ares I and Ares V designs may face difficulty in closing.

Source Traceability

ATK 1

Bottom Line - **Magnitude of potential savings implies that this should be investigated further.**

23. Vertical Integration Timeline

4 PRIORITY

Stretch Goal Description/Implementation

From the start of stacking of major elements in the vertical integration facility to initiation of roll out must be accomplished within a 20 workday span. This provides for reduction in the number of processing bays in order to support launch manifest.

Cost Implications

	Score	Discussion
Cost Savings	M-H	Assume 25-40% savings in ground integrated operations through 2025.
Cost of Implementation	M	Potential for significant design costs to increase operability.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Designing less-than-optimal systems may be difficult -- goes against what's been done in the past.
Organizational	M	Greater focus on operability may increase conflict among different centers

Program Impacts

	Score	Discussion
Schedule	L	Would at most reduce schedule by a matter of days.
Performance	M	Increased design for operability, thus reducing performance.
Safety & Reliability	None Expected	

Unintended Consequences

Source Traceability

LM 1

Bottom Line - **Magnitude of potential savings implies that this should be investigated further.**

24. Project Knowledge

4 PRIORITY

Stretch Goal Description/Implementation

Implement Knowledge Management processes. Establish knowledge structure to allow sharing of work and experiences. Utilize technology to archive written or recorded work and experiences. Develop and maintain visual model and matrix relating archived written or recorded experiences to specific hardware/software attributes.

Cost Implications

	Score	Discussion
Cost Savings	M-H	Should facilitate design especially at the system and element interfaces. 5% reduction in design costs.
Cost of Implementation	M	Requires development of a very capable database and effort to ensure proper data formatting.

Roadblocks

	Score	Discussion
Political	H	Contractor proprietary data will be a major challenge.
Cultural	L	Some additional work to fully document data.
Organizational	H	Will require common database with common data formatting across all centers.

Program Impacts

	Score	Discussion
Schedule	L	Each element may take a bit longer in design phase to fully document, but should reduce assembly issues.
Performance	L	Little impact seen.
Safety & Reliability	Will facilitate systems level analysis of safety and reliability.	

Unintended Consequences

Will facilitate block upgrades and minimize design obsolescence.

Source Traceability

USA 9

Bottom Line - Will facilitate various centers and contractors working from same set of data. Will be a major undertaking requiring cooperation from all centers and contractors.

25. Mission Control at Second Stage Separation

4 PRIORITY

Stretch Goal Description/Implementation

Launch and flight control systems shall be consolidated and control turned over to mission control after second stage separation.

Cost Implications

	Score	Discussion
Cost Savings	L	Small cost savings through 2025 due to the reduction in MCC requirements (at the level of ~4 technicians) at JSC and streamlined accountability
Cost of Implementation	L	Low cost of implementation.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability		Reduction in redundancy of mission control operations.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	None Expected
Organizational	H	Will give KSC more influence vs. JSC.

Unintended Consequences

None foreseen, but would prompt discussion on moving to single control center for entire mission.

Source Traceability

Boeing 22

Bottom Line - **Current method is a historical throwback. No significant cost savings, but no substantial reason not to give further attention.**

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26. Reduced Sparing

3 PRIORITY

Stretch Goal Description/Implementation

50% reduction in hardware redundancies; dissimilar sparing; more serviceable in orbit.

Cost Implications

	Score	Discussion
Cost Savings	H	Reparability will drive use of common components/interfaces. Up to 5% reduction in LCC for increased commonality.
Cost of Implementation	M	Will require more coordination among different subsystem teams, implementation of tools to increase data/knowledge sharing.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Requires focus on less-optimal but more-redundant systems.
Organizational	M	Requires focus on less-optimal but more-redundant systems.

Program Impacts

	Score	Discussion
Schedule	L	Minimal impact if changes are propagated to different teams in a timely fashion.
Performance	M	May lead to less-structurally efficient (i.e. less-optimized) components.
Safety & Reliability		Increased safety due to ability of crew to perform on-orbit repairs; increased redundancy.

Unintended Consequences

Possible mass growth in CEV and LSAM may impact available launch margins (e.g. Boeing indicated 5-7% mass growth due to common parts/interfaces on commercial aircraft)

Source Traceability

H-S 5

Bottom Line - **Degree of savings depends on how much commonality is increased. Could lead to substantial savings with relatively low cost incurred, and should be investigated more thoroughly. Degree of practical implementation is unknown.**

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27. Streamline Testing

3 PRIORITY

Stretch Goal Description/Implementation

Test beyond nominal to establish acceptable parameters (reduces MRBs disposition time and specific testing, and reduces MRBs). Establish test requirements that will meet the program requirements. Design to those requirements only (don't over-design). Also, test to those design requirements rather than finding the edge of the cliff. Project PMs need to use judgment on what limits to test depending on the criticality of the system.

Cost Implications

	Score	Discussion
Cost Savings	H	Less testing (i.e. not testing to failure) will result in 10% reduction in flight integration ops and element production costs.
Cost of Implementation	L-M	Trade studies and review panels will need to be formed during the DDT&E process to determine appropriate requirements to test to.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	H	Could result in less-efficient designs if requirements are higher than currently applied.
Safety & Reliability		Less testing (and not testing to find failure points) may result in less confidence in safety and reliability of elements.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Requires shift in testing/development mindset.
Organizational	L-M	Could result in shifting of responsibilities to different groups/organizations.

Unintended Consequences

Less testing and not finding failure points implies that block changes may be harder to implement or may require significant redesigns (due to design/requirement changes).

Source Traceability

Aerospace via industry discussions

Bottom Line - **Potential for large cost savings, but needs to be studied further to verify the numbers. May be hard to justify this approach for human-rated systems.**

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28. Adaptable Surface Systems

3 PRIORITY

Stretch Goal Description/Implementation

Design surface systems to be readily disassembled to accommodate multiple applications/functions.

Cost Implications

	Score	Discussion
Cost Savings	H	Estimated 10% savings of surface systems through 2025.
Cost of Implementation	M-H	Extra requirements levied on individual systems, somewhat alleviated if the systems are made for commonality.

Roadblocks

	Score	Discussion
Political	L-M	May result in fewer contracts and will increase difficulty of subcontracts.
Cultural	M	Will move away from idea of keeping things as simple as possible. Shift from custom building each module, and need for up-front cost for subsequent savings.
Organizational	M	If common modules belong to different centers, sharing of multi-use development may be difficult.

Program Impacts

	Score	Discussion
Schedule	L	Systems will be more complex, but surface systems are a far-term item with plenty of time to adapt.
Performance	L	Overall, adaptability will lead to more useful mass per mission. However, specific elements may end up being heavier due to multi-use capabilities.
Safety & Reliability	Increase in system complexity will lower reliability. However, potentially slight advantage for having flight experience on other uses.	

Unintended Consequences

Will require longer life items and more future-proofing. May add to commonality requirements.

Source Traceability

Boeing 25

Bottom Line - **Savings in DDT&E costs down the line requires up front DDT&E penalty and additional requirements on near term module development. Potential for large savings and acceleration in lunar infrastructure development, but has the potential for adding to system complexity. Should be evaluated on an individual basis.**

29. Metric Evaluation

3 PRIORITY

Stretch Goal Description/Implementation

Use metrics from automated, paperless business systems to understand flow and evaluate for efficiency.

Cost Implications

	Score	Discussion
Cost Savings	H	Improvement of processes over time may lead to a 5% savings in recurring costs.
Cost of Implementation	M-H	Will require a sizeable team to "understand flow and evaluate for efficiency" and the development of automated systems.

Program Impacts

	Score	Discussion
Schedule	L	Should improve schedule.
Performance	L	Little impact seen.
Safety & Reliability	Should improve system reliability and safety.	

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Will change the current practices.
Organizational	L	None Expected

Unintended Consequences

May result in some centers/areas being shown as non-useful. May cause increases in oversight and reporting requirements.

Source Traceability

Aerospace via industry discussions.

Bottom Line - **Will modernize many NASA operations, but it may be very difficult to generate tracking metrics and automated systems that are useful.**

30. Crew Logistics

3 PRIORITY

Stretch Goal Description/Implementation

Improve ECLS systems by closing the consumable loop.

Cost Implications

	Score	Discussion
Cost Savings	M	Small savings for water delivery for 7 astronauts on ISS, 5-10x more costly for lunar missions. More significant savings for 7-day, 4-crew lunar sortie mission over 20 yrs. More significant for outpost/long-duration missions.
Cost of Implementation	M-H	EADS has an Air Revitalization System demonstrator that has passed 700 hrs of closed chamber testing and "is ready for flight hardware production."

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	None Expected
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	M	Possibility of delays due to low TRL. Could have less impact on far-term elements (e.g. LSAM and outpost).
Performance	L	Theoretically, this will reduce the amount of water that must be carried per mission, but may trade with increased mass due to more complex ECLS system.
Safety & Reliability		Safety and reliability would have to be ensured by system redundancy.

Unintended Consequences

Could allow more flexible mission operations due to less limits on crew support. Enables long-duration safe-haven of existing elements.

Source Traceability

H-S 6

Bottom Line - **Depending on TRL, could result in long-term savings particularly for lunar outpost and Mars missions. Too much tech/schedule risk for near-term elements, but enabling technology for long-duration outpost missions.**

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31. Launch after Reaching Pad

3 PRIORITY

Stretch Goal Description/Implementation

All flight and ground systems shall be designed for 95% launch probability and/or launch within 24 hours of reaching the pad.

Cost Implications

	Score	Discussion
Cost Savings	M	Reduction in launch delays, medium savings over the Cx life. Higher savings if this requires more efficient pad operations. Could reduce boiloff reqs. for EDS, and possibility of losing a LSAM/EDS from inability to launch.
Cost of Implementation	M	May require DDT&E changes to increase launch availability & larger crew for faster ops; potential for shifting delays from pad to VAB.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	Less time before launch may lead to issues in safety/checklist centric culture.
Organizational	L	Less time before launch may lead to issues in safety/checklist centric culture.

Program Impacts

	Score	Discussion
Schedule	L-M	Possible schedule impact due to design changes.
Performance	M	Higher launch availability capability may drive towards less-efficient design / lower performance.
Safety & Reliability		None Expected

Unintended Consequences

May drive pad/crawler/MLP DDT&E to meet requirement. “Spikes" in ops could result in larger workforce and/or more cost. ay lead to decision to launch with reduced safety checks and/or under adverse conditions.

Source Traceability

Boeing 18, 20 / LM 7, 8

Bottom Line - **Has potential to offer medium LCC savings, but highly dependent on changes required (e.g. larger ground crew, more VAB ops, etc.) to implement 24 hour launch requirement. Unable to recommend as further investigations are required.**

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32. Reduce Process Related Testing

3 PRIORITY

Stretch Goal Description/Implementation

Implement a master verification approach based on on-board vehicle health maintenance data, rather than ground processing-related test and checkout.

Cost Implications

	Score	Discussion
Cost Savings	M-H	Will incorporate on-board health monitoring. Reduction in ground processing-related tests will result in 20% reduction in flight integration operations cost.
Cost of Implementation	M	Will require advanced health monitoring systems to be added to all vehicles, thus increasing DDT&E & production costs.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M-H	Will require PMs to place confidence in health monitoring and reduce testing to save costs.
Organizational	M	May reduce work done by KSC, etc.

Program Impacts

	Score	Discussion
Schedule	M	Redundant health-monitoring systems will drive complexity and schedule.
Performance	M	Redundant health-monitoring systems will drive complexity and mass.
Safety & Reliability		Reliance on health monitoring reduces testing done per mission; may be both negative (i.e. not finding potential failures) and positive (i.e. less chance to cause problems by over-testing) ways.

Unintended Consequences

False positives/negatives. Will provide more mission data, which could be useful in event of an anomaly.

Source Traceability

USA 6

Bottom Line - **Less testing and more reliance on integrated health monitoring shifts to aircraft-like operations. Level of cost savings dependent on amount testing is reduced, and cost impact to incorporating advanced monitoring equipment. Further investigation required.**

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33. Hands-off Umbilicals

3 PRIORITY

Stretch Goal Description/Implementation

Design all flight vehicle-to-ground system umbilicals to be mated and verified without hands-on involvement.

Cost Implications

	Score	Discussion
Cost Savings	M	Assume save 25% in ground integrated operations through 2025. Expected higher number of umbilicals CLV and CaLV, may result in significant savings in labor at pad & VAB.
Cost of Implementation	M	Due to umbilical complexity, especially cryogenics, as confirmed with KSC; DDT&E may be substantial, and will be required for both ground & LV designs.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Traditionally, launch vehicle designers maximize performance at the expense of operability.
Organizational	L	Higher initial costs in development.

Program Impacts

	Score	Discussion
Schedule	M	Possibility of delays due to low TRL.
Performance	L-M	Increased hardware on the LVs will decrease performance.
Safety & Reliability	Reduction in touch labor should increase ground crew safety.	

Unintended Consequences

Faster turnaround to a VAB rollback if necessary.

Reduction in ground crew accessibility requirements.

Source Traceability

Boeing 7 / USA 13

Bottom Line - This may be a means to meet fast launch after rollout to pad goal. Further investigation is required for cost/benefit analysis due to low launch rate.

34. Skill-based Crew Training

3 PRIORITY

Stretch Goal Description/Implementation

Develop philosophy and approach for skill-based vs. task-based crew training. Reduce training requirement time and dependency upon specific flight products. Conduct study of existing vs. predicted training requirements to identify how much of task-based training could be more generic.

