

Constellation Acceleration Study Report

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Executive Summary

In 2004, the White House formulated a Vision for Space Exploration (VSE). The VSE called for retiring the Space Shuttle in September 2010, developing and flying the Orion Crew Exploration Vehicle (CEV) to the International Space Station (ISS) and return to the Moon before 2020, and building upon the Orion lunar architecture to explore Mars in the future. Currently the gap between Space Shuttle retirement and Orion initial operational capability (IOC) in March 2015 is potentially five years.

The purpose of the Constellation Program Acceleration (CxAccel) Study is to identify potential program content and budget options to accelerate Constellation schedules to minimize the gap in US human spaceflight post-shuttle retirement and to decrease reliance on international assets for crew rescue from ISS. The Terms of Reference for the study were provided by the Constellation Program Manager. The CxAccel Study was comprised of representatives from the Constellation Program (CxP) office and each of the projects. To ensure diversity of thought, and to challenge assumptions, the team also included senior systems engineers and managers external to the CxP and the Agency.

For the purposes of this study an authority to proceed (ATP) date of April 1, 2009 was established. In addition, it has been assumed that the Space Shuttle Program (SSP) will not be extended and that the current manifest will be flown out through STS-133. Another ground rule for this study was that any suggested deferment of lunar vehicle capability would be incorporated into a future block upgrade. However, currently no lunar capabilities have been deferred as a result of this study. At the acceleration decision point, the Program can decide to implement design simplifications identified in this study that provide the best opportunity for acceleration. These suggested simplifications can be implemented independent of acceleration to realize a cost savings of up to \$500M. This study did not address the cost for re-establishing any potential deferred lunar capabilities. Although the external IOC commitment date is March 2015, all cost and schedules impacts for this study were based from the CxP Manager Recommend (PMR) 08, Revision 1 (PMR08 Rev 1) baseline of September 2014. An overall, qualitative risk assessment (high, medium, low) of achieving the options was performed. In addition, an overall technical risk assessment (safety and mission success) was performed for each option relative to the current baseline.

This study considered three acceleration options:

- Option #1 Increase confidence in PMR08 Rev 1 (Sept 2014)
- Option #2 Accelerate PMR08 Rev 1 by 12 months (Sept 2013)
- Option #3 Accelerate PMR08 Rev 1 by 18 months (March 2013)

The current contracts were reviewed and no contractual impediments to implementing these options were identified. Several contractual strategies were evaluated but none resulted in significant schedule acceleration. However, several shuttle transition dates

will need to be either maintained or accelerated (based on the option) in order to enable acceleration, including, A2 test stand, Vehicle Assembly Building (VAB) High Bay 3, Launch Pad 39B, Michoud Assembly Facility (MAF) floor space, and Orion docking system hardware.

In developing these options, the current technical, cost, and schedule status for each of the projects was reviewed. The program has developed a robust technical design for the Lunar mission. Due to an insufficient funding profile and the lack of adequate Program reserves in 2009 and 2010, in conjunction with the effect of two consecutive Continuing Resolutions, the CxP has had to defer development of facilities, equipment, engineering development units, tooling, ground testing and wind tunnel testing. The flight test program had to be minimized to a success oriented program with no room for test failures. These changes effectively represent the deferral of a significant portion of the development phase of the program and result in a significant increase in risk to achieving the schedule. Today's integrated program critical path is artificially driven by the insufficient funding profile in 2009/2010 and technical content deferral - not by optimal hardware design, build and test constraints and deliveries. Normally the integrated critical path would be key to defining the best approach to acceleration; however, because the program critical path had not been re-established in response to changes resulting from the PMR08 Rev 1, each project focused on accelerating the fundamental phases of design, development, test and evaluation (DDT&E). Furthermore, the program's lack of reserves has driven numerous items in the current technical baseline to not be fully funded, including some design changes that are being carried as threats. These changes are documented in two categories: current baseline shortfall and technical baseline changes. The current baseline shortfall includes undefinitized changes in the Orion contract, affects on reusability due to the design change from land landing to water landing, additional Upper Stage Engine testing and program challenges to the projects. The technical baseline changes include recent design changes that are currently unfunded including phased array communication system, high voltage power system, thrust oscillation mitigations, First Stage nozzle extension, and implementation of the International System of units (SI). The result is a \$1.9B shortfall between the available funding and the technical baseline. These costs must be addressed irrespective of acceleration and therefore will be shown separately from the costs for acceleration.

Due to these factors, achieving the current baseline schedule, PMR08 Rev 1, with a September 2014 IOC is high programmatic risk and considered not achievable with the corresponding current technical content, cost, and schedule. Option 1 increases the confidence in meeting the current PMR08 Rev 1 baseline by increasing funding early enough in 2009 and 2010 to ensure a more robust vehicle development and test phase. This includes restoring adequate program reserves, restoring deferred design and development work, early procurement of long lead time items, and acceleration of assembly, integration and test. Option 1 also accelerates the flight test program and adds an additional Ascent Abort test of opportunity. This ensures a more robust flight test program that buys down abort and integrated vehicle risks earlier and has the capacity to have a failed flight test, recover and minimize schedule delay. Orion accelerates assembly

by incorporation of a segmented design. Ares includes two additional development Upper Stage Engines for accelerated testing; restores manufacturing capability at Marshall Space Flight Center (MSFC) for parallel manufacturing of the development Upper Stages; and incorporates manufacturing improvements on the First Stage. Ground Operations accelerates development of the mobile launcher and utilizes a high-fidelity Orion mock-up as a pathfinder to reduce processing time. In addition Orion has identified potential hardware and software simplifications that can be implemented at the acceleration decision point, based on their potential for acceleration at that time. Option 1 (September 2014) is achievable at a decreased programmatic risk posture from the baseline (high to medium) because of increased early funding and reserves, the more robust test program, and acceleration of ground and flight tests. The cost to implement Option 1 is \$1.8B to 2015 (\$1.7B in 2009 and 2010).

Option 2 accelerates IOC by 12 months to September 2013 by utilizing all steps in Option 1 (less the addition of two Ares development engines), eliminating Ares I-Y flight test, accelerating manufacturing for Orion, compressing First Stage test schedules, deferring upper stage engine testing for lunar requirements, accelerating ground operations development and processing, and performing qualification testing incrementally in parallel with the flight test program. Eliminating the Ares I-Y flight test reduces the integrated vehicle test opportunities, but has the benefit of removing a unique hardware and software configuration. Option 2 (September 2013) is achievable at a similar high programmatic risk posture as the baseline, but with adequate funds to execute, and requires an aggressive schedule with no margin available for test failures, flight or ground. Technical risk is increased relative to the baseline primarily because of the deletion of the Ares I-Y flight test. The cost to implement Option 2 is \$2.6B to 2015 (\$2.3B in 2009 and 2010).

Option 3 accelerates IOC by 18 months. In order to accomplish this, over 50% of the Orion hardware would need to be procured prior to the Preliminary Design Review, increasing the likelihood that incorrect or unnecessary parts are purchased. In addition, the required hardware deliveries for the launch vehicle are not achievable. As such, Option 3 was deemed to be too high a risk to implement successfully. While Option 3 content will be described for evaluation, it was not costed for this study.

To further enable these options, there are a few key decisions that need to be made prior to the April 1, 2009 assumed ATP date. The decisions include initiating design for Upper Stage manufacturing at MSFC, notifying contractors to prepare for staffing ramp up, and program pre-planning efforts for acceleration before the turn on date.

This CxAccel Study has concluded that with adequate funding, the risk of achieving Option 1 is reduced from the baseline (high risk to medium risk). Option 2 is achievable at a similar high programmatic risk posture as the baseline - with adequate funds to execute but requires an aggressive schedule with no margin available for test failures, flight or ground. Option 2 represents the limit to which funding can accelerate IOC.