Cost Implications

	Score	Discussion
Cost Savings	M	Enables less scripting of flight ops. If 20% savings through personnel reduction in Training and Mission Execution in Cx Budget.
Cost of Implementation	L	Requires changes in training methods, but new methods will be required anyway for Cx missions to some extent.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M-H	Reducing specific task training may be difficult to accept -- greater reliance on astronaut skills is paradigm shift.
Organizational	M	Any alteration in training and/or facilities may be difficult.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability		Could provide astronauts with more training and experience in specific skills. Less task-based training places greater reliance on astronaut skills vs. specific training for contingencies/etc.

Unintended Consequences

Reduction in task-specific training may not be met depending on mission complexities. Less training for contingencies could impact mission success during anomalies.

Source Traceability

USA 21

Bottom Line - Potential for some savings by reducing training/support expenditures, but savings is relatively low compared to overall Cx budget. Further investigation required on detailed changes that will be implemented to training program.

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35. Asset Based Configuration Management Guidelines

3 PRIORITY

Stretch Goal Description/Implementation

Establish clear and consistent guidelines for configuration management and tracking items that reflect the configuration of facilities, systems and equipment.

Cost Implications

	Score	Discussion
Cost Savings	M	Improved manufacturing techniques resulting in less downtime. Up to 1-2% savings on production and operations costs.
Cost of Implementation	M	Will require creation of advanced tracking system.

Program Impacts

	Score	Discussion
Schedule	L	Should improve schedule.
Performance	L	Little impact seen.
Safety & Reliability	Should improve system reliability and safety.	

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	None Expected
Organizational	M	Will require common system across all centers and contractors.

Unintended Consequences

Will facilitate lean manufacturing, allow for easier auditing and may improve ease of design upgrades. May create overly complex configuration bureaucracy.

Source Traceability

USA 22

Bottom Line - **Will require upfront effort, but should streamline operations once it is in place. Care must be made to make system as simple as possible while maintaining flexibility to cover all areas.**

36. Smart Descent Stage

3 PRIORITY

Stretch Goal Description/Implementation

LSAM Descent Stage shall be designed to operate with or without the Ascent Stage attached.

Cost Implications

	Score	Discussion
Cost Savings	L	Allows different payloads to land on surface. Higher LCC impact/reduction if more custom payloads are flown. May reduce AS cost due to lower reqs., depending on current AS descent role.
Cost of Implementation	L-M	Will be required for outpost missions anyway, so mainly shifts smart DS avionics development from far-term to near-term -- resulting in slight cost-savings vs. adding new avionics later.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	None Expected
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	L	Will increase development time required, but LSAM is already automated (e.g. 1st lunar mission test)
Performance	L	Minimal impact expected -- changes will include avionics and structure/interface for with/without AS
Safety & Reliability	Safety impact is unknown, but more-capable (?) Avionics could increase reliability	

Unintended Consequences

Could lead to large lunar science missions (e.g. telescope) using LSAM Descent Stage, and enable other Exploration payloads (e.g. reactor).

Source Traceability

Boeing 24

Bottom Line - **If baseline outpost does not use same LSAM DS, implementing this requirement could induce more commonality between outpost and LSAM, and potentially save development cost for a new or substantially-modified outpost DS. Adding as a requirement could help enforce use of common DS to both LSAM and outpost designs.**

37. Hypergolic Servicing Consideration

3 PRIORITY

Stretch Goal Description/Implementation

Service sub elements with hypergolic propellant prior to delivery to the vertical integration facility. Eliminates the need for a servicing capability at the pad or in the vertical integration facility.

Cost Implications

	Score	Discussion
Cost Savings	M	10% reduction in integrated launch ops and a 5% reduction in ground systems facilities development for removal of hypergolic servicing requirement.
Cost of Implementation	L-M	Could require hazmat conditions to be enforced near payload due to pre-serviced hypergolic fuels. Could lead to higher costs overall depending on classification of different stages of work.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Requires shift in processing methodology.
Organizational	M	KSC may lose some of its current hypergolic servicing work.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability		Could substantially increase risks to ground crew due to more work being performed in vicinity of hypergolic fuels.

Unintended Consequences

Any leaks of pre-serviced payloads could cause substantial damage and be difficult to clean up, depending on how much hypergolic support facilities are cut back.

Source Traceability

LM 6

Bottom Line - **For small satellites this seems reasonable -- but the CEV & LSAM will have on the order of 30 tons of hypergolic fuels, implying the potential for catastrophe during an accident is increased substantially. Further investigation may be warranted.**

38. Common Flight Software

3
PRIORITY

Stretch Goal Description/Implementation

Program-wide multi-use simulation and flight software verification and models that are independent of unique flight software.

Cost Implications

	Score	Discussion
Cost Savings	M	Assuming a 10% reduction in all flight software development and production costs, a medium possible savings may be realized.
Cost of Implementation	M	Implementation of a more robust flight software system may have additional upfront development costs.

Program Impacts

	Score	Discussion
Schedule	L	None Expected
Performance	L	None Expected
Safety & Reliability		Application of common code to different systems could result unforeseen errors. (e.g. Ariane 5)

Roadblocks

	Score	Discussion
Political	M	Designing common software for flight elements that have been rewarded to different contractors may have problems
Cultural	M	Some resistance to designing SW not tailored for flight-specific applications.
Organizational	L	None Expected

Unintended Consequences

Application of common code to different systems could result unforeseen errors.

Source Traceability

Boeing 16 / USA 7

Bottom Line - **Common flight software may show savings once implemented, but the upfront costs and contractual complications may prove to be challenging.**

39. MLP and Launch Pad Refurbishment

3 PRIORITY

Stretch Goal Description/Implementation

Infrastructure at the pad designed robust enough to support numerous launches without requiring refurbishment. MLP structure design robust enough to support numerous launches without requiring refurbishment.

Cost Implications

	Score	Discussion
Cost Savings	M	Assuming that the proportion of facilities sustainment cost for the MLP & Pad refurbishment is equivalent to the Shuttle and that Cx MLP & Pad refurbishment cost is reduced by 50% then a low-medium total cost savings of, if reduced by 75% then an upper-medium savings though 2025.
Cost of Implementation	M	Extra cost assuming a 10% increase in MLP & Pad facilities development.

Roadblocks

	Score	Discussion
Political	M	Environmental impact concerns.
Cultural	L	None Expected
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	M	Would increase MLP complexity and possibly weight and dimensions, which might increase complexity of the crawler, crawlerway, and other facilities and operations. Would increase Pad complexity.
Performance	L	None Expected
Safety & Reliability		May increase environmental hazards to ground crew (e.g. SRB exhaust).

Unintended Consequences

Could enable an emergency rescue mission due to lower turnaround time. May increase environmental hazards to ground crew and ecosystem (e.g. SRB exhaust).

Source Traceability

LM 9, 10

Bottom Line - Making the MLP and Pads reusable may create some cost savings, depending on the design complexity, but could also incur development costs that outstrip the benefits. Further study is required.

40. Launch Site Verification Accessibility

PRIORITY 3

Stretch Goal Description/Implementation

Allow for all system verification at the launch site to be performed from outside the vehicle outer mold.

Cost Implications

	Score	Discussion
Cost Savings	M	Will reduce delays due to launch site access to vehicle and mitigate human errors due to multiple OML intrusions. 10% of mission integration. Higher savings if allows for reduced verification.
Cost of Implementation	M	Will require verification/testing equipment to be built inside the OML. Increase development cost and complexity. May be partially offset by designing for less launch-site access.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Traditionally, LV designers maximize performance at the expense of operability.
Organizational	L	May impact KSC role in launch site testing/verification

Program Impacts

	Score	Discussion
Schedule	L	If more complex inside-OML testing systems are required, could drive development schedule.
Performance	L-M	May lead to slightly heavier systems due to incorporation of increased verification equipment inside OML..
Safety & Reliability		May reduce safety if less launch-site verification. May increase safety by mitigating mistakes due to multiple human access inside the OML.

Unintended Consequences

Designing for less launch site access to OML interior could create delays if access is required (e.g. for major system that requires replacement). Significant vehicle changes (e.g. CEV block update) may require additional changes to other vehicles (e.g. Ares I) due to access/testing issues.

Source Traceability

Boeing 15

Bottom Line - Has potential to offer high cost savings by reducing/eliminating required access to vehicle interior, but requires further study to recommend.

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41. Implement Lean Manufacturing

3 PRIORITY

Stretch Goal Description/Implementation

Minimal warehousing and "just in time" deliveries from the suppliers.

Cost Implications

	Score	Discussion
Cost Savings	L-M	Assume 2% reduction in mission ops cost due to less warehousing of vehicle components.
Cost of Implementation	L	Extra cost may be incurred in component cost due to storage at contractor site and/or lower production.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	None Expected
Organizational	M	Could reduce work done by NASA sites (e.g. KSC).

Program Impacts

	Score	Discussion
Schedule	M	If components need to be ordered or emergency needs develop, could impact mission launch schedule.
Performance	L	None Expected
Safety & Reliability		Potential for less testing if components are not stored at NASA site.

Unintended Consequences

"Order as needed" approach could reduce costs if flight manifest is reduced after start of operations. Cost savings may be hard to realize due to low production rates.

Source Traceability

Aerospace via industry discussions

Bottom Line - **Difficult to estimate cost savings - further study required. Cx elements are low production, so goal may impact refurbishment costs more than anything.**

42. Hardware Accessibility

3 PRIORITY

Stretch Goal Description/Implementation

Design for improved LRU and wire insulation accessibility at launch pad.

Cost Implications

	Score	Discussion
Cost Savings	L-M	Assuming that a 20% savings could be reached in CEV refurbishment, plus a 30% reduction in days lost due to mechanical anomalies.
Cost of Implementation	L-M	Assume 5% increase in CEV and launch vehicle structure DDT&E.

Program Impacts

	Score	Discussion
Schedule	L	Possibility of delays due to designing for increased accessibility.
Performance	M	Possibility of heavier systems/mechanisms to allow for greater HW accessibility.
Safety & Reliability	None Expected	

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M-H	Shift from performance a priority to operability as a priority.
Organizational	L	None Expected

Unintended Consequences

Reduced tool cost if special tools would have been needed due to poor accessibility.

Source Traceability

Boeing 10, 11, 12 / USA 14, 16

Bottom Line - **HW Accessibility should be a design goal and should be considered, but creating a hard requirement may lead to increased DDT&E complexity.**

43. Standby Payload

3 PRIORITY

Stretch Goal Description/Implementation

Permits substitution of “stand by” payload for any mission delayed “x” period of time (TBD).

Cost Implications

	Score	Discussion
Cost Savings	M-H	Reduction of probability of extended-length stand-downs. Cost savings could be up to 1 year of ground and mission ops budget over life cycle.
Cost of Implementation	M-H	Non-recurring cost to make vehicle more robust, recurring cost to maintain spare payloads. May require unique instruments meet specific standards.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Would require move to operational status as opposed to developmental status with significant reduction in required pre-flight analysis.
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	L	Possible schedule impact due to design changes, but should be low.
Performance	M	Extra margins required for robustness will reduce performance.
Safety & Reliability		Improved due to reduction in schedule pressures.

Unintended Consequences

Would require move to operational status as opposed to developmental status with significant reduction in required pre-flight analysis. Another solution would be to use current techniques and just double the analysis which would significantly increase cost.

Source Traceability

USA 15

Bottom Line - **Potential reduction in launch delay would require significant move from developmental to operational status to be implemented, further study required. A goal of reduced pre-flight analysis would be preferred.**

44. Automate Launch and Pre-Launch Control

3 PRIORITY

Stretch Goal Description/Implementation

Automate pre-launch and launch control systems.

Cost Implications

	Score	Discussion
Cost Savings	L	Cost savings through 2025 due to the reduction in launch control staff (at the level of ~6 staff), which results in small savings.
Cost of Implementation	L-M	Unmanned launch vehicles already use automated control systems to some degree, but automated support methods must be developed.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Automated pre-launch and launch controls involve taking the crew out of active participation.
Organizational	L	Higher initial costs in development.

Program Impacts

	Score	Discussion
Schedule	L	Minor impact on development schedule.
Performance	L	Should be minimal.
Safety & Reliability		System reliability should increase due to automation, but may be reduced due to reduction in staff used to realize cost savings.

Unintended Consequences

Problems in automated systems (e.g. software bugs) could go unnoticed and impact launches. Less staff could inhibit response to launch anomalies.

Source Traceability

Boeing 21

Bottom Line - **Automating is potentially a good idea, but the cost/benefit trade-offs and impacts on safety and reliability need to be investigated further.**

45. Automate On-orbit Capabilities

3 PRIORITY

Stretch Goal Description/Implementation

Provide automated capabilities for in-situ crew environments and long-term autonomous orbit operations.

Cost Implications

	Score	Discussion
Cost Savings	M	Assume 10% savings of Mission Ops budget through 2025. Reduction of crew requirements and risk leads to reduced training requirements and improved mission safety.
Cost of Implementation	H	Automation of tasks and abilities will add significant development costs.

Program Impacts

	Score	Discussion
Schedule	M	Development of critical systems with high degree of automation will partially be offset by reduction in crew related requirements.
Performance	L	May add some mass to Cx systems.
Safety & Reliability		May enable reparability and reduction in dangerous crewed tasks.

Roadblocks

	Score	Discussion
Political	M	May raise the question of "why send people?"
Cultural	H	May be seen as robotics infringing on roles of astronauts.
Organizational	M	NASA experts in robotics typically are not associated with manned systems.

Unintended Consequences

May raise the question of "why send people?“ inadvertently loosing some Congressional or public support for manned exploration. Shuttle landing system example: may end up with a complex system that is not used.

Source Traceability

Boeing 28 / H-S 1 / USA 17

Bottom Line - **Potential for moderate savings and acceleration in lunar infrastructure development, but has the potential for adding to system complexity and significant cultural roadblocks. Should be evaluated on an individual basis.**

46. Clean Pad

PRIORITY 3

Stretch Goal Description/Implementation

Defined as “minimal structures, equipment, and access; with no contingency access”.

Cost Implications

	Score	Discussion
Cost Savings	M	Given fairly “clean” baseline design, assume maximum savings 10% of ground ops flight integration (except LSAM) cost.
Cost of Implementation	H	Significant development costs would be required to fully implement clean pad operations in the current Constellation architecture.

Program Impacts

	Score	Discussion
Schedule	M	Due to more development for a clean pad concept, schedule delays are probable.
Performance	L	None Expected
Safety & Reliability		Safety for ground crews would increase due to the minimal access requirement.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Significant changes from current Shuttle pad operations.
Organizational	L	None Expected

Unintended Consequences

Flight rates remain low or decrease and the high development costs are never recovered by operational savings.

Source Traceability

LM 3

Bottom Line – **For high flight rate systems, a clean pad design has the potential to see significant savings; however, for a crewed flight system scheduled for only two flights per year, high LCC savings may not be achievable.**

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47. On-orbit Servicing

PRIORITY 2

Stretch Goal Description/Implementation

Design in-space transportation systems to enable refueling.

Cost Implications

	Score	Discussion
Cost Savings	H	Cost savings from reuse thus build less units. Assume over 5 yrs of LSAM operations, buy 2 LSAMs instead of 10 LSAMs. No savings over 5 years. However, over 20 years and 10 LSAMs there is a multi-billion dollar savings.
Cost of Implementation	H	Heavier, more complex and costly reusable LSAM. Increase DDT&E cost.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Goes against risk averse culture.
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	H	Additional complexity adds significantly to development timeline. Some elements are cost constrained which will impact schedule even further.
Performance	L	Specific elements will be heavier, but overall performance should improve.
Safety & Reliability		On-orbit servicing still immature technology, therefore, there will be more risks.

Unintended Consequences

Low rate of usage would result in large sunk cost with little benefit. Will provide path for use of commercial services.

Source Traceability

Boeing 23 / NGC 6

Bottom Line - **Changes baseline architecture. Potential for long term savings exists, but will require more upfront money (which NASA doesn't have.) Not Recommended for inclusion into requirements, but keep option open in case whole architecture changes**

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48. Roll Out and Launch Timeline

PRIORITY 2

Stretch Goal Description/Implementation

From roll out initiation to launch must be accomplished within a 5 workday span. This provides for reduction in the number of launch complexes and MLPs in order to support the launch manifest.

Cost Implications

	Score	Discussion
Cost Savings	L-M	Small savings if assume savings compared to Shuttle design baseline. Medium savings against STS historical performance. Also less delays due to weather, assuming a 50% reduction.
Cost of Implementation	L-M	Theoretically easy as more-complex Shuttle designed for ~6 day. Realistically, may be as hard to achieve with a significant level of confidence, considering Shuttle history.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Opposition due to fear a ticking clock atmosphere may cause people to rush.
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	L-M	Low if considering that Shuttle was already designed for a similar timeline, but if the design is forced to prove with a high degree of certainty that the 5 day timeline will be met, then this might create a difficult DDT&E problem.
Performance	L	None Expected
Safety & Reliability	If goal reached by increasing vehicle reliability, then safety increased. If vehicle design not inherently more reliable, then ticking clock may create a "rush" atmosphere decreasing safety.	

Unintended Consequences

May lead to decision to launch with reduced safety checks and/or under adverse conditions.

Source Traceability

LM 2

Bottom Line - **The 5 day goal may be too similar to original Shuttle expectations to make it a stretch goal; however, the Shuttle program's history of delays shows that meeting this goal throughout the life of the Constellation program may result in higher savings.**

49. Reliability and Redundancy (R&R)

PRIORITY 2

Stretch Goal Description/Implementation

Emphasize use of high reliability components and use redundant paths for critical functions that cannot be repaired in 24 hours.

Cost Implications

	Score	Discussion
Cost Savings	M	Increased R&R leads to less delays and less preflight testing, for medium savings. Possibly more savings by initially designing R&R vs. adding later.
Cost of Implementation	M-H	Add redundancy for all components less than 99% reliability. Assume 1% of all human rated systems.

Roadblocks

	Score	Discussion
Political	M	Budget scrutiny due to rising development cost, but call sell as safer.
Cultural	M	Launching with failed (but redundant) systems may be hard to accept. Safer systems are always desirable, but for cost savings less preflight test needed.
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	M-H	Designing increased R&R systems will drive development time and require more testing before operational phase.
Performance	H	Will lead to heavier systems due to increased redundancy & parts count.
Safety & Reliability	Text	

Unintended Consequences

If launching with failed components is avoided, the whole purpose of this goal would not be realized. Increased reliance and use of redundant systems could cause more post-flight analysis, if anomaly sources must be investigated thoroughly each time. May also lead to more complex systems.

Source Traceability

Boeing 13, 29, 30, 31, 32 / USA 19

Bottom Line - **Increasing launch availability is a good thing, but any potential savings must be balanced by the cost of implementation. Human-rated systems already have high reliability, and this could potentially increase costs significantly.**

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50. Rollback Safety Requirement

2 PRIORITY

Stretch Goal Description/Implementation

Begin the move from the pad before the LH levels reach 1% residual in the tank. Allows the removal of the vehicle for protection, facilitates reduced access at the pad and roll out to launch.

Cost Implications

	Score	Discussion
Cost Savings	L	Assume a 10% reduction in all launch delays due to ability to rollback with partial propellant load.
Cost of Implementation	L-M	Assume a 10% reduction in all launch delays due to ability to rollback with partial propellant load.

Program Impacts

	Score	Discussion
Schedule	L-M	Could impact schedule if new crawler is required for Ares I.
Performance	L	None Expected
Safety & Reliability		Should increase vehicle protection by allowing quicker rollback (if desired due to weather/etc.), but transporting and storing a partially propellant-loaded vehicle in the VIF will reduce ground crew safety.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	M	Transporting a fueled vehicle on the MLP may require culture shifts.
Organizational	L	None Expected

Unintended Consequences

Transporting partially-fueled vehicles could increase risks of an accident.

Source Traceability

LM 5

Bottom Line - **Seems to enable ground ops flexibility more than anything (i.e. ability to rollback on shorter notice if necessary). Cost of implementation appears to outweigh savings, so not recommended without further study.**

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51. Vehicle Transport Timeline

1 PRIORITY

Stretch Goal Description/Implementation

Starting with roll out from the vertical integration building until the vehicle is down hard at the pad shall not take more than four (4) clock hours. Limits the environmental exposure of the vehicle while in transit.

Cost Implications

	Score	Discussion
Cost Savings	L	Currently the Shuttle 7 hours. Thus goal saves 3 hours per rollout/rollback. With only 4 flts/ year and 1 less rollback due to weather over Cx lifetime are expected, there is minimal cost savings.
Cost of Implementation	M	Would drive CaLV crawler design and require large modifications/new CLV crawler. Or would require a new VAB or Launch Pads that are closer to each other. Could also impact crawlerway.

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L	None Expected
Organizational	L	None Expected

Program Impacts

	Score	Discussion
Schedule	L-M	Would increase complexity in crawler, and possibly MLP, design which could lead to delays.
Performance	L	Vehicles would have to be designed for higher loads due to faster rollout.
Safety & Reliability		None Expected

Unintended Consequences

May increase probability of returning vehicle to VAB if repair is needed. May lower requirements for accessibility on the LUT.

Source Traceability

LM 4

Bottom Line - Due to the low expected flight rate is little or no cost savings but there would be substantial implementation cost for modifications to the crawler, VAB or launch pads.

52. Nuclear Power

1 PRIORITY

Stretch Goal Description/Implementation

Develop nuclear power systems for each Cx element.

Cost Implications

	Score	Discussion
Cost Savings	L-H	Large reduction in cost power-dependent subsystems offset by high recurring costs of nuclear subsystem. Actual savings difficult to quantify. Actual costs and savings are difficult to quantify due to very low TRL.
Cost of Implementation	H	The implementation costs of for a nuclear power system for use in human space flight will be very expensive due to high development costs.

Roadblocks

	Score	Discussion
Political	H	Combination of safety implications and upfront cost.
Cultural	M-H	Large paradigm shift.
Organizational	H	High near-term development costs.

Program Impacts

	Score	Discussion
Schedule	H	Development timeline will result in substantial delays.
Performance	M	Increased weight of the power system should be offset by a decrease in avionics and ECLS weight.
Safety & Reliability		Significant safety concerns with launching a nuclear reactor with humans into space.

Unintended Consequences

Significant coordination with DOE would be required. Would facilitate transition to long duration manned, space missions. Increased launch delays due to public outcries/more stringent requirements.

Source Traceability

H-S 3

Bottom Line - **While using nuclear power systems shows great design advantages for other subsystems, the huge upfront costs and political implications make such a system not feasible for Constellation.**

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53. Lightning Protected LAS

1 PRIORITY

Stretch Goal Description/Implementation

Design LAS to withstand a lightning strike and capable of being activated by triply redundant paths.

Cost Implications

	Score	Discussion
Cost Savings	L	Assuming baseline CEV would have similar weather constraints to Shuttle, if reduce "overall bad weather" delays by even by 100%, very small savings.
Cost of Implementation	L-M	Ares/Orion vehicles can inexpensively be designed to reduce susceptibility to an average lightning strike. Greater DDT&E cost would incur if design to operate though any lightning strike, easily offsetting any potential savings.

Program Impacts

	Score	Discussion
Schedule	M	Possibility of delays due to increase in LAS design complexity, as LAS development needs to be done early in CEV program.
Performance	L	Possibility of a heavier TO weight due to materials/systems changes to meet lightning strike requirements.
Safety & Reliability	Text	

Roadblocks

	Score	Discussion
Political	L	None Expected
Cultural	L-M	Operators would have to become accustomed to launching in poor weather.
Organizational	L	None Expected

Unintended Consequences

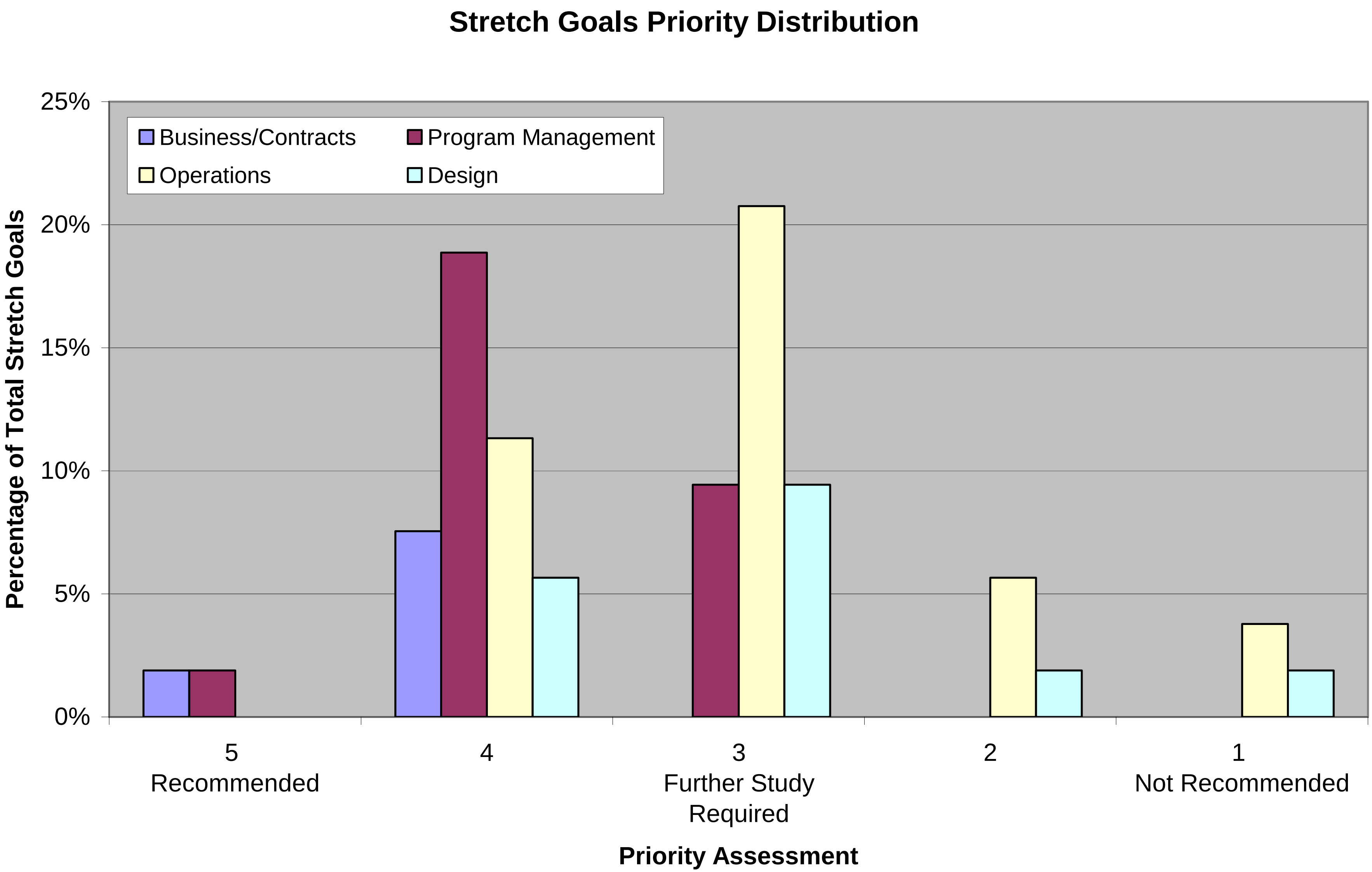
May cause operability impacts to LAS.