It is recognized that additional funding for acceleration may not be available. Because the current baseline is high risk, and if additional funding is not available, the Program should implement the no-cost or cost avoidance ideas identified in this study as soon as possible to ensure the external IOC commitment date of March 2015 is still achievable. This includes assembly, integration and test improvements; software reductions; incremental qualification; and design simplifications of Orion.

The CxAccel Study results are based on a single point in time and the baseline may change between report's release and approval to accelerate. Upon authority to proceed, the Program will need to determine the best use of funding to buy down the most risk. In addition, there are programmatic decisions that can be made from a program lifecycle perspective that may result in an increased risk to realizing acceleration but they are deemed to be necessary from a broader program perspective. The opportunity for acceleration is a limited window. Because of the need to initiate long lead item procurements, any delay in an acceleration decision beyond mid-2009 would preclude any significant acceleration.

1.0 Introduction

The purpose of the Constellation Program Acceleration (CxAccel) Study is to identify potential program content and budget options to accelerate Constellation schedules to minimize the gap in US human spaceflight post-shuttle retirement and to decrease reliance on international assets for crew rescue from ISS. The Terms of Reference for the study were provided by the Constellation Program Manager.

The CxAccel Study was performed by a team whose core included each of the deputy project managers within the Constellation Program (CxP) as well as a group of senior engineers from across the Agency and outside the agency with Apollo, Space Shuttle, International Space Station, and Robotic spaceflight experience to ensure the broadest possible perspective on this issue. The team was organized by projects with a cross-cutting team providing integration across five sub-teams. The Program Planning and Control (PP&C) team provided analysis integration of all study costs. The CxAccel Study structure is shown in Figure 1.

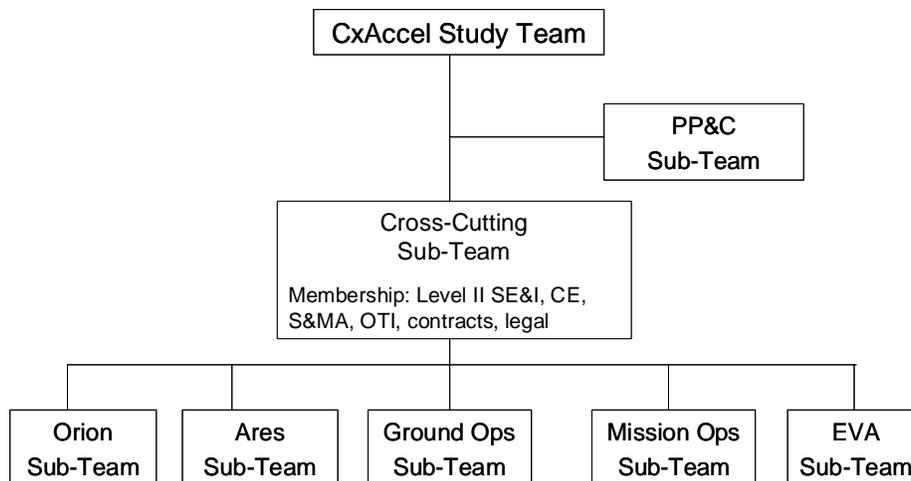


Figure 1 - CxAccel Study Team Structure

To provide the study with a common baseline, each of the five Constellation Projects provided a current status of their project including cost, technical and schedule data. This status highlighted the fact that the program has developed a robust technical design for the Lunar mission. However, due to an insufficient funding profile and the lack of adequate Program reserves in 2009 and 2010, in conjunction with the effect of two consecutive Continuing Resolutions, the CxP has had to defer development of facilities, equipment, engineering development units, tooling, ground testing and wind tunnel testing. The flight test program had to be minimized to an aggressive success oriented program with no room for test failures. These changes effectively represent the deferral of a large portion of the development phase of the program and result in a significant increase in risk to achieving the schedule. Furthermore, the program's lack of reserves

has driven numerous items in the current technical baseline to not be fully funded, including some design changes that are being carried as threats. These changes are documented in two categories: current baseline shortfall and technical baseline changes. The current baseline shortfall includes undefinitized changes in the Orion contract, affects on reusability due to the design change from land landing to water landing, additional Upper Stage Engine testing and program challenges to the projects. The technical baseline changes include recent design changes that are currently unfunded including phased array communication system, high voltage power system, thrust oscillation mitigations, First Stage nozzle extension, and implementation of the International System of units (SI). The result is a \$1.9B shortfall between the available funding and the technical baseline. These costs must be addressed irrespective of acceleration and therefore will be shown separately from the costs for acceleration.

Due to these factors, achieving the current baseline schedule, PMR08 Rev 1, with a September 2014 IOC, is high risk and considered not achievable with the corresponding current technical content, cost, and schedule.

With this data as a reference, the diverse team then brainstormed ideas on how to accelerate the program. This resulted in over 160 different ideas for acceleration. After evaluating the brainstorming ideas some very fundamental strategies were developed that could be applied consistently across the projects. Today’s integrated program critical path is artificially driven by the insufficient funding profile in 2009/2010 and technical content deferral - not by optimal hardware design, build and test constraints and deliveries. Normally, the integrated critical path would be key to defining the best approach to acceleration; however, because the program critical path had not been re-established in response to changes resulting from the PMR08 Rev 1, each project focused on accelerating the fundamental phases of design, development, test and evaluation (DDT&E). Figure 2 shows a notional schedule for DDT&E of spaceflight hardware.

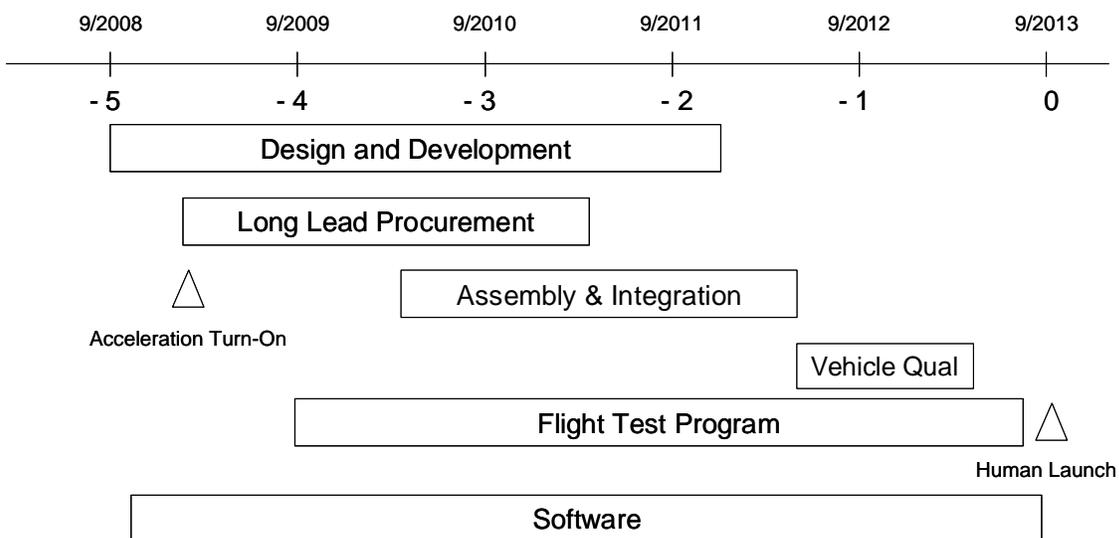


Figure 2 - Notional Development Schedule

Each project identified opportunities for acceleration in each step of DDT&E. Then these opportunities for acceleration were evaluated for implementation into three basic schedule options. This general schedule provided the team the areas of focus for acceleration. The cost and schedule impacts for the three study options were based from the internal PMR08 Rev 1 IOC baseline of September 2014. These dates represent a 6 month acceleration from the external IOC date of March 2015.