Source Traceability

Boeing 29, 30

Bottom Line - **Not recommended due to low probability of impact.**

Priority Distribution



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Summary

- Many good ideas received based on industry experience
  - Shuttle operations
  - Commercial aircraft production
  - NASA's historical way of doing business
  - Military and commercial programs
- Aerospace performed preliminary analysis
  - Potential savings
  - Cost of implementation
  - Performance or other impact/penalties
  - Roadblocks
  - Unintended consequences
  - Bottom line
- Significant work ahead for a "Stretch Goal" to become a good, documented requirement
  - As a group, the relative "value" of goals are uneven
  - Focused analysis on each goal is required
    - Need to ensure that a new requirement produces the desired consequence
    - It is not certain that some goals will not create problems elsewhere
  - Individual implementation path needs to be studied
    - Best place to insert requirement (what level, which document)
    - Appropriate wording for the requirement
- Many goals reflect "best practices" based on lessons learned and may have value beyond near-term CxP requirements process

Appendices

Acronym List

and

Industry Submissions at TIM #2

Acronym List

Acronym List

AF	Air Force
ATK	Alliant Techsystems
BIT	Built-in Test
CaLV	Cargo Launch Vehicle (Ares V)
CEV	Crew Exploration Vehicle
CLV	Crew Launch Vehicle (Ares I)
COTS	Commercial Off The Shelf
Cx	Constellation
CxP	Constellation Program
DDT&E	Design, Development and Evaluation
DoD	Department of Defense
DS	Descent Stage
EADS	European Aeronautic Defense and Space Company
ECLS	Environmental Control and Life Support
EDS	Earth Departure Stage
ESMD	Exploration Systems Mission Directorate
HQ	Headquarters
H-S	Hamilton-Sundstrand
HW	Hardware
IP	International Partner
ISRU	In-situ Resource Utilization
ISS	International Space Station
JSC	Johnson Space Center
KSC	Kennedy Space Center
LAS	Launch Abort System
LCC	Life-cycle Cost

LM	Lockheed Martin
LRU	Line Replaceable Unit
LSAM	Lunar Surface Access Module
LUT	Launch Umbilical Tower
LV	Launch Vehicle
MCC	Mission Control Center
MLP	Mobile Launch Platform
MRB	Material Review Board
NASA	National Air and Space Administration
NGC	Northrop Grumman Corporation
OEM	Original Equipment Manufacturer
OML	Outer Mold Line
PM	Program Manager
PWR	Pratt and Whitney Rocketdyne
R&R	Reliability and Redundancy
RAA	Responsibility, Authority, and Accountability
SRR	System Requirements Review
STS	Space Transportation System
SW	Software
TIM	Technical Interface Meetings
TO	Take Off
TOR	Technical Operating Report
TRL	Technology Readiness Level
USA	United Space Alliance
VAB	Vehicle Assembly Building

ATK

ATK – Optimize Workforce

Proposed Constellation Stretch Goal Overview

- **Optimize Workforce (both civil service (CS) and contractor)**
  - Workforce is the largest driver for NASA cost and therefore the biggest opportunity for cost savings. Suggest more effective use of workforce (both CS and contractor) to accomplish more.
- **Pros**
  - Decrease overall development cost
  - Lower unit cost due to increased production
  - Reduce number of reviews and number of people on review teams
  - Increased employee morale as they look ahead to the next program challenge rather than continuing to redesign the existing vehicle
  - Potential acceleration of Ares V
- **Cons**
  - Potential to overlook a design flaw
  - Potential development/unit cost increase for redesign
- **Cost impact**
  - Overall savings expected on Ares I due to lower number of CS & contractors
- **Implementation approach**
  - Maximize the timing of CS transition from DDT&E to operations. There is a direct correlation between the number of NASA employees on a program to the number of contractor employees required to feed the inquiries.
  - Design and budget to end state vision; design for operability
  - Declare operational state after X number of flights and plan towards that end
  - Define staffing transition plan from DDT&E to Operations NOW so as to create a waive effect (from DDT&E to operations) of both CS and contractors
- **Examples**

ATK – Contract Structure/Bonuses

Proposed Constellation Stretch Goal Overview

- **Motivate Operational End State**
  - Establish contract structure and civil service (CS) bonuses to motivate operational end state
- **Pros**
  - Decrease overall development cost
  - Lower unit cost due to increased production
  - Reduce number of reviews and number of people on review teams
  - Increased employee morale as they look ahead to the next program challenge rather than continuing to redesign the existing vehicle
  - Potential acceleration of Ares V
- **Cons**
  - Potential to overlook a design flaw
  - Potential development/unit cost increase for redesign
- **Cost impact**
  - Overall savings expected on Ares I due to lower number of CS & contractors
- **Implementation approach**
  - Establish incentive contract for DDT&E Life Cycle Cost with look-back feature; Award Fee for safety performance
  - Establish CS bonuses for DDT&E Life Cycle Cost
- **Examples**
  - Space Shuttle RSRM Buy III Production Contract

ATK – Small Business Goals

Proposed Constellation Stretch Goal Overview

- **Flexibility in Meeting Small Business Goals**
  - Allow Primes to cum all supplier small business to meet the small business goal
- **Pros**
  - Primes can use the most cost effective contracting approach to get the job done
  - If a vendor has a relationship with a small business, it is technically more feasible for that vendor to maintain that responsibility
  - Prevents primes from pulling small business work from a vendor and contracting with the small business directly in order to meet the prime goal (in some cases, only a piece of the work is pulled which then requires two separate contracts with the same small business; one with the prime and one with the vendor)
- **Cons**
  - As long as small business goal is met, there is no negative
- **Cost impact**
  - Overall savings expected on Ares I due to lower base
- **Implementation approach**
  - Validate that cum approach is satisfactory to meet federal laws
  - Change future RFPs to reflect cum approach
  - Potentially re-baseline all contracts to reflect cum approach
- **Examples**
  - DOD allows Primes to cum all supplier small business to meet goal

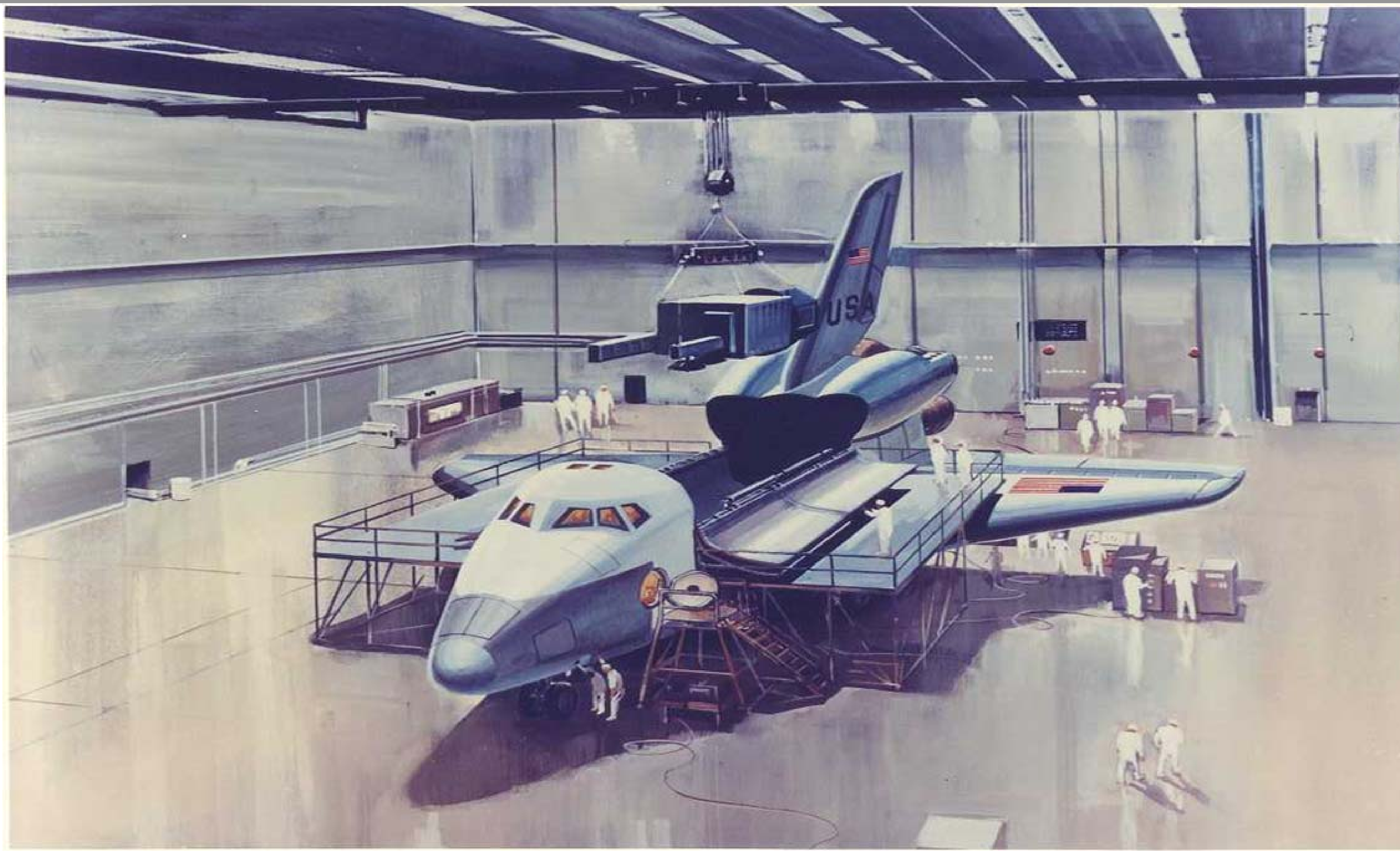
Boeing

Constellation Stretch Goals

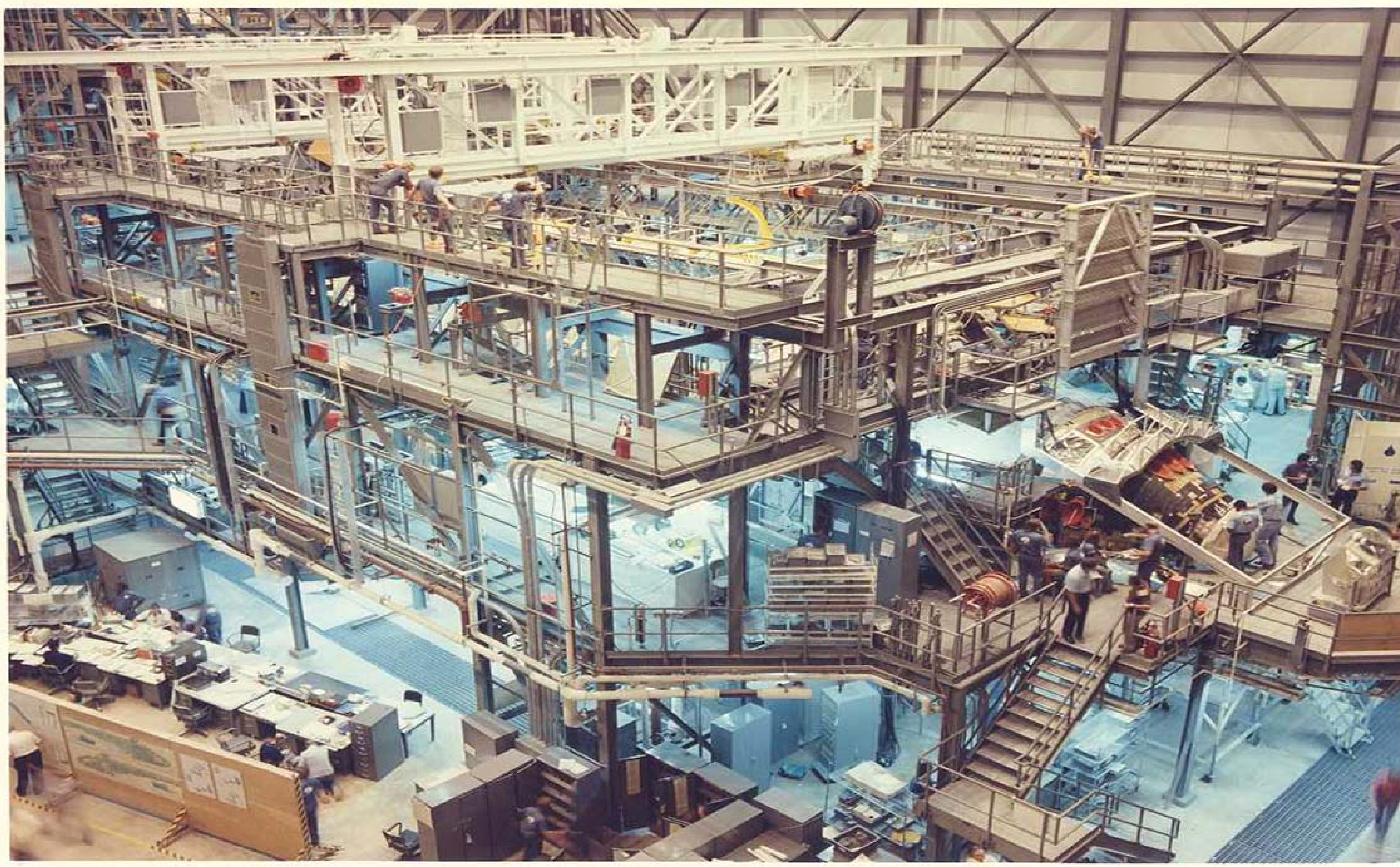
October 31, 2006

Bo Bejmuk

Initial Naive Concept of Operations



Operational Reality



NASA, KSC Photo, dated September 25, 1979, index number "KSC-79PC-500"