- Option #1 Increase confidence in PMR08 Rev 1 (Sept 2014)
- Option #2 Accelerate PMR08 Rev 1 by 12 months (Sept 2013)
- Option #3 Accelerate PMR08 Rev 1 by 18 months (March 2013)

For the purposes of this study an authority to proceed (ATP) date of April 1, 2009 was established. In addition, it has been assumed that the Space Shuttle Program (SSP) will not be extended and that the current manifest will be flown out through STS-133. Another ground rule for this study was that any suggested deferment of lunar capability would be incorporated into a future block upgrade. However, currently no lunar capabilities have been deferred as a result of this study. At the acceleration decision point, the Program can decide to implement design simplifications identified in this study that provide the best opportunity for acceleration. These suggested simplifications can be implemented independent of acceleration to realize a cost savings of up to \$500M. This study did not address the cost for re-establishing any potential deferred lunar capabilities. An overall, qualitative risk assessment (high, medium, low) of achieving the options was performed. In addition, an overall technical risk assessment (safety and mission success) was performed for each option relative to the current baseline.

Figure 3 depicts the manifest developed for this study. The details of the three options and manifest changes are described in greater detail in the subsequent sections of this report.

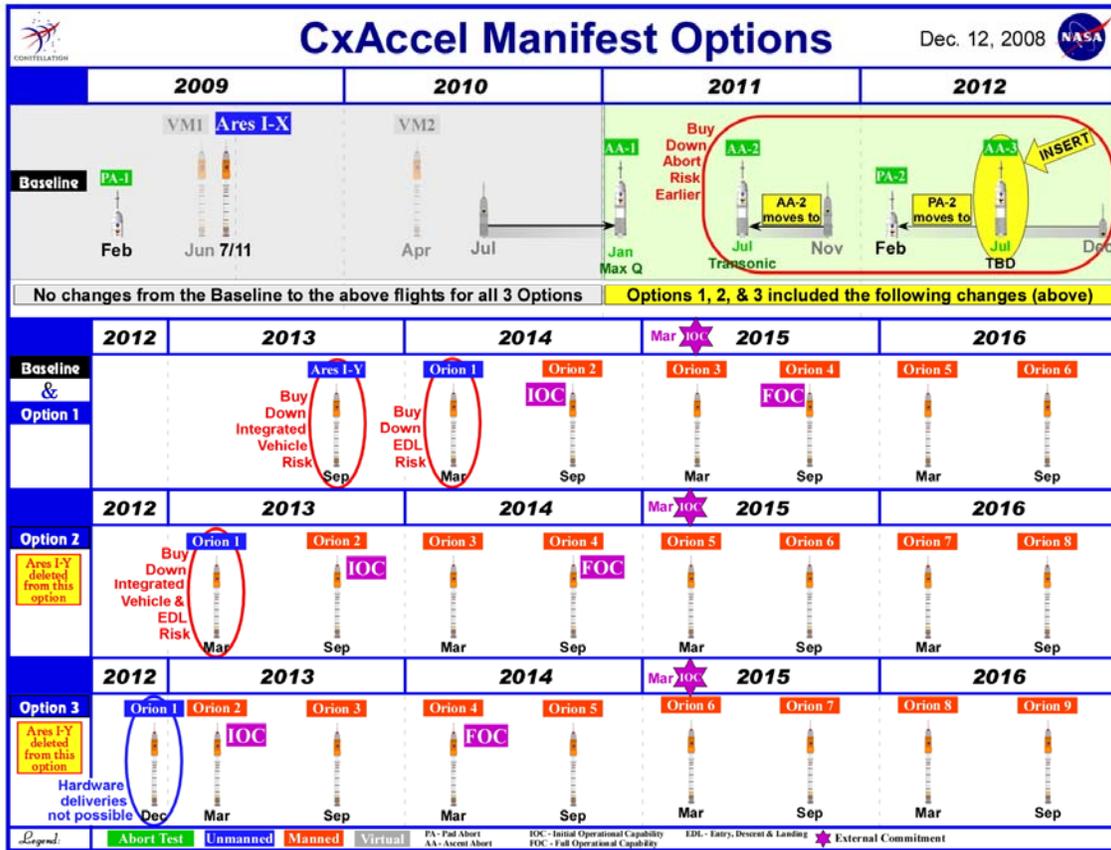


Figure 3 – CxAccel Study Manifest

In order to enable acceleration, the CxAccel study reviewed contracts, procurement mechanisms and facilities. The current contracts were reviewed and no contractual impediments to implementing these options were identified. The following contractual and budgetary strategies were evaluated:

- A change to no-year funding is not recommended due to additional reporting and oversight outweighing the benefits
- The change in account reporting going below the CxP level would hinder acceleration and it is recommended that the Agency continue to push-back on this change
- The Agency should seek indemnification authority in the FY10 budget request
- While relief from external reporting requirements is not practical at this time, Headquarters is attempting to minimize the direct impact to the Constellation Program
- The CxP should work with Headquarters Facilities Engineering and Real Property Division and Headquarters Comptroller to better utilize existing CoF flexibility

- As acceleration options are placed under contract, existing contract incentives should be revisited to determine if adjustments would be appropriate to properly motivate the new contract objectives (including any enhanced emphasis on schedule)
- If acceleration is pursued, the CxP should identify any critical items (i.e. helium, titanium) that may benefit from a DX priority rating. If so, pursue adding Cx to the DoD list of approved programs. [Note that Ares and Orion are currently DO rated and are prioritized over unrated contracts.]

To further enable the acceleration options the team recommends that the Systems Engineering and Technical Integration (Program Integration) function be strengthened to ensure the proper coordination, communication and technical leadership. In addition, there are a number of key decisions that need to be made prior to the April 1, 2009 assumed authority to proceed date. The decisions include Upper Stage parallel manufacturing, contractor preparations for staffing ramp up, and pre-planning efforts before the turn on date. Several shuttle transition dates will need to be accelerated in order to enable acceleration, including the docking system hardware delivery, A2 test stand, Vehicle Assembly Building, Launch Pad 39B, Michoud Assembly Facility (MAF) floor space, and Orion docking system hardware.

For each of the options, the hardware dependencies and delivery dates were assessed and all conflicts resolved or mitigation steps identified. The remainder of this CxAccel Study report will describe the details of the three options.

2.0 Option 1 - Summary

The intent of option 1 is to increase confidence in meeting PMR08 Rev 1 (September 2014) IOC. This represents a 6 month acceleration from the external IOC commitment date of March 2015. The general approach is to increase funding in 2009 and 2010 to ensure a more robust vehicle development and test phase. This includes restoring adequate program reserves, restoring deferred design and development work, early procurement of long lead time items, and acceleration of assembly, integration and test. Option 1 also accelerates the flight test program and adds an additional Ascent Abort test of opportunity. This ensures a more robust flight test program that buys down abort and integrated vehicle risks earlier and has the capacity to have a failed flight test, recover and maintain schedule.

For the Orion Project, the vehicle would incorporate a segmented crew module to facilitate spacecraft subsystem integration and a high-fidelity production pathfinder to verify and identify issues with planned processing. There are options identified within Orion for decreasing vehicle complexity for the ISS missions by deferring specific lunar technical capabilities for a block upgrade that can be implemented at acceleration turn on if additional schedule margin is desired. These options are provided as a means for deferring development costs and would reduce schedule risk by reducing qualification testing and vehicle integration and tests of lunar capabilities.

For the Ares Project, emphasis is primarily on accelerating and increasing production rates and increasing ground and flight testing, specifically, an upper stage engine would be added to Ares I-Y. For the Upper Stage (US), the production line at MSFC would be restored for manufacturing the qualification and test units. Production would be increased to two shifts on both production lines. Authority and funding for completing the design of the MSFC production line would need to occur prior to April 1, 2009. For Upper Stage Engine (USE), two additional development engines would be added to the test matrix and the availability of test stand A-2 at Stennis Space Center would be accelerated to July 2009, with initial operation in July 2010, enabling approximately 10% more testing than currently planned. For First Stage a new nondestructive examination approach would be implemented on the propellant casting to reduce overall production duration. Additionally, parallel processing of the propellant liner insulation would be pursued. In order to provide additional performance margin for ascent, the 9.3 expansion ratio nozzle, now planned for lunar missions, would be introduced on DM-4.

For the Extravehicular Project hardware, Option 1 is executable within the current baseline with schedule margin and represents the lowest lifecycle cost and quickest path to lunar solutions.

Ground Operations accelerates development of the mobile launcher and utilizes a high-fidelity Orion mock-up as a pathfinder to reduce processing time. Additionally command and control system software, and instrumentation and design of cable plants at Launch

Pad 39B would be accelerated. Furthermore, key SSP assets must be turned over in time to support critical path development work. Specifically, the Vehicle Assembly Building, High Bay 3 no later than January 2010, Launch Pad 39B no later than July 2009, and moving Hubble Space Telescope Launch on need to Pad 39A.

Mission Operations is coupled to Orion and Ares vehicle design and flight software and is not an impediment to acceleration. Flight software across all of the projects is being scrubbed and reduced, and is incrementally developed and released according to critical functions. By adding an USE to the Ares I-Y flight, the flight software for Ares I-Y is no longer unique from Orion 1, and efforts can be dedicated to accelerating Orion 1 software release. Option 1 does not require any deviations to the technical baseline beyond the early introduction of the 9.3 FS nozzle and the addition of an USE on Ares I-Y.

Compared to the PMR08 Rev 1 baseline, the overall Option 1 delta costs are listed below:

<u>Option 1 (\$M)</u>	<u>FY09</u>	<u>FY10</u>	<u>FY11</u>	<u>FY12</u>	<u>FY13</u>	<u>FY14</u>	<u>FY15</u>	<u>Total</u>
Current Baseline Shortfall	172	135	18	165	140	364	160	1154
Technical Baseline Changes	183	263	160	96	71	21	10	804
<u>Acceleration</u>	<u>355</u>	<u>1384</u>	<u>365</u>	<u>3</u>	<u>5</u>	<u>(71)</u>	<u>(200)</u>	<u>1842</u>
Total	710	1782	543	265	217	314	(30)	3801

Option 1 (September 2014) is achievable at a decreased programmatic risk posture from the baseline (high to medium) because of increased funding and reserves, the more robust test program, and acceleration of ground and flight tests.

2.1 Option 1 - Orion Overview

Orion Option 1 provides a higher confidence schedule to a September 2014 Constellation IOC date. This higher confidence schedule is achieved by restoring critical work that was deferred during the PMR08 Rev 1 budget process due to FY 09 and FY10 funding limitations. This work includes the tests necessary to define and characterize Orion environments, developmental testing of critical Orion systems and the procurement of engineering development units and long lead components. Orion abort system development confidence is improved by advancing the abort flight test schedule to retire development risk early. An additional flight test was also added to increase development confidence and to mitigate the potential impact of a loss of objectives in early testing.

Two improvements to the Orion manufacturing process will be incorporated in order to resolve the current schedule disconnect between Orion and the Ground Operations Project. The first improvement will be to implement a segmented crew module manufacturing approach. This approach, which is being developed during the current Orion design analysis cycle (DAC), will reduce Orion production and integration time by 3 to 4 months. Second, a high-fidelity Orion production pathfinder article will be developed to verify and identify issues with the Orion assembly and Ground Operations

integration processes. This pathfinder allows the Ground Operations Project to accept early Orion flight articles 1 to 2 months later than currently planned.

No specific deviations from the baseline lunar plan are included in this option. However, a list of potential Orion design simplifications was developed. Currently, the Orion design must meet all Space Station and Lunar Sortie mission requirements prior to PDR. Not all of these capabilities are required for a Space Station mission. Upon a decision to accelerate, the Orion design can be simplified by deferring capabilities not required for a Station flight to provide additional schedule confidence or to reduce Project cost. The cost savings for implementing these simplifications could potentially be as high as \$500M. All deferred capabilities would be restored in future block upgrades. The design simplification list was developed from a long list of proposals which were evaluated from a simplification standpoint and for their potential to streamline design, development, test and evaluation. In addition, a review of Orion software requirements to determine which can be reduced or deferred to provide software development schedule margin was initiated. The results of this study will be available for use by an April 1, 2009 Acceleration decision date.

The April 1, 2009 authorization to proceed (ATP) date, the reduced ISS Flight Operations Scenario, and the Option 1 flight manifest were the driving assumptions for the Orion Acceleration analyses.

The primary risk of Option 1 is potential technical or schedule issues with segmented crew module manufacturing. This new approach is being studied extensively in DAC-3.

2.2 Option 1 - Ares Overview

2.2.1 Option 1 - First Stage (FS) Element:

The FS Element's current plan to meet the PMR08 Rev 1 Schedule provides a fully qualified stage in time for Ares I-Y. The FS Element has identified some opportunities to increase the confidence of meeting that schedule. FS will test four Development Motors (DMs) to complete the design and resolve major design decisions such as Propellant/Liner/Insulation (PLI) processing, ply lifting in the nozzle, and insulation design both in the aft dome and on the case walls. Opportunities to test the 9.3 area ratio nozzle and the reaction mass actuators to suppress thrust oscillation are also included in the DM plan. All major structures, avionics, separation and pyrotechnics, and control systems will be completely verified prior to the Design Certification Review (DCR). Testing of the three Qualification Motors (QMs) and FS DCR will be completed prior to the Orion 2 (crewed) flight. The manufacturing, evaluation, and test schedule for this plan assumes standard manufacturing processes and shift schedules at ATK.

To increase confidence in meeting this schedule, the FS Element looked at five major areas of schedule risk: (1) thrust oscillation mitigation design; (2) PLI processing; (3) motor inspection techniques; (4) accelerating the development of the 9.3 area ratio nozzle; and (5) nozzle manufacturing. The increase to Design, Development, Test, and Evaluation (DDT&E) cost will be offset by lowering the cost of anomaly resolutions in the production phase of the program.

Based on the results of the Flight Support Motor No. 15 investigation, the FS manufacturing processes are being modified to ensure minimal voids and a secure bond between the insulation and the propellant. In order to provide additional risk reduction and increase schedule confidence, the FS Element wants to evaluate three major PLI acceleration process changes in parallel. These changes that require characterization are: (1) a mechanized case strip-lining insulation process; (2) using vacuum during insulation processing to remove entrapped gas; and (3) a pressurized curing process for the propellant after casting. These process changes have a medium Technology Readiness Level (TRL) and could provide significant schedule savings based upon their success.

The FS Element wants to aggressively develop a new, faster digital Non-Destructive Evaluation (NDE) approach for evaluating insulated motors with cured propellant to provide additional risk reduction and increased schedule confidence. Two digital NDE options being pursued for evaluation have a medium TRL.

The FS Element needs to accelerate the development of the larger area ratio nozzle (the 9.3 nozzle) to allow implementation on DM-4 and on the qualification series of motor tests. This saves the cost of a later re-qualification as well as avoids the complication and schedule impacts of developing two vehicle designs and two designs of the mobile launch platform at Kennedy Space Center (KSC).

One of the major objectives of the development test program is to eliminate ply lifting in the nozzle exit cone. Improved manufacturing methods need to be developed to reduce the variability of these new designs. A near-term programmatic decision is requested to permit First Stage to select proposed schedule confidence options for implementation.

2.2.2 Option 1 - Upper Stage (US) Element:

The US Element considered Option 1 with the following assumptions being made: (1) ATP is April 1, 2009; (2) no shuttle extension beyond CY 2010; (3) five days/two shifts in production at the Michoud Assembly Facility (MAF) and manufacturing at the Marshall Space Flight Center (MSFC); and (4) the addition of a J-2X engine on Ares I-Y.

The US Element would augment MAF production with a manufacturing line at MSFC to allow for parallel fabrication of test article and qualification/flight units.