Suggested Goals to Reduce Cost of Ownership for Constellation Systems

- **Based on experience from**
  - **Shuttle**
    - **Designed for performance and multi-functionality**
  - **Sea Launch, DC-X, 787 Dreamliner and 737 production changes**
    - **Designed for operations**
  - **Work on ESMD advanced programs**

Status Since Initial Briefing to Industry Team on October 16, 2006 in Washington DC

- Nine additional potential stretch goals were added
- All 34 suggested stretch goals were sorted and evaluated
- Package was briefed to Aerospace Corporation team on October 19, 2006
- This briefing will concentrate on the 9 new stretch goals

Evaluation Methodology Utilized

- Goals were categorized and SWAG developed based on manned space experience
- Categories used were:
  - Program Management
  - Technical
  - Risk Reduction
  - Contractual
- Evaluation criteria used

  Management Actions Required

  Low - <$1M ; Medium - $1M-$10M ; High - >$10M

  Design Actions Required

  Low - <$1M ; Medium - $1M-$10M ; High - >$10M

  Operations cost benefit over life cycle of constellation

  Low - <$10M ; Medium - $10M-$100M ; High - >$100M

  Cost / Benefit Ratio

  RDT&E Cost : Reduction of Life Cycle Cost through 2028

  No time value of money factored in

ESMD System Stretch Goals/Requirements - Program Management Goals

Stretch Goals | IDS Network & Space Systems | Space Exploration

		Management Actions Required*	Design Actions Required**	Operations Benefit***	Cost / Benefit Ratio****
1	Margin management shall be implemented during the development phase of each new system: Structural, Weight, Performance, Consumables, Other	M	-	H	1:50
2	Life cycle cost management shall be implemented at Constellation Program level, and at each element of Constellation	M	-	H	1:100
3	Each Constellation element shall implement a probability based risk management program	L	-	M	1:20
4	Establish a Constellation Office responsible for management of life cycle cost for all Constellation programs: During DDT&E, During transition to operations and operations	M	-	H	1:50

*Management Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
**Design Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
***Operations cost benefit over life cycle of constellation: Low - <$10M ; Medium - $10M-$100M ; High - >$100M
****Cost / Benefit Ratio = RDT&E Cost : Reduction of Life Cycle Cost through 2028, with no time value of money factored in

ESMD System Stretch Goals/Requirements - Technical Goals

		Management Actions Required*	Design Actions Required**	Operations Benefit***	Cost / Benefit Ratio****
5	All new Constellation system shall be designed to require non-toxic propellants	-	H	H	1:20
6	The system shall be designed to allow flight software reconfiguration between flights within 24 hours	-	H	H	1:50
7	All flight vehicle to ground system umbilical's shall be designed to be mated and verified without crew hands-on involvement	-	M	M	1:20
8	No mission specific compatibility analysis with induced or natural environments shall be required after 4 flights of every new system	L	L	M	1:50
9	Commonality management shall be implemented at the Constellation program for flight and ground systems	L	L	M	1:30
10	LRU Design for Operations: All LRU's which weigh less than 50 lbs shall be designed to be replaceable at the launch site within one hour, and with no more than two technicians	-	L	M	1:30

*Management Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
**Design Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
***Operations cost benefit over life cycle of constellation: Low - <$10M ; Medium - $10M-$100M ; High - >$100M
****Cost / Benefit Ratio = RDT&E Cost : Reduction of Life Cycle Cost through 2028, with no time value of money factored in

ESMD System Stretch Goals/Requirements - Technical Goals

		Management Actions Required*	Design Actions Required**	Operations Benefit***	Cost / Benefit Ratio****
11	LRU Design for Operations: All LRU's which weigh between 50-500 lbs shall be replaceable within 4 hours, and with no more than four technicians	-	L	M	1:35
12	LRU Design for Operations: Concept of operations for LRU's in excess of 500 lbs. shall be approved by Constellation Program Manager	-	L	M	1:40
13	Redundant paths of critical functions with reliability of less than .99, which cannot be repaired within 24 hours, shall require additional redundancy to protect a launch opportunity with a failed single redundancy	-	L	M	1:40
14	All stages and elements of Constellation shall be verified prior to delivery to the launch site. Check-out and verification at the launch site shall be limited to functions, including redundant paths which are affected by interface mating at the launch site	-	M	H	1:40
15	All system verification at the launch site for new vehicle stages shall be accomplished from outside of the vehicle outer mold line	-	M	H	1:50
16	All launch vehicles shall utilize a software system in which common multi-use flight software is independent of mission unique flight software	-	L	M	1:20

*Management Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
**Design Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
***Operations cost benefit over life cycle of constellation: Low - <$10M ; Medium - $10M-$100M ; High - >$100M
****Cost / Benefit Ratio = RDT&E Cost : Reduction of Life Cycle Cost through 2028, with no time value of money factored in

ESMD System Stretch Goals/Requirements - Technical Goals

		Management Actions Required*	Design Actions Required**	Operations Benefit***	Cost / Benefit Ratio****
17	Flight and test hardware shall utilize components with Built In Test (BIT) capability that provides self-test capabilities and functions	-	M	H	1:30
18	Flight and ground systems shall be designed for 95% launch probability	-	H	H	1:30
19	Flight and Ground systems including GSE should be treated as one system for the purpose of trade-offs and design decisions during DDT&E	L	M	H	1:30
20	Flight and Ground systems shall be designed to support launch within 24 hours of vehicle arrival at pad	-	M	M	1:20
21	Pre-launch and launch control systems shall be fully automated with no crew active participation – interaction will be limited to monitoring only	-	H	H	1:50
22	Launch and flight control systems shall be consolidated and turn over to mission control shall occur after second stage separation	L	H	H	1:40

*Management Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
**Design Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
***Operations cost benefit over life cycle of constellation: Low - <$10M ; Medium - $10M-$100M ; High - >$100M
****Cost / Benefit Ratio = RDT&E Cost : Reduction of Life Cycle Cost through 2028, with no time value of money factored in

ESMD System Stretch Goals/Requirements - Technical Goals

Stretch Goals | IDS Network & Space Systems | Space Exploration

		Management Actions Required*	Design Actions Required**	Operations Benefit***	Cost / Benefit Ratio****
23	In-space transportation systems shall be designed to enable refueling	-	H	H	1:20
24	LSAM Descent Stage shall be designed to operate with and without the Ascent Stage attached	-	H	H	1:20
25	Design surface systems to be readily disassembled to accommodate multiple applications/functions	-	H	H	1:20
26	Design the descent lander to facilitate crew and cargo access for lunar surface transfer	-	H	H	1:20
27	Adopt state based modeling to drive software design; Allow auto coding	-	H	H	1:20
28	Extend autonomous operations to the spacecraft by using goals in the place of detailed commands, utilizing event driven telemetry systems, and incorporating real time onboard IVHM	-	M	H	1:50

*Management Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
**Design Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
***Operations cost benefit over life cycle of constellation: Low - <$10M ; Medium - $10M-$100M ; High - >$100M
****Cost / Benefit Ratio = RDT&E Cost : Reduction of Life Cycle Cost through 2028, with no time value of money factored in

ESMD System Stretch Goals/Requirements - Risk Reduction Goals

		Management Actions Required*	Design Actions Required**	Operations Benefit***	Cost / Benefit Ratio****
29	The LAS shall be designed and certified to withstand a 150,000 Amp lightning strike (Risk Reduction)	-	M	L	-
30	The LAS shall be capable of being activated by three redundant paths; From the ground by wire, From the crew, From the ground by wireless (Risk Reduction)	-	M	L	-
31	The Orion parachute system shall be designed to enable parachute deployment with any Orion orientation and any kinematic initial condition (Risk Reduction)	-	M	L	-
32	Design the descent vehicle for 'helicopter like' vision for the pilot (Risk Reduction)	-	H	M	-

*Management Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
**Design Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
***Operations cost benefit over life cycle of constellation: Low - <$10M ; Medium - $10M-$100M ; High - >$100M
****Cost / Benefit Ratio = RDT&E Cost : Reduction of Life Cycle Cost through 2028, with no time value of money factored in

ESMD System Stretch Goals/Requirements - Contractual Goals

		Management Actions Required*	Design Actions Required**	Operations Benefit***	Cost / Benefit Ratio****	
33	Reduce cost of NASA/Industry interface by minimizing NASA's oversight role in development and operations of systems procured from Industry. This delegating of responsibility to Industry will free NASA to design, build, and operate additional systems reta	L	-	H	1:100	
34	Engage industry to help NASA reduce the cost of operations. (Example: Develop incentive program for industry to promote self-funded life cycle cost improvements. Offer up to 50% of operational cost savings back to industry for developing cost saving initi	L	-	H	1:1000	

*Management Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
**Design Actions Required: Low - <$1M ; Medium - $1M-$10M ; High - >$10M
***Operations cost benefit over life cycle of constellation: Low - <$10M ; Medium - $10M-$100M ; High - >$100M
****Cost / Benefit Ratio = RDT&E Cost : Reduction of Life Cycle Cost through 2028, with no time value of money factored in

The Big Lesson

- **If we want simple and cost effective operations we must design for operations**
  - **Shuttle designed for performance and multi-functionality**
  - **DC-X and Sea Launch Zenit Rocket designed for strict operational scenarios**
    - **Small operations team and low cost**
  - **787 Dreamliner designed for cost effective ownership**
- **NASA is in control of operations destiny of new programs**
  - **Narrow window of opportunity**

Hamilton-Sundstrand

Hamilton-Sundstrand Stretch Goals

Goal ID	Stretch Goal	Examples/Description
H-S 1	Robotics perform 50% of all EVA and IVA operations.	
H-S 2	Develop nuclear power systems for each CxP element.	
H-S 3	Commonality - no unique subsystems.	
H-S 4	International collaboration.	French-built lunar lander.
H-S 5	50% reduction in hardware redundancies. Dissimilar sparing. More serviceable in orbit.	
H-S 6	50% reduction in crew logistics.	Closed water/air loop. Advanced life support technology.
H-S 7	25% funding through commercial means. Encourage contractor participation/cost sharing, other creative business arrangements.	Turn operations over to industry (i.e., government buys rides). Future resource ownership. Stakes in future space tourism use.
H-S 8	25% funding from military programs. Technology or hardware sharing or leverage investment.	EELV launches. RS-68 engine.

Lockheed Martin

Lockheed Martin
Proposed Constellation Stretch Goal Overview

31 October 2006

Overview

- **Stretch goals**
  - #1 – Vertical Integration
  - #2 – Roll out and Launch Timeline
  - #3 – Vehicle Access at the pad
  - #4 – Vehicle Transport Timeline
  - #5 – Rollback Safety Requirement
  - #6 – Hypergolic Servicing Consideration
  - #7 – Launch Countdown Timeline
  - #8 – Launch Countdown Duration
  - #9 – Launch Pad Refurbishment
  - #10 – MLP Refurbishment
- **Recommendation for future support**

Lockheed Martin #1– Vertical Integration Timeline

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **Vertical integration of the vehicle shall be less than 40 working days (60 Calendar days).** From the start of stacking of major elements in the vertical integration facility to initiation of roll out must be accomplished within a 40 workday span. This provides for reduction in the number of processing bays in order to support launch manifest
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE
  - Facilitates and enables the launch manifest during high launch rate periods
  - Has schedule margin incorporated
- **Cons**
  - May drive processing crew size
  - May require parallel hazardous operations
  - May drive component design to accommodate reduced post integration access or simplified mate verification
- **Cost impact**
  - Qualitative assessment indicates a possible reduction in non-recurring but may increase the recurring
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in vehicle for rapid mate, verifications and checkout
  - Move servicing of sub-elements to pre-integration processing
  - Design and implements more parallel processing during integration
- **Historical examples**
  - Atlas services some vehicle components prior to delivery to the Vertical Integration Facility (VIF)
  - Satellite arrives serviced and encapsulated in the PLF

Lockheed Martin #2– Roll out and Launch Timeline

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **Roll to pad through launch shall be less than 5 working days (7 calendar days).** From roll out initiation to launch must be accomplished within a 5 workday span. This provides for reduction in the number of launch complexes and MLPs in order to support the launch manifest
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE
  - Facilitates and enables the launch manifest during high launch rate periods
  - Reduces the vehicle environmental exposure
  - Has schedule margin incorporated
- **Cons**
  - Will drive pad configuration for quick connection and checkout
  - May require parallel hazardous operations
  - Will drive component design to accommodate reduced pad access or simplified MLP mate verification
- **Cost impact**
  - Qualitative assessment indicates a possible reduction in non-recurring
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in MLP for rapid mate, verifications and checkout
  - Move servicing of sub elements to off pad facilities (Hypergolic propellant, ECS, ECLSS etc.)
  - Design MLP/Crawler transporter for rapid transit
- **Historical examples**
  - Atlas rolls to the pad, services propellant and launches in less than 24 hours