This would include shifting manufacturing of the Ground Vibration Test Article (GVTA), Integrated Stage Test Article (ISTA), and Ares I-Y Test Article to MSFC. As part of this option, the US Element would add back the MSFC Building 4707 Vertical Assembly and MSFC Building 4708 Integration areas that were eliminated in the recent PMR08 REV 1 re-planning activity, which reduced budget in FY09 and FY10. Also, the US Element would accelerate the MSFC Building 4755 Liquid Oxygen Tank/Thrust Cone test area that was delayed in the recent re-planning activity. This approach takes advantage of tooling already in place at MSFC. After IOC, these facilities and tooling will be utilized by Ares V for their development activities. It should be noted that production of US qualification/flight units would remain at MAF and the integrity of the US qualification program will be maintained. In order to accommodate an accelerated schedule, two shifts would be implemented on MAF and MSFC lines.

Another vital part of the US approach is to implement parallel testing in the Software Integration Test Facility (SITF). Shifting from serial to parallel software qualification testing could potentially save 4 months. However, risk is associated with this approach, as there would be a lack of capacity to support regression testing and problem solving. A third SITF line could be created to mitigate this risk. Additionally, efficiencies must be gained by supplementing the NASA Design Team (NDT) with experienced Instrument Unit Avionics Contractor (IUAC) (Boeing) personnel. This augmentation could potentially save 2 months in schedule.

Another critical element pertaining to the acceleration of software development is the elimination of a unique software package for Ares I-Y. The addition of an engine to Ares I-Y makes the software package consistent with the Orion 1 and Orion 2 software and saves an additional 6 months.

Finally, procurement of all hardware components would need to be re-phased to support the accelerated schedule.

The main schedule risk with respect to US acceleration is that facilities will not be available in a timely fashion. In PMR08 Rev 1, the US Element is already assuming an aggressive facility build schedule at MAF. The new High Bay 103 is the "long pole in the tent." This effort will have to be further accelerated and MSFC Construction of Facility (CoF) activities have to be re-initiated.

It must be noted that the ability to activate a manufacturing line at MSFC in a timely manner to support the acceleration options would be severely impacted if the facility design for MSFC Buildings 4707 and 4708 is not completed by April 1, 2009. If the US Element waits until April to re-start the design effort, 5 months will be added for the completion of schedule design, and it is doubtful that construction for Building 4707 can be accelerated enough to recover the added schedule burden. Immediate CoF authority and \$650k is required to complete the design effort prior to April 1, 2009.

CoF projects require congressional authorization via the Agency's Operating Plan and are at risk until a FY 2009 authorization is approved. Possible mitigation steps for this risk are: immediate re-start of the design effort for MSFC manufacturing capability which was halted in the latest budget reduction exercise, utilizing on-hand CoF authority beginning now (December 2008); pre-approval of a possible CoF update for FY09 in the early April timeframe, or a waiver of CoF regulations for FY09 and FY10; and the availability of additional budget authority in FY09 and FY10 to augment present CoF and local authority budgets to provide incentives for rapid design, deployment, and delivery.

In addition to acceleration capability, the implementation of a manufacturing line at MSFC would build robustness into the CxP schedule without additional technical risk.

No negative impacts are foreseen in regard to lunar capability.

2.2.3 Option 1 - Upper Stage Engine (USE) Element:

The J-2X development effort recently completed a successful Critical Design Review (CDR). Thus, the USE Element's current plan to meet the current PMR08 Rev 1 schedule by accelerating or further ensuring engine availability for the first human flight of the CxP must be focused on the engine development, qualification, and certification effort that follows the initial completion of the design rather than re-definition or re-design activities.

Due to the programmatic and technical challenges for accomplishing the current schedule, there are two significant constraints that specifically affect J-2X development. First, no plausible path exists for accelerating the Powerpack Assembly (PPA-2). Second, no viable option exists for accelerating the construction of Test Stand A-3.

The current schedule utilizes a development engine on the first Ares I uncrewed flight test and the first production engine on the second Ares I uncrewed flight. The first crewed flight is scheduled to use the second production engine. For Option 1, this approach is maintained.

The fidelity of the USE Element's assessment of Option 1 is based on top-down parametric assessments with regards to test-turnaround capabilities, engine testing costs, and engine-build and delivery schedules. Detailed planning, should it become necessary, would follow at a later date.

The basic strategies for accelerating J-2X development were derived from the preliminary list of acceleration ideas generated by the CxP Acceleration study. The first overriding strategy is to get as much hardware into testing as quickly as possible.

This approach assumes a risk that some hardware may be fabricated without incorporating lessons learned from development testing. The accelerated availability of Test Stand A-2 is necessary to accomplish this strategy.

To acquire Test Stand A-2 sooner, the handover of the stand from the Space Shuttle Main Engine (SSME) Project is approximately 3 months earlier and the work on converting the stand for the J-2X starts immediately after handover. The end result assumes that Test Stand A-2 is ready for J-2X testing in July 2010, which is 1 year earlier than currently planned.

There is a possibility that some verification activities relating to performance and design requirements beyond the IOC may be deferred to reduce time-consuming test-fail-fix scenarios. The functional requirements dedicated to the lunar mission and the Ares V vehicle are prime candidates. Furthermore, while the engine is designed for certain performance requirements, an allowance for lower levels of initial performance may be necessary if setbacks occur during development testing.

The final overarching strategy is the full funding of identified cost threats against PMR08 Rev 1 and the removal of imposed challenges and work deferments to fit under related current funding profiles.

The USE Element may accomplish the Option 1 objectives by incorporating the following:

- Test Stand A-2 availability for J-2X testing is accelerated.
- Several of the early development engines are fabricated, assembled, and delivered earlier (approximately 5-7 months) than the current PMR08 Rev 1 schedule.
- Two new engines are added to the development schedule to enhance the robustness of earlier hardware testing.
- Approximately 10 percent more engine testing is added due to Test Stand A-2 and two new engines being made available.
- Cost threats identified against PMR08 Rev 1 are funded and imposed funding challenges in FY09 and FY10 are removed.
- One development engine supports one uncrewed test flight, the first production engine supports a second uncrewed flight, and then the second production engine supports the first crewed flight.
- IOC performance and design requirements are retained at current values unless or until an issue arises.

The net result of the J-2X acceleration strategy is a production engine that incurs reduced risk for supporting the currently PMR08 Rev 1 scheduled first human flight with a substantial increase in necessary workforce funding in FY09 and FY10.

2.3 Option 1 - EVA Overview

The EVA System baseline schedule and architecture is considered to be executable with minimal risk. Therefore, Option 1 is the same as the current EVA Systems Project baseline. The initial capability system is designed to support all Orion operations, including lunar transportation, while incorporating as much commonality as possible to support Lunar Surface EVA. As such, the suit used on ISS missions supports the required ascent, entry, 1-g crew survival and survival in a depressurized cabin. Additionally, though enabling hardware may not be manifested on ISS missions, the system is capable of supporting microgravity EVA and long-term (144 hour) survival in a depressurized cabin. This option assumes that the Orion vehicle maintains the capability to support an Orion-based EVA and that the decision to do an EVA will simply be a manifesting decision and will not be designed out. This option maintains the current program schedule for launch in September 2014 and has no funding delta from the PMR08 Rev 1 budget baseline. Option 1 has no decrease in capability in Configuration 1, does not sacrifice lunar commonality, and does not require a block upgrade for the lunar mission.

2.4 Option 1 - Ground Operations Overview

Ground Operations (GO) Option 1 provides opportunities to increase schedule confidence by mitigating known risks. Because the current baseline was previously delayed by PMR08 Rev 1 budget, Option 1 provides modest funding to allow earlier starts in construction and fabrication projects, minimizing the number of major projects on the GO critical path. New funding is also included to address known technical risks and ground systems modifications related to acceleration of the 9.3 Nozzle Extension for Ares I. Processing schedules were compressed based on incorporating an Orion Project provided pathfinder to mitigate first flight processing issues, and the need for on-time turnover of shuttle assets was reiterated.

Four specific factors addressed baseline planning for Option 1.