Lockheed Martin #3– Vehicle Access at the Pad

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **Vehicle access at the pad shall be limited to crew ingress, S&A and arming plug.** This provides for reduction in the tasks, time and people on the pad in order to support the launch manifest (subset of stretch goal # 2)
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE
  - Facilitates and enables the launch manifest during high rate periods
  - Enables the reduced time period from arrival to launch
- **Cons**
  - Will drive vehicle component design to accommodate reduced pad access
  - Will drive vehicle design to have systems that can be serviced, activated before arrival
  - May require parallel hazardous operations
- **Cost impact**
  - Qualitative assessment indicates a possible reduction in non-recurring and could reduce recurring parallel pad operations
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in vehicle for longer standby life systems (batteries, propellant systems ECS etc)
  - Move servicing of sub elements to off pad facilities (Hypergolic propellant, ECS, ECLSS etc.)
- **Historical examples**
  - Atlas provides only emergency access to components - when a problem arises the vehicle is returned to the VIF for repair

Lockheed Martin #4 – Vehicle Transport Timeline

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **Vehicle roll-out to and/or roll-back from the Pad shall take no more than four hours.** Starting with roll out from the vertical integration building until the vehicle is down hard at the pad shall not take more than four (4) clock hours. Limits the environmental exposure of the vehicle while in transit, supports stretch goal #2
- **Pros**
  - Limits or reduces the exposure of the vehicle while in transit
  - Enables the rapid move to a safe haven
  - Facilitates and enables the launch manifest during high launch rate periods
  - Enables the reduce time period for rollout to launch (#2)
- **Cons**
  - Will drive Crawler transporter design requirements
  - May drive vehicle monitoring during transit
  - May require design of more robust sway damper system
- **Cost impact**
  - Qualitative assessment indicates a possible increase in non-recurring for the crawler transporter and a reduction in recurring due to duration of the move
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in crawler transporter for moving at higher speeds, gradual acceleration and deceleration, precise positioning and stability
  - Vertical integration facility closer to the pad
- **Historical examples**
  - Atlas rolls to the pad, services propellant and launches in less than 24 hours

Lockheed Martin #5– Rollback Safety Requirement

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **Vehicle roll-back following tanking can commence prior to full cryo burn off ($GH_2<1\%$)** Begin the move from the pad before the LH levels reach 1% residual in the tank. Allows the removal of the vehicle for protection, facilitates reduced access at the pad and roll out to launch
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE
  - Facilitates and enables the launch manifest during high launch rate periods
  - Enables the reduced time period roll out to launch (Stretch goal #2)
  - Enables reduced access at the pad (stretch goal #3)
- **Cons**
  - Will drive vehicle component design to accommodate lockup of cryo propellant
  - Will drive vehicle design to have systems that can be monitored
  - May require parallel hazardous operations
- **Cost impact**
  - Qualitative assessment indicates a possible increase in non-recurring and could reduce recurring parallel pad operations
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in vehicle for lockup of the cryogenic propellant (increased pressure relief)
  - Design provisions to monitor the tank pressure continuously
  - Design flyaway vent that interfaces to vertical integration facility emergency burn stack
- **Historical examples**

Lockheed Martin #6– Hypergolic Servicing Consideration

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **All elements requiring Hypergolic propellants shall be serviced prior to stacking/integration.** Service sub elements with hypergolic propellant prior to delivery to the vertical integration facility. Eliminates the need for a servicing capability at the pad or in the vertical integration facility.
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE at the pad where it is exposed to the elements and harder to maintain
  - Facilitates and enables the vertical integration and pad time reduction in support of launch manifest during high launch rate periods
  - Servicing is a parallel operation away from the serial vertical integration and pad operations
- **Cons**
  - Will drive vehicle design to accommodate transportation and integration after servicing
  - Will drive vehicle design to have systems that are monitored during transport or integration
  - May require parallel hazardous operations
- **Cost impact**
  - Qualitative assessment indicates a possible reduction in non-recurring and could reduce recurring parallel pad operations
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in vehicle for transportation , handling and vertical integration after hypergolic servicing
  - Develop hypergolic servicing capability at element processing location
- **Historical examples**
  - Atlas services some vehicle components prior to delivery to the Vertical Integration Facility (VIF)
  - Satellite arrives serviced and encapsulated in the PLF

Lockheed Martin #7– Launch Countdown Timeline

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **Launch Countdown shall nominally begin the day following vehicle roll out to the pad.** MLP position, connection and verification should require less than 2 work shifts prior to countdown. Enabled by the capability of the MLP positioning, alignment, commodity connection and verification.
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE
  - Facilitates and enables the launch manifest during high launch rate periods
  - Enables the reduced time period from arrival to launch
- **Cons**
  - May drive facility and GSE design cost
  - Will drive vehicle design to have systems that can be serviced, activated before arrival
  - May require parallel hazardous operations
- **Cost impact**
  - Qualitative assessment indicates a possible reduction in non-recurring and could reduce recurring parallel pad operations
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in MLP and Crawler transporter to accommodate positioning, alignment, commodity connection and verification
  - Move servicing of sub elements to off pad facilities (Hypergolic propellant, ECS, ECLSS etc.)
- **Historical examples**
  - Atlas rolls to the pad, connects verifies and is ready to begin countdown in hours rather than days

Lockheed Martin #8– Launch Countdown Duration

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **Launch Countdown shall nominally be less than 24 hours.** From the time the MLP is connected and verified to commit to launch shall take 24 or less clock hours. Enables roll out and launch timeline
- **Pros**
  - Facilitates and enables the launch manifest during high launch rate periods
  - Enables the reduce time period from arrival to launch
  - Limits vehicle on pad exposure to the environment
- **Cons**
  - Will drive vehicle component design to accommodate reduced pad access
  - Will drive vehicle design to have systems that can be serviced, activated before arrival
  - May require parallel hazardous operations
- **Cost impact**
  - Qualitative assessment indicates a possible increase in non-recurring and could reduce recurring for limited time on pad operations
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions in vehicle for BIT and self test
  - Move servicing of sub elements to off pad facilities (Hypergolic propellant, ECS, ECLSS etc.)
- **Historical examples**
  - Atlas rolls to the pad, services propellant and launches in less than 24 hours

Lockheed Martin #9– Launch Pad Refurbishment

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **The pad shall not require refurbishment following launch.** Infrastructure at the pad designed robust enough to support numerous launches without requiring refurbishment. Enables closer launch centers during manifest high launch rate periods.
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE
  - Facilitates and enables the launch manifest during high launch rate periods
  - Enables the reduced time period between launches
- **Cons**
  - Will drive launch pad design to be more robust
  - Will drive launch pad design to eliminate the potential of launch debris
- **Cost impact**
  - Qualitative assessment indicates a possible increase in non-recurring and could reduce recurring for refurbishment
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions for the launch pad with sacrificial plates, water deluge and rapid replenishment of cryogenic propellant tanks
- **Historical examples**
  - Atlas pad can support multiple launches with minimal time between launch servicing

Lockheed Martin #10– MLP Refurbishment

Proposed Constellation Stretch Goal Overview

- **Goal statement**
  - **The MLP/LUT shall not require refurbishment following launch.** MLP structure design robust enough to support numerous launches without requiring refurbishment. Enables closer launch centers during manifest high rate periods.
- **Pros**
  - Limits or reduces the cost for infrastructure and GSE
  - Facilitates and enables the launch manifest during high launch rate periods
  - Enables the reduced time period from arrival to launch
- **Cons**
  - Will drive launch pad design to be more robust
  - Will drive launch pad design to eliminate the potential of launch debris
- **Cost impact**
  - Qualitative assessment indicates a possible reduction in non-recurring and could reduce recurring parallel pad operations
  - Recommend a further detailed quantitative cost and schedule analysis to determine feasibility
- **Implementation approach**
  - Design provisions for the MLP with sacrificial plates, water deluge and rapid replacement and verification of umbilicals
- **Historical examples**
  - Atlas provides only emergency access to components and when a problem arises the vehicle is returned to the VIF for repair

Northrop Grumman

NORTHROP GRUMMAN
DEFINING THE FUTURE

NASA ESMD Constellation System Stretch Goal Considerations

Northrop Grumman Corporation

October 31st, 2006

NGC: Problem Statement Interpretation

- Increase Affordability Of Future Constellation Program Elements By Reducing Nearer Term Element Life Cycle Costs Through Increased Operability

- Recommend Big Hairy Audacious Goals (BHAGs) That:
  - **Represent An Aggressive Yet Feasible Constraint Upon The System**
  - **Are Suitable For Direct Insertion As A Requirement**
  - **Cannot Be Met By Current Systems Unless The Systems Incorporate Discontinuous Changes In Operations Or Design**
  - **Should Result In Dramatic Reductions In Operational Life Cycle Cost And Improve System Operability**
  - **Are Focused On The Entire System, Not On Individual Elements**

NGC: Affordability Improvement Construct

- Design / Produce Fewer End Items - Maximize Multi-functionality
  - **Use The Same End Item To Perform More Functions**
  - **Maximize Re-use**
- Design / Produce Fewer Different Things
  - **Maximize Commonality Across Unique End Items**
- Reduce Overall System Labor (Dedicated and per Mission)
  - **Increase Automation**
  - **Increase Effectiveness**
  - **Shared Resources**
- Evolve Using System Block Changes & Operate Within Established Envelopes
- Maximize Employment of Elements That Are Already Expensed
  - **Existing Facilities, COTS**
- Share Costs With Other Space-Faring Nations
  - **Foreign Participation - As Long As Everyone Pays Their Own Way**

NGC Goal 1:
Identification /Allocation of LCC Drivers

- Issue: LCC Drivers That Can Significantly Impact Infrequently Operated Systems Are Not Always Apparent – Must Identified And Allocated To Reduce LCC
- Recommendations: Study Relevant Aircraft and Ship Systems LCC Drivers To Identify and Impose On Constellation Systems Elements
  - **e.g: Total System Fixed Support Labor; Support Crew Hours Per Mission; $/Pound To Lunar Surface; Lunar Surface Crew Hours/Year; Reusable Flight Element Turnaround Time**
- Pros:
  - **Reduced LCC Costs**
- Cons:
  - **None, If Correctly Identified and Applied**
- Cost Impact:
  - **Little, If Allocated and Enforced Early**
- Implementation Approach:
  - **Benchmark Other Systems Where Similar Experience Produced System LCC Reductions (B-2, Twin-Engine Trans Oceanic Airplane Design, etc.)**
- Historical Examples:
  - **B-2 Life Cycle Costs, Twinjet (B-757/767/777) Aircraft LCC**

THE AEROSPACE CORPORATION

NGC Goal 2:
Failure Mode Mitigation Improvement

- **Issue: Failure Modes Mitigation Consumes Disproportionate Resources During Both Element DDT&E And Operational Life Cycle Phases**
- **Recommendation: Heavy Emphasis On *Preservation of Life***
  - **More Low-Tonnage Flights vs. Fewer High-Tonnage Flights**
  - **Autonomous Lifeboat Outpost Stationed In Appropriate Lunar And Earth Orbits**
  - **Ability To Rapidly Launch A Rescue Vehicle On Demand**
- **Cost Impact: Net Reduction In System Life Cycle Costs**
  - **Increased System Reliability, More Cost Efficient Use of Fixed Overhead Costs**
- **Prior Analysis: Aircraft and Launch Systems History**
- **Implementation Approach: Optimize Flight Frequency**
  - **Assess Launch Rate / Launch Mass vs. System Reliability And LCC**
- **Unintended Consequences: Potentially, Unforseen Development Schedule Risks**
- **Other Lessons Learned To Date:**
  - **Baseline Shuttle Flight Frequency (5 Orbiters, ~55 Flights Per Year) Drove Infrastructure Designs And Costs That Were Never Efficiently Used At Lower Actual Flight Rates**
- **Related Constellation Stretch Goals:**
  - **Sustained, Sustainable Human Lunar Presence (Increased Missions Per Year Could Result)**

NGC Goal 3:
Mandate Green Propulsion Across The System

- Issue: Hypergolic Propellant And Propulsion Systems Result In Greater Life Cycle Costs Than Non-Hypergolic Systems
- Recommendation: Mandate "Green", i.e., Non-Hypergolic Propulsion Systems In All Constellation System Elements
- Cost Impact:
  - 7 to 1 Cost Reduction Benefit – Operations and Environmental Tail
- Prior Analysis:
  - CEV Phase 1 Contract Studies
- Implementation Approach:
  - Mandate Requirement On All System Elements
  - Complete Low(er) TRL Propulsion Device(s) DDT&E
  - Requires Long Term In-Space Cyro Fluid Storage and Handling
- Unintended Consequences:
  - Potentially, Unforseen Development Schedule Risks
  - Potentially, System Performance
- Other Lessons Learned To Date:
  - High Costs Associated With Hypergolic Propellants/Systems Well-Documented From Prior and Current Flight Systems
- Related Constellation Stretch Goals:
  - In-Situ Resource Use, Both Moon and Mars

NGC Goal 4:
Improved Mission Control Operating Modes

- **Issue: Continuous MCC Staffing And Current Methods For Communicating Objectives To Flight Crews Drive Excessive Facilities And Personnel Resources**
- **Recommendations:**
  - **Change Current CONOPS To "Normal" Dispersed Operations**
  - **Upon Emergency Onset, Automatically "Safe" The Spacecraft Until Response Team Assembles In The MCC To Resolve Issues**
  - **During Transition From Day-To-Day Dispersed Ops To MCC-Dominated Emergency Ops, Establish The Ground Team Virtually Using Modern Networked Communication**
  - **Communicate Specific Objectives To Flight Crews Versus Step By Step Procedures**
- **Cost Impact: Reduced MCC and Training Manning**
- **Prior Analysis:**
  - **USN - Reduced Ships Crew Achieved Through Contemporary System Design**
- **Implementation Approach:**
  - **Study USN Ship Systems Design / Crew Sizing Techniques**
- **Unintended Consequences:**
  - **None, Assuming Flight Systems Are Designed Accordingly**
- **Other Lessons Learned To Date:**
  - **Navy Crew Size Reductions Without Mission Impairment**