1. *Accelerate ground systems development through accelerated funding* from FY11 to FY09 and FY10, removing key projects from critical path. With early funding, critical path assessment of both ground systems development and processing operations determined that only VAB and Mobile Launcher (ML) remained on critical path.
2. *Address technical risks through new funding.* Additional funding was included to mitigate priority risks for incorporating SI units and sound suppression system capability. New funding was also included to modify ground systems in support of the early implementation of Ares I 9.3 First Stage nozzle extension. Modifications include retractable vehicle support post development, a new Rotation Processing and Surge Facility (RPSF) and supporting GSE.
3. *Maintain current Shuttle facilities transition planning.* Existing negotiated turnover of critical assets from the SSP would be maintained as defined in the Cx

Ground Operations baseline (VAB high bay no later than January 2010 and Launch Pad 39B no later than July 2009).

4. *Minimal compression of baseline processing schedules.* Incorporation of Orion Project provided high-fidelity pathfinder serves as a key mitigation for first flight issues. Baseline processing schedules are reduced as a result of exercising the ground systems, procedures and processes with flight-like systems.

As a result, Option 1 would enhance schedule confidence, but does not impact baselined architecture plans or require additional scope.

With accelerated funding -- for ML; Launch Pad 39B construction; Command, Control, & Communications (CCC) software development; and additional funding for highly likely cost threats. The cost analysis for Option 1 is determined to be high fidelity. Content was derived from the PMR08 Rev 1 baseline. Option 1 adjustments were based on project manager-lead assessments, including estimates from in-house design and Architects & Engineering (A&E) analysis support.

Through accelerated and new funding, on-time shuttle transitions, and incorporation of the Orion high-fidelity pathfinder, Option 1 would increase confidence in the baseline schedule to IOC.

2.5 Option 1 - Mission Operations Overview

Mission Operations was evaluated for Option 1, but because the Mission Operations critical path is dependent on the final configuration of the Ares and Orion vehicle design and flight software, acceleration opportunities and impediments for Option 1 within Mission Operations were not specifically identified. Mission Operations opportunities may be reevaluated once the Orion and Ares Flight Software Scrubs are complete. Any design simplifications implemented by the Orion Project will also need to be evaluated for effects on the Mission Operations critical path.

3.0 Option 2 - Summary

Option 2 accelerates the Program initial operational capability (IOC) date one year from September 2014 to September 2013. This represents an 18 month acceleration from the external IOC commitment date of March 2015. In addition to the steps taken in Option 1 (less the addition of two Ares development engines), Option 2 eliminates Ares I-Y flight test (reference Figure 3 - CxAccel Study Manifest), accelerates manufacturing for Orion, compresses First Stage test schedules, defers Upper Stage Engine testing for lunar requirements, accelerates ground operations development and processing, and performs qualification testing incrementally in parallel with the flight test program. Eliminating the Ares I-Y flight test reduces the integrated vehicle test opportunities, but has the benefit of removing a unique hardware and software configuration. Option 2 does maintain the additional Ascent Abort test of opportunity that was added in Option 1. It should be noted that Option 2 includes one additional operational flight in 2015.

For the Orion spacecraft, Design Analysis Cycle (DAC)-3 will be nearly complete at the acceleration authority to proceed (ATP) date of April 1, 2009. As such, the vehicle design will proceed through Preliminary Design Review in August 2009. The focus for acceleration will be on long lead procurements and performing qualification testing in parallel with assembly and integration. Qualification will be aligned with the Orion 1 test flight. The Orion 1 spacecraft will be fully capable for the ISS mission but some hardware and software capabilities may be deferred to a future upgrade.

The Ares First Stage static test schedule will be compressed by 10 months. Compressing the development and qualification motor schedule is challenging and requires some different linkages between static tests to make configuration decisions for each motor, but all major test objectives will still be achieved. All First Stage subsystems will address long-lead time needs for drawings and procurements. The Upper Stage Element would again augment Michoud Assembly Facility (MAF) production with a second production line at Marshall Space Flight Center (MSFC) to allow for parallel fabrication of test article and qualification/flight test units. This line would only remain in operation through IOC and will then be transitioned to the Ares V vehicle. The basic strategy for accelerating J-2X development is to get as much hardware into testing as quickly as possible. This approach assumes a risk that some hardware may be fabricated without incorporating lessons learned from development testing. The additional development engines identified in Option 1 would not be included in Option 2. The availability of Test Stand A-2 by July 2009 is required to accomplish this strategy.

Option 2 requires a more aggressive approach to accelerating the Ground Operations baseline. Although Ares I-Y is removed, due to the single string architecture and launch spacing, the complete operational capability is still required for the first Ares I launch of mission Orion-1. To achieve this acceleration, the ground systems development will need to be accelerated by six months, the aggressive turnover of some shuttle assets will be required (VAB high bay, Launch Pad 39B, etc.), and the processing schedule will be

compressed. Processing improvements will be achieved through the proposed Orion and other potential pathfinders that would validate Ground Operations prior to Orion 1 processing. Finally, the Multi-Element Integration Testing (MEIT) will be moved from Orion 1 to Orion 2.

For the EVA system, the initial capability technical baseline will be de-scoped to only include ISS requirements for the ISS Design Reference Mission; extensibility to meet lunar transportation requirements will be maintained as a goal to minimize cost. However, commonality between the ISS and lunar suits is decreased compared with the baseline, increasing life cycle costs.

Compared to the PMR08 Rev 1 baseline, the overall Option 2 delta costs are listed below:

<u>Option 2 (\$M)</u>	<u>FY09</u>	<u>FY10</u>	<u>FY11</u>	<u>FY12</u>	<u>FY13</u>	<u>FY14</u>	<u>FY15</u>	<u>Total</u>
Current Baseline Shortfall	172	135	18	165	140	364	160	1154
Technical Baseline Changes	156	231	151	75	46	14	9	683
<u>Acceleration</u>	<u>479</u>	<u>1849</u>	<u>815</u>	<u>126</u>	<u>40</u>	<u>(286)</u>	<u>(465)</u>	<u>2556</u>
Total	806	2216	983	366	226	92	(295)	4393

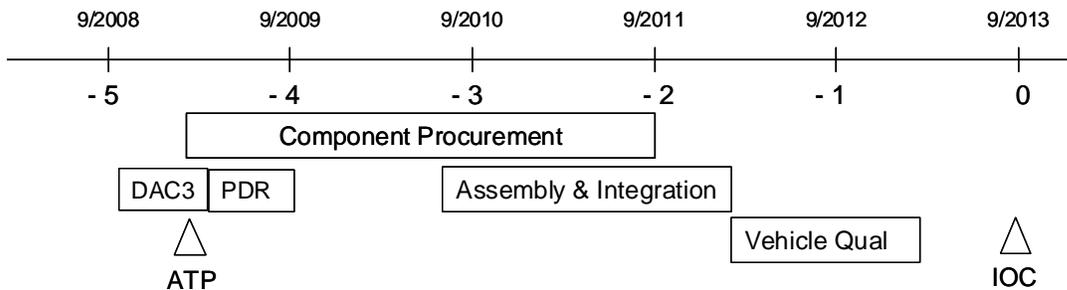
Option 2 (September 2013) is achievable at a similar high programmatic risk posture as the baseline, but with adequate funds to execute, and requires an aggressive schedule with no margin available for test failures, flight or ground. Technical risk is increased relative to the baseline primarily because of the deletion of the Ares I-Y flight test.

3.1 Option 2 - Orion Overview

For Option 2, acceleration is enabled by advancing the first full up Ares I flight by 6 months and replacing Ares I-Y by the Orion 1 orbital mission. Required Orion related abort test objectives planned for Ares I-Y will be accomplished on one of the existing abort test booster flights in the Option 1 Orion flight test program.