NGC Goal 5: System Element Flight Envelope Certification/Ops

- Issue: Historically ‘Experimental’ Nature Of Spacecraft and Launch Vehicle CONOPs Involves An Arduous Analysis Cycle Before Every Flight, and Thus Commensurate Recurring Expense That Is Avoidable
- Recommendations:
  - **During The DDT&E Flight Test Phase Establish and Certify A Flight Envelope. Clear And Operate A Vehicle *Only* Within Said Flight Envelope**
  - **Implement Flight Element Block Upgrades/Envelope Expansion-Certification To Accommodate System Growth When Required**
- Pros:
  - **Reduces Mission Preparation Resources By Elimination Of Mission-specific Environments And Loads Analyses**
- Cons:
  - ***May* Require A Longer, More Expensive Certification Process**
- Cost Impact:
  - **Areas Of Anticipated Savings And/Or Additional Cost**
- Implementation Approach:
  - **Model After Aircraft Systems**
- Historical Examples:
  - **Aircraft Developments / Evolutions / Upgrades / Ops**

NGC Goal 6: In-Space Re-Supply / Reuse Extensibility

- Issue: Architecture Based On High Levels Of Expendability Is Costly
- Recommendations: Incorporate Provisions For Evolution To Flight Systems Reuse Using In-space Re-fueling Or Re-supply
- Pros:
  - **Eliminates Production Cost Of Single-use Elements**
  - **Reduces Number Of Ares Launches**
  - **Reduces Cost Of Commodity Space Launch – Benefit From Competition**
  - **Enables Increased Mission Capability**
- Cons:
  - **Additional Design Complexity For Longer Life, Reusable Elements**
  - **Complexity And Risk Of EDS Or LSAM Storage In Lunar Orbit And EDS Or SM Earth Aerocapture.**
  - **Increased Risk- Increased Launches/In-space AR&D, And Transfer Operations**
- Cost Impact:
  - **Reduction In Flight Vehicle Production Cost Proportional To Number Of Reuses.**
- Implementation Approach: Refuel / Reuse Of LSAM After Ten Lunar Missions
- Historical Examples: Aircraft, Shuttle, ISS And Other Space Stations, Aerial Refueling, Shipping Containers
- Related Constellation Stretch Goals:
  - **In-Situ Resource Use, Both Moon and Mars – Major LCC Reductions**

NGC Goal 7: Maximize Subsystem / Component Commonality

- Maximum Commonality Of Subsystems And Components
  - **Combined Logistics And Support Infrastructures**
  - **Reduced Production Infrastructure**
  - **Increased Potential For Competitive Sourcing**
  - **Enables More Efficient Integrated Constellation Supply Chain**
  - **Avoidance Of New Designs – Some Performance Penalty**

- Common / Standardized Hardware and Software
  - **Flight Hardware Systems – e.g., Common Avionics And Power Systems Between Orion, Ares, EDS, And LSAM; Common ECLSS Between Orion and LSAM, Standardized LOX Modules For LSAM Refueling, etc..**
  - **Flight Software**
    - **Operating System**
    - **Middleware and Utilities**
    - **Module Standards and Interfaces**
    - **Development tools and programming language**
  - **Mission Operations Software**
    - **Flight Planning and Simulation**
    - **Communication and Networking**
    - **Ground Interfaces**

Pratt & Whitney Rocketdyne

Stretch Goals

- **Streamline Acquisition Process**
  - **Partner with NASA/DOD/DCMC - lessons learned**
  - **Fee Structure**
  - **Intellectual Property**
  - **SDB Goals - total contract value vs. function of sub-contracted $$**
  - **Redundant Data**
  - **DRD's - too many**
  - **Organization reporting relationships**

Stretch Goals

- Work Scope and Requirements Creep
  - Functional organizations and programs not aligned
    - Causes significant cost and schedule impact
    - Examples - fracture control, A- basis materials, factor of safety, human rating, etc.
    - Using HDQTR's dictated systems/tools without consultation with contractors
      - Pro-E vs. Catia
      - Primavera vs. Microsoft Project
      - Risk control tools

Stretch Goals

- Oversight vs. Insight
  - Apply lessons learned from RS-68 development, certification and production to Constellation
  - Engine developed and certified and is now produced using same robust systems as SSME uses with minimal insight by AF/Aerospace
    - Company processes/tools used meet/exceed NASA requirements
    - No DRD's - All data exists in systems used - data available
  - NASA should audit contractors tools and processes to determine if they meet or exceed NASA requirements

USA

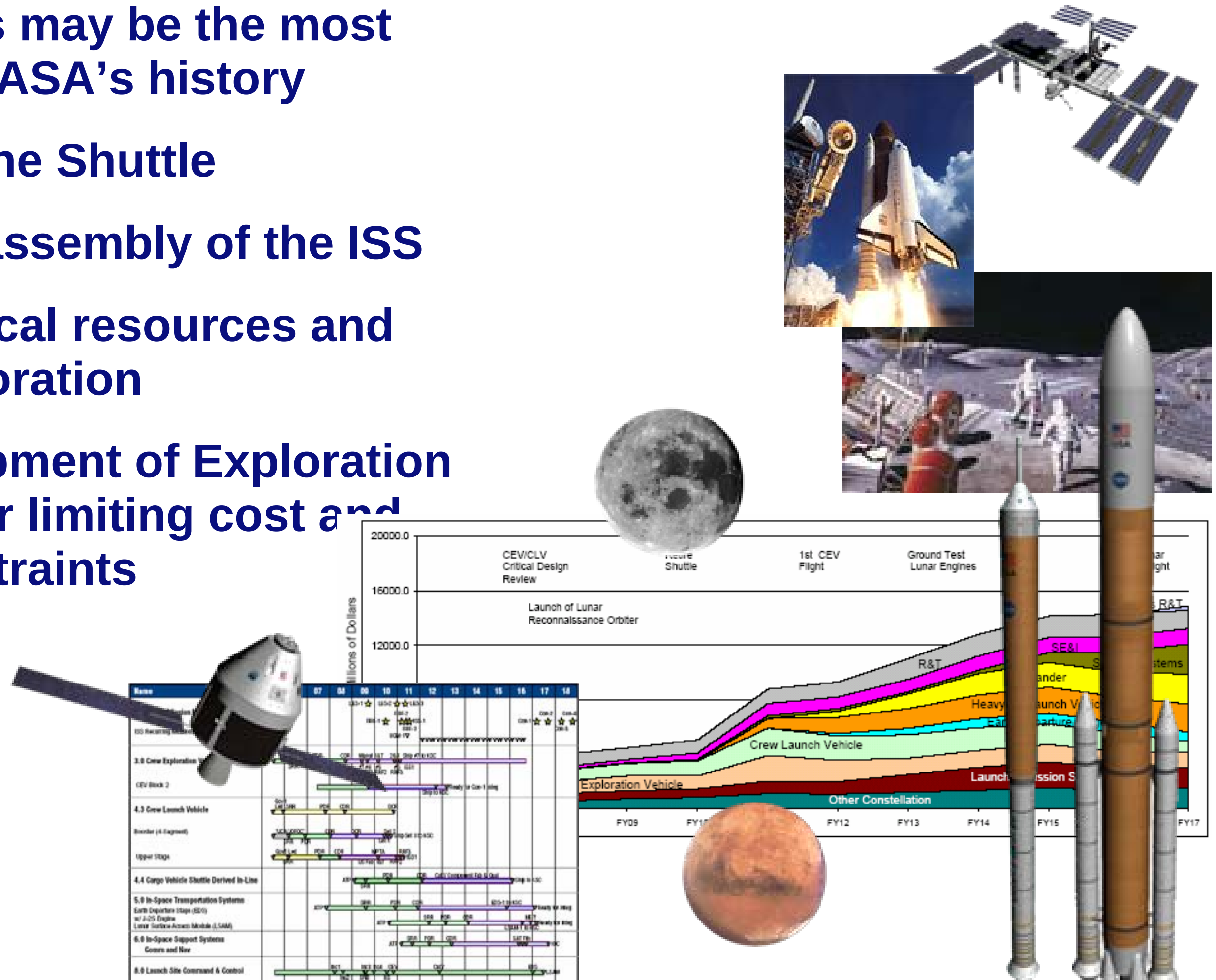

Constellation
Stretch Goals
United Space Alliance

Background: Constellation (Cx) Stretch Goals

- Exploration Systems Mission Directorate (ESMD), with support of Space Operations Mission Directorate (SOMD) initiated effort to identify “stretch goals” for Constellation Program
- Stretch goal: An aggressive system requirement which, if implemented, could result in a dramatic reduction in life cycle cost
- Input requested from industry partners
  - Boeing
  - Lockheed Martin
  - United Space Alliance
  - Pratt & Whitney Rocketdyne
  - Hamilton Sunstrand
  - ATK
- Aerospace Corporation chartered to facilitate process, collect and report data
- TIMs scheduled for October 16th and 31st

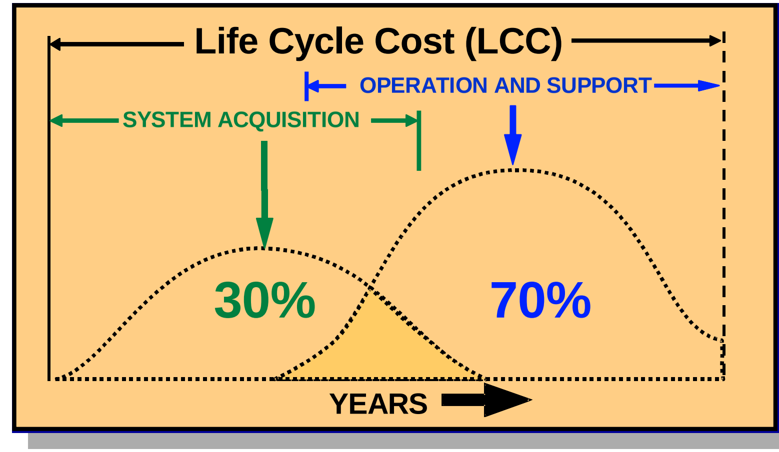
NASA’s Cx Challenges and Opportunities

- The next few years may be the most crucial period in NASA’s history
  - Safely fly out the Shuttle
  - Complete the assembly of the ISS
  - Transition critical resources and assets to Exploration
  - Initiate development of Exploration elements under limiting cost and schedule constraints



Design Activities Have Far Reaching Impacts to the Overall Project Life Cycle

- DDT&E decisions can drive up to 70% of a project's life cycle costs
- System development goals are often just the tip of the project "iceberg"
- Less visible life cycle costs are driven by development goals and need to be considered early in the DDT&E phase
  - Sustaining engineering
  - Shipping / storage
  - Facilities / equipment
  - Ops planning and execution
  - GSE
  - Commonality

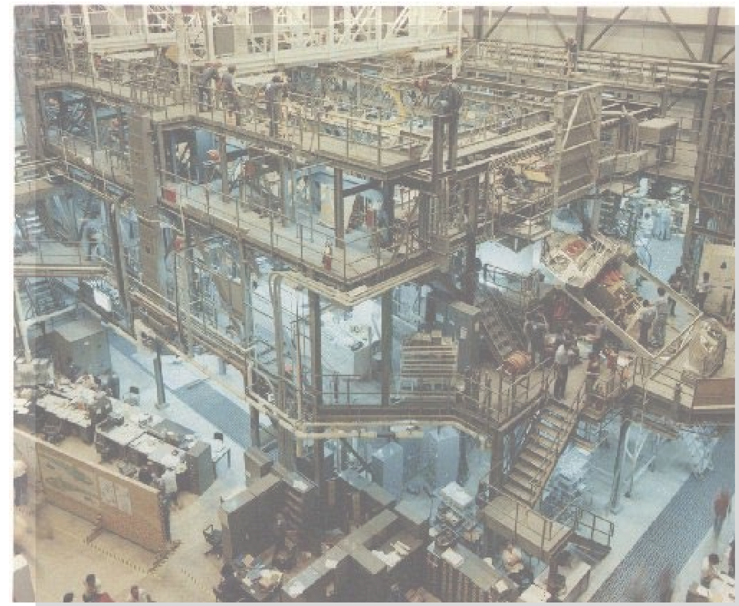


Developers Need to Consider the Recurring Impacts on Operations for Decisions Made During the Development Process