In addition to the actions taken in Option 1, assembly of the Orion qualification vehicle and system qualification testing will be advanced 6 months to support this option. Procurements for this assembly must begin immediately upon the authorization to accelerate and docking systems hardware transfer from the SSP must occur as currently planned. The system PDR will be conducted as planned as approximately 28% of the vehicle must be in procurement by the PDR for this option. Orion spacecraft qualification itself will be aligned with the Orion 1 flight. As in Option 1, the Orion design will be evaluated and any vehicle simplifications necessary to enable the accelerated schedule will be incorporated (deferred capabilities will be restored in subsequent Orion block upgrades). Software acceleration will be achieved by moving capabilities required for Orion 1 and Orion 2 into earlier releases. This will be enabled by the deletion of the Ares I-Y unique load and software simplification.

A review of the primary Orion critical path as depicted below was conducted to verify the viability of this plan. Component procurement, vehicle manufacturing and vehicle qualification were reviewed. The results were reviewed with an independent team of experienced aerospace managers and compared with similar activities on other similar aerospace development projects. This activity was done at the vehicle level. Component level developmental testing and qualification was not assessed in detail for either prime or GFE equipment and some risk may exist in individual component qualification plans.



Flight article delivery for Orion 1 and 2 to Ground Operations was also advanced. A 2nd structural test capability at MAF and a 2nd integration station in the Operations and Checkout (O&C) building will be provided to enhance the ability to manufacture, integrate and test two vehicles in parallel to meet these schedules.

3.2 Option 2 - Ares Overview

3.2.1 Option 2 - First Stage (FS) Element:

The FS Element assessed Option 2 (accelerating the ISS launch schedule by 12 months) as executable with a medium degree of risk based on an engineering and risk analysis. Basically, FS compressed the static test schedule by 10 months. The QM-1 Motor Fabrication Review is moved from April 2011 to July 2010. Compressing the DM/QM schedule is challenging and requires some different linkages between static tests to make configuration decisions for each motor, but major test objectives will still be met. For example, the design of the QM and flight motor nozzles will be influenced by the DM-4 post-test evaluation results because the decision on the nozzle can be postponed until after the DM-4 tests are complete. The Ares I-Y flight stage is deleted from the manifest. The 9.3 area ratio nozzle is deleted from the FS Element Option 2 configuration.

Motor qualification will be complete and evaluated prior to the Orion 1 (uncrewed) and 2 (crewed) flights. The manufacturing, evaluation, and test schedule for this plan assumes standard manufacturing processes and shift schedules at ATK.

All FS subsystems will address long-lead time needs for drawings and procurements. Full-scale acoustics loads validation, separation shock testing, and full-scale Structural Test Article (STA) testing, plus model validation and certification analyses, must be completed prior to the FS DCR and the Orion 2 (crewed) flight. Long-lead procurements and test schedules will be adjusted to ensure this requirement is met.

Options will be considered to resolve cooling designs for the avionics within the forward skirt to support this acceleration. The structures subsystem will assess conducting forward skirt thermal environments validation using a full-scale test article. This would support launching the Orion 1 vehicle without an Environmental Control System (ECS) for cooling the forward skirt. Options to minimize program risk are either baselining an ECS now or alternatively (not preferred) implementing a Launch Commit Criteria (LCC) and appropriate sensors to operate avionics boxes up to thermal limits.

The FS Element is evaluating hardware and booster processing options for a programmatic decision as described in Option 1 (thrust oscillation mitigation design, PLI processing, motor inspection techniques, and improving nozzle manufacturing) to increase confidence in meeting the motor processing schedule.

3.2.2 Option 2 - Upper Stage (US) Element:

The US Element would augment MAF production with a manufacturing line at MSFC to allow for parallel fabrication of test article and qualification/flight units. This would include shifting manufacturing of the Ground Vibration Test Article (GVTA) and Integrated Stage Test Article (ISTA) to MSFC. As part of this option, the US Element would add back the MSFC Building 4707 Vertical Assembly and MSFC Building 4708 Integration areas that were eliminated in the recent PMR08 Rev 1 re-planning activity, and reduced the budget in FY09 and FY10. Also, the US Element would accelerate the MSFC Building 4755 Liquid Oxygen Tank/Thrust Cone test area that was delayed in the recent re-planning activity. This approach takes advantage of tooling already in place at MSFC. After IOC, these facilities and tooling will be utilized by Ares V for their development activities. It should be noted that production of US qualification/flight units would remain at MAF and the integrity of the US qualification program will be maintained. In order to accommodate an accelerated schedule, two shifts would be implemented on MAF and MSFC lines.

Another vital part of the US approach is to implement parallel testing in the Software Integration Test Facility (SITF). Shifting from serial to parallel software qualification testing could potentially save 4 months. However, risk is associated with this approach, as there would be a lack of capacity to support regression testing and problem solving. A third SITF line could be created to mitigate this risk. Additionally, efficiencies must be gained by supplementing the NASA Design Team (NDT) with approximately 10 experienced Instrument Unit Avionics Contractor (IUAC) (Boeing) personnel. This augmentation could potentially save 2 months in schedule.

Another critical element pertaining to the acceleration of software development is the elimination of a unique software package for Ares I-Y. The deletion of Ares I-Y saves an additional 6 months in schedule.

Finally, procurement of all hardware components would need to be re-phased to support the accelerated schedule.

The main schedule risk with respect to US acceleration is that facilities will not be available in a timely fashion. In PMR08 Rev 1, the US Element is already assuming an aggressive facility build schedule at MAF. The new High Bay 103 is the “long pole in the tent.” This effort will have to be further accelerated and MSFC CoF activities have to be re-initiated.

It must be noted that the ability to activate a manufacturing line at MSFC in a timely manner to support the acceleration options would be severely impacted if the facility design for MSFC Buildings 4707 and 4708 is not completed by April 1, 2009. Re-starting the MSFC manufacturing line requires early finalization of requirements for facility interfaces. If the US Element waits until April to re-start the design effort, 5 months will be added for the completion of schedule design, and it is doubtful that construction for Building 4707 can be accelerated enough to recover the added schedule burden. Immediate Construction of Facility (CoF) authority and \$650k is required to complete the design effort prior to April 1, 2009.

Construction of Facilities (CoF) projects require congressional authorization via the Agency’s Operating Plan and are at risk until a fiscal year 2009 authorization is approved. Possible mitigation steps for this risk are: immediate re-start of the design effort for MSFC manufacturing capability which was halted in the latest budget reduction exercise, utilizing on-hand CoF authority beginning now (December 2008); pre-approval of a possible CoF update for FY09 in the early April timeframe, or a waiver of CoF regulations for FY09 and FY10; and the availability of additional budget authority in FY09 and FY10 to augment present CoF and local authority budgets to provide incentives for rapid design, deployment, and delivery.

In addition to acceleration capability, the implementation of a manufacturing line at MSFC would build robustness into the CxP schedule without additional technical risk.

No negative impacts are foreseen in regard to lunar capability.

3.2.3 Option 2 - Upper Stage Engine (USE) Element:

The J-2X development effort recently completed a successful CDR. Thus, the USE Element’s current plan to accomplish the first crewed flight 1 year earlier than the PMR08 Rev 1 schedule by accelerating or further ensuring engine availability for the first human flight of the CxP must be focused on the engine development,

qualification, and certification effort that follows the initial completion of the design rather than re-definition or re-design activities.

Due to the programmatic and technical challenges for accomplishing the current schedule, there are two significant constraints that specifically affect J-2X development. First, no plausible path exists for accelerating the PPA-2. Second, no viable option exists for accelerating Test Stand A-3 construction.

The current schedule utilizes a development engine on the first Ares I uncrewed flight test and the first production engine on the second Ares I uncrewed flight. The first crewed flight is scheduled to use the second production engine. For acceleration consideration, any uncrewed flight must use a development engine and the first crewed flight must use the first production engine.

The fidelity of the USE Element's assessment of Option 2 is based on top-down parametric assessments with regards to test-turnaround capabilities, engine testing costs, and engine-build and delivery schedules. Detailed planning, should it become necessary, would follow at a later date.