Moving From Viewgraphs to Reality Can Be Expensive

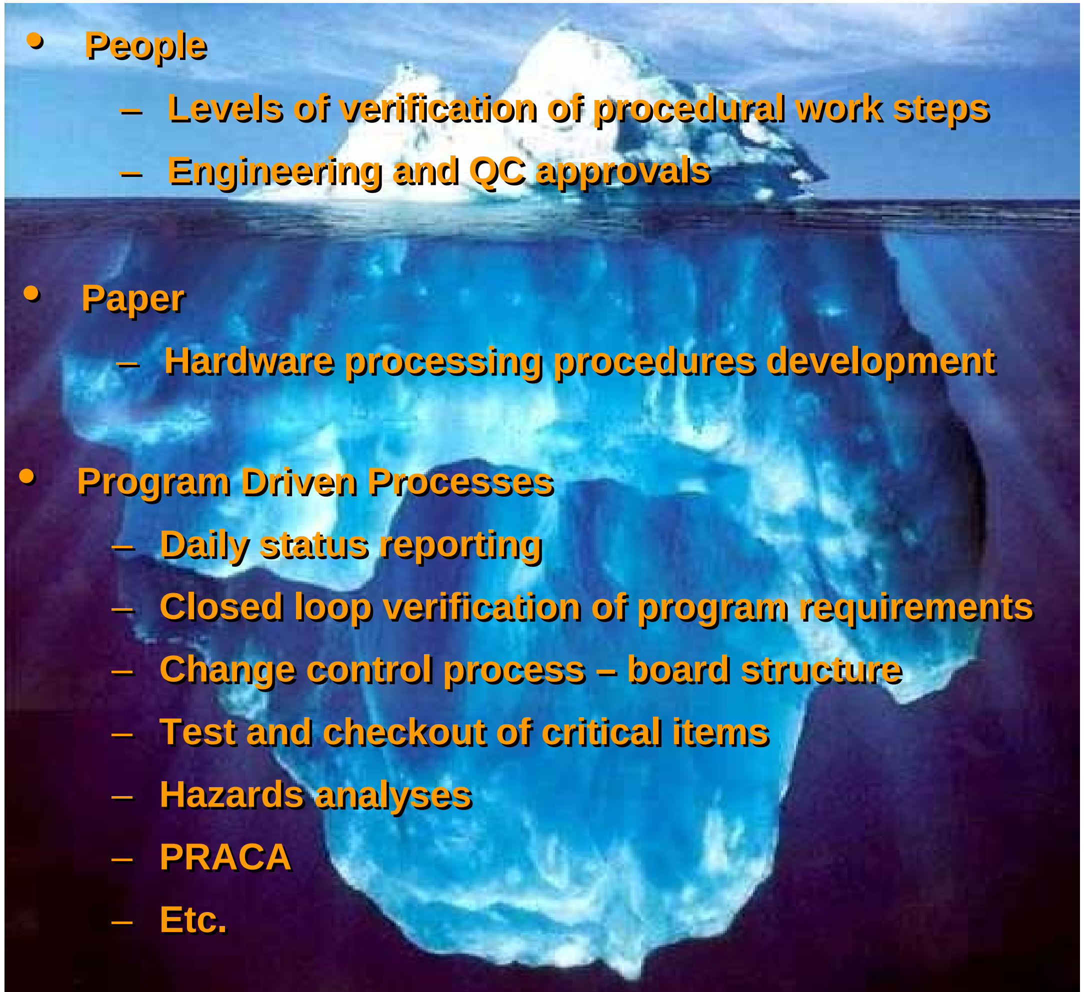
- Developers must adopt a “Design for Support” instead of a “Support the Design” approach, as seen in the Shuttle Program

Plan



Actual

The Hidden Costs of Operations



- People
  - Levels of verification of procedural work steps
  - Engineering and QC approvals
- Paper
  - Hardware processing procedures development
- Program Driven Processes
  - Daily status reporting
  - Closed loop verification of program requirements
  - Change control process – board structure
  - Test and checkout of critical items
  - Hazards analyses
  - PRACA
  - Etc.

Constellation Stretch Goals

- Goals grouped into three categories:
  - Program Management (PM) – Goals related to philosophy and approach to managing Cx Program, including requirements, processes and systems
  - Design and Operations (D/O) – Goals related to technical approaches or system performance
  - Business/Financial (B/F) – Goals related to new ways of doing business or contracting for Cx work

Constellation Stretch Goals – Program Management

PM 1

Implement maximum commonality across Constellation Program including:

- **Common processes**
- **Common components**
- **Common subsystems**
- **Common GSE**
- **Common materials/specifications**
- **Common LRUs**
- **Common interfaces**
- **Common tools**

BENEFIT:

Lower life cycle costs

- Reduces number and variety of parts at all levels
- Eliminates redundant qualification and certification
- Eliminates redundant production and procurement
- Reduces number of spares and inventory costs
- Lowers weight of in-flight spares
- Reduces environmental waste streams
- Reduces manpower for training and operations

APPROACH:

- Levy goal at Level 1
- Identify pilot areas for implementation
- Develop “standards” board for review of practices

Why Commonality?

- The Apollo 13 crew was saved by taping a round lithium hydroxide canister from the Command Module to a square air duct in the Lunar Module
  - The Mission Support team were heroes!
- If we have to do something like that again during a Constellation mission, we won’t be heroes
  - We’ll be considered technically incompetent because we never addressed the “lesson learned” on commonality

Constellation Stretch Goals – Program Management

PM 2

Implement single, Program-wide management systems in key areas, including:

CAD, Engineering Drawing and Release Systems

Configuration Management System

Non-conformance Tracking System

Cost Accounting and Reporting System

BENEFIT:	APPROACH:
Significant cost reduction in overhead associated with utilizing/maintaining multiple systems; costs of data conversion between systems	Start with single set of standards, levy requirement for all to use program-defined systems by projected date

Constellation Stretch Goals – Program Management

PM 3

Create clearly defined approach for declaring vehicles operational; establish criteria and clear RAA for development and operations organizations and their contractors during each phase

BENEFIT:	APPROACH:
Besides clear RAA, reduces cost of maintaining expensive or redundant engineering skills	Create joint DDT&E/Ops team to define philosophy criteria and roles

PM 4

Establish a data warehouse approach for all information, requirements and data utilized by multiple centers for analysis, production and reconfiguration; adopt the philosophy of using common data systems across all elements of Exploration

BENEFIT:	APPROACH:
Significant reduction in cost of maintaining/delivering critical program data	Must first define program data architecture and accountability

Constellation Stretch Goals – Program Management

PM 5

Implement a single Requirements Management Process and system for all levels of the Constellation Program and its associated projects

BENEFIT:	APPROACH:
Significant reduction in personnel and IT costs associated with multiple levels of CM, changes processes and control boards	• Start with single set of standards for tools and processes across projects and centers • Levy requirement for all to use single system by projected date

Constellation Stretch Goals – Program Management

PM 6

Implement a master verification approach based on on-board vehicle health maintenance data, rather than ground processing-related test and checkout; zero-base the Constellation OMRSD or equivalent (all must fight their way in, including Shuttle-based hardware); use COTS IT solutions to provide decision makers with immediate health/status of many launch processing systems

BENEFIT:	APPROACH:
• Significant reduction in invasive, labor-intensive ground testing during processing • Simplifies design standards, reduces acquisition/maintenance costs	Design requirements for flight hardware must include adequate vehicle health data gathering and instrumentation approach; also must be common across hardware elements

Constellation Stretch Goals – Program Management

PM 7

Develop centralized math models for simulation and flight software verification capabilities across the program

BENEFIT:	APPROACH:
Reduces software development and sustaining costs	Establish Level II SE&I office as accountable organization

PM 8

Establish operations concepts that minimize dependence on multiple mission evaluation capabilities

BENEFIT:	APPROACH:
Reduces overall life cycle costs for personnel	Define clear roles (RAA) for operators, developing/sustaining engineering organizations during mission execution (see also PM 3)

Constellation Stretch Goals – Program Management

PM 9

Implement Knowledge Management processes

BENEFIT:	APPROACH:
• Maintains “corporate knowledge” for use during times when original designers, managers, operators, planners are no longer available for problem solving, anomaly resolution or other activities vested in a prior time • Closes the loop from requirements to implementation work and experiences	• Establish knowledge structure to allow sharing of work and experiences. Utilize technology to archive written or recorded work and experiences • Develop and maintain visual model and matrix relating archived written or recorded experiences to specific hardware/software attributes

Constellation Stretch Goals – Design/Operations

D/O 1

Exclude all significant vehicle modifications or configuration changes from ground processing flow; implement as block updates by OEM at predetermined intervals and prior to KSC processing

BENEFIT:	APPROACH:
Predictable, repeatable (and therefore more efficient) processing templates	Implement through Level 1 requirement and basic Program Operational Philosophy

D/O 2

Develop crew cadre sizing model such that size of astronaut corps is optimized and crew support infrastructure is reduced

BENEFIT:	APPROACH:
Reduces costs associated with crew support infrastructure	Create independent study team to define criteria/approach

Constellation Stretch Goals – Design/Operations

D/O 3

Design all new Constellation systems to require non-toxic propellants

BENEFIT:

- Increases safety of ground personnel
- Reduces processing time

APPROACH:

Evaluate requirement across program immediately – key architecture driver

D/O 4

Design all flight vehicle-to-ground system umbilicals to be mated and verified without hands-on involvement

BENEFIT:

- Reduced processing time
- Increased flexibility in maintaining flight schedules

APPROACH:

Create Level 1 requirement

Constellation Stretch Goals – Design/Operations

D/O 5

Maximize number of LRUs accessible at pad

BENEFIT:	APPROACH:
• Flexibility in processing and launch preparation • Reduces likelihood of costly roll-backs	Create Level 1 design requirement

D/O 6

Implement “Stand By” Payload Planning

BENEFIT:	APPROACH:
Permits substitution of “stand by” payload for any mission delayed “x” period of time (TBD)	Establish policy to accomplish planning and preparation of payload complement

Constellation Stretch Goals – Design/Operations

D/O 7

Select wire insulation, routing and protection for accessibility, repair, inspection and use/abuse from handling, traffic and environment

BENEFIT:	**APPROACH:**
Reduces cost/schedule associated with wire problems	Use lessons learned from STS and Expendable vehicles to define clear standards and requirements

D/O 8

Provide automated capabilities for in-situ crew environments and long-term autonomous orbit operations

BENEFIT:	**APPROACH:**
Lessens dependence on ground-based solutions generated by large numbers of personnel	Significant capability development required

Constellation Stretch Goals – Design/Operations

D/O 9

Automate ground system reconfiguration capabilities

BENEFIT:	APPROACH:
• Increases adaptability for manifest-driven change traffic • Decreases ground processing cycle time	Identify areas for greatest payback

Constellation Stretch Goals – Design/Operations

D/O 10

Establish design philosophy that emphasizes demonstrated high reliability component selection, coupled with testing and inspection prior to shipment to KSC; use commercially available components wherever possible to assure longevity of availability; use COTS and COTS performance-based specifications wherever possible

BENEFIT:	APPROACH:
• Minimizes need to re-test at KSC • Reduces software development and sustaining costs	Must be levied as requirement to all Constellation projects

Constellation Stretch Goals – Design/Operations

D/O 11

Require BITE (Built in Test Equipment) for all avionics hardware

BENEFIT:	APPROACH:
• Provides self-test capabilities and functions • Significantly reduces test and checkout costs • Eliminates need to remove, handle, bench test, reinstall and retest disturbed interface connections	Levy as requirement

Constellation Stretch Goals – Design/Operations

D/O 12

Develop philosophy and approach for skill-based vs. task-based crew training

BENEFIT:	APPROACH:
Reduces training requirement time and dependency upon specific flight products	Conduct study of existing vs. predicted training requirements to identify how much of task-based training could be more generic

D/O 13

Establish clear and consistent guidelines for configuration management and tracking items that reflect the configuration of facilities, systems and equipment

BENEFIT:	APPROACH:
Reduces overhead of maintaining multiple systems, databases and reporting	Form Tiger Team to define program-level requirements and implementation approach

Constellation Stretch Goals – Business/Financial

B/F 1

Implement life cycle cost management at the Constellation Program level and at each element of Constellation

BENEFIT:	APPROACH:
Maintains focus and accountability on LCC at all levels	Just do it

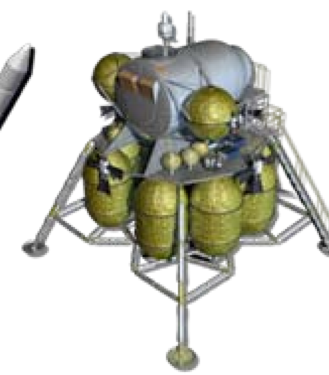
B/F 2

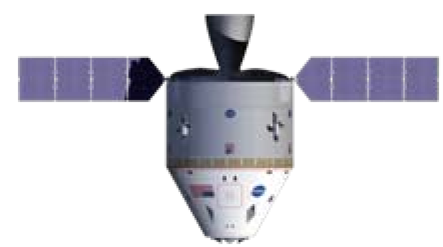
Implement Constellation Contracts which directly incentivize industry to contain and reduce program life cycle costs

BENEFIT:	APPROACH:
Historical data shows this effective in direct cost reduction	Just do it

The Need for Operations Involvement

- Up-front investment in operations will pay major dividends in the future
- Insufficient definition of operational requirements and lack of consideration for the operational environment during the development phase of a program results in:
  - A labor intensive operational vehicle
  - High operational costs
  - Sub-optimized safety and schedule performance
- Designing for operations is especially critical when the system being developed is:
  - Human-rated
  - Complex
  - Reusable





Existing Capability/Experience Can Be Applied to Support Constellation Success

- **Launch Vehicle Design for Operability**
  - Help adopt a "Design for Support" instead of a "Support the Design" approach, as seen in the Shuttle Program
  - Operations analysis, trade studies and simulations to establish initial schedules, costs and validate changes
  - Human Factors analysis to ensure user friendly interfaces
  - Industrial Engineering analysis to optimize process and operations flows
  - Manage System Requirements to minimize risk and optimize efficiency
  - Effective methods to minimize risk during hazardous operations and material handling
- **Ability to draw upon existing vendor base for additional depth**