The basic strategies for accelerating J-2X development were derived from the preliminary list of acceleration ideas generated by the CxP Acceleration study. The first overriding strategy is to get as much hardware into testing as quickly as possible. This approach assumes a risk that some hardware may be fabricated without incorporating lessons learned from development testing. The accelerated availability of Test Stand A-2 is necessary to accomplish this strategy.

To acquire Test Stand A-2 sooner, the handover of the stand from the SSME project is approximately 3 months earlier and the work on converting the stand for the J-2X starts immediately after handover. The end result assumes that Test Stand A-2 is ready for J-2X testing in July 2010, which is 1 year earlier than currently planned.

There is a possibility that some verification activities relating to performance and design requirements beyond the IOC may be deferred to reduce time-consuming test-fail-fix scenarios. The functional requirements dedicated to the lunar mission and the Ares V vehicle are prime candidates. Furthermore, while the engine is designed for certain performance requirements, an allowance for lower levels of initial performance may be necessary if setbacks occur during development testing.

The final overarching strategy is the full funding of identified cost threats against PMR08 Rev 1 and the removal of imposed challenges and work deferments to fit under related current funding profiles.

The J-2X may accomplish the Option 2 objectives by incorporating the following:

- Test Stand A-2 availability for J-2X testing is accelerated.

- All of the early development engines are fabricated, assembled, and delivered earlier (approximately 5-9 months) than the current PMR08 Rev 1 schedule. The two certification engines are delivered approximately 8-9 months early, and the production engine is delivered approximately 5 months earlier.
- Engine testing is reduced by approximately 10 percent since some verification activities are deferred.
- Cost threats identified against PMR08 Rev 1 are funded and imposed funding challenges in FY09 and FY10 are removed.
- One development engine supports one uncrewed test flight and the first production engine supports the first crewed flight.
- IOC performance and design requirements are retained at current values unless or until an issue arises.

The net result of the J-2X acceleration strategy is a production engine supporting the first human flight approximately 1 year earlier than the PMR08 Rev 1 schedule with a substantial increase in necessary workforce funding in FY09 and FY10.

3.3 Option 2 - EVA Overview

In order to attain 12-month acceleration, the initial capability technical baseline will be de-scoped to address only ISS requirements for the ISS DRM; extensibility to meet lunar transportation requirements will be maintained as a goal to minimize redesign as much as possible. Hardware unique to microgravity EVA (e.g. long EVA umbilical, suit thermal and micrometeoroid protection garment, etc) and long-term unpressurized survival (e.g. long-term waste management) will not be developed or built to support the ISS mission. This option will require a second development cycle to upgrade the Launch, Entry, and Abort (LEA) configuration from ISS-only to be lunar transportation capable. The EVA Systems Project will continue to strive for maximum commonality between all suit configurations, but this commonality will be sacrificed as needed to meet the schedule. Option 2 has a decreased capability for Configuration 1 for the ISS mission, sacrifices lunar commonality as needed, and requires a block upgrade for the lunar mission.

3.4 Option 2 - Ground Operations Overview

Option 2 requires a more aggressive approach to accelerating the baseline. Although Ares I-Y is removed, due to the single string architecture and launch spacing, the complete operational capability is still required for the first launch of Orion 1. Early funding limits, an even greater dependence on shuttle infrastructure transition, and remaining flight design ambiguities limit opportunities to accelerate ground development and operations schedules.

To accomplish Option 2, more aggressive funding was included to further accelerate construction and fabrication projects and decouple the integrated ground systems operational readiness dates (ORD), enabling an eight-month acceleration to ground systems development. But with the more aggressive schedule, additional ground projects enter the GO critical path, re-introducing schedule risk. New development funding was also included in Option 2 to address known technical risks.

In Option 2, four elements are required:

1. *Accelerated ground systems development* including earlier design in FY 2009 and start of fabrication and installation in FY 2010. Accomplishing this requires early development of ML, VAB, CCC, Pad 39B, and Multi-Purpose Processing Facility (MPPF) projects, as well as increasing capabilities for umbilical testing at the Launch Equipment Test Facility (LETF). With Option 2, the critical path would include Ares I-X and the MPPF, as well as the VAB and ML projects described in Option 1.
2. *Address technical risks through new funding.* Additional funding was again included to mitigate priority risks for incorporating SI units and post liftoff sound suppression system capability. In Option 2, the early implementation of the Ares I First Stage 9.3 nozzle extension has not been incorporated.
3. *Early turnover of Shuttle assets.* Critical turnovers, including VAB High Bay and Pad 39B, are required by July 2009. This accelerates the current VAB milestone by approximately six months and requires execution of HST LON activities from Pad 39A.
4. *Compressed processing schedules.* Additional schedule compression is enabled by the incorporation of Orion Project provided high-fidelity pathfinder as a key mitigation for first flight issues. This approach is sensitive to flight hardware and software configurations and delivery schedules, as the ground system validation and verification, pathfinder mitigation flow, ORD, and turnover to operations are tightly coupled to predicted nominal launch site processing flows. High-fidelity pathfinders are instrumental in reducing risk to first flight processing schedules. However, risk remains in the spacecraft servicing and integration schedule. After adjusting MEIT from Orion 1 to Orion 2, a six-week disconnect exists between Orion 1 delivery and Ground Operations need dates. Further adjustments to the Ground Operations shifting during spacecraft offline processing would mitigate approximately one month. The remainder of the schedule mitigation would be addressed as forward work.

Although a schedule benefit would be realized, the deletion of Ares I-Y is a significant challenge to supporting Option 2. Ares I-Y would have provided a dry-run simulation of many ground processes, loading propellants, J-2X support and other services. Implementing Orion 1 as the first flight would require functionality of all ground systems and operations, without prior validation. Acquiring structural and test articles for First Stage and Upper Stage hardware would mitigate first flight issues and technical risks in

safety and reliability associated with eliminating the Ares I-Y integrated vehicle flow. Mitigations would include retiring integrated vehicle risks early in the processing environment, as well as verification of flight validated and loads models with ground systems.

The cost analysis for Option 2 is determined to be lower in fidelity from Option 1 based on the assumptions regarding vehicle requirement stability. The schedule risk for Option 2 is determined to be moderate-to-high risk based on the elimination of Ares I-Y as a pathfinder to Orion 1, as well as removal of schedule contingencies in the offline spacecraft processing flows. However, through aggressive acceleration and new funding, earlier shuttle asset transitions, and incorporation of the Orion and potential Ares high-fidelity pathfinders, Option 2 strategies would enable approximate 12 month acceleration to IOC.

3.5 Option 2 - Mission Operations Overview

Mission Operations Option 2 is similar to Option 1 because the Mission Operations critical path dependencies on Ares and Orion have not changed.

4.0 Option 3 - Summary

Option 3 intended to accelerate the CxP IOC date by 18 months from September, 2014 to March 2013. This would have represented a 24 month acceleration from the external IOC commitment date of March 2015. In order to achieve this acceleration the Orion Project would have to immediately initiate long lead procurement orders, prior to the acceleration authority to proceed date of April 1, 2009. Further, over 50% of the vehicle components would have been in the procurement process prior to the Orion System level PDR, increasing the likelihood that incorrect or unnecessary parts are purchased. The Ares development, qualification, and manufacturing timeline would require an unrealistic compression of hardware qualification and manufacturing schedules. The EVA Project would need to develop and certify an ISS transition suit comprised mainly of heritage hardware. This heritage suit would provide basic launch/entry/abort and crew survival protection and short term unpressurized survival capability, but would not be upgradeable for lunar capability.

These factors would result in an unacceptable risk to implementation and Option 3 was determined to not be viable. It will be described in the study for evaluation but the costs were not analyzed.

4.1 Option 3 - Orion Overview

Option 3 accelerates the CxP IOC date by 18 months to March 2013. A detailed analysis of the Orion critical path demonstrated that in order to achieve this acceleration, the Project would have had to ramp up long lead procurement orders in the fall of 2008 to support production of the qualification vehicle. Further, over 54% of the vehicle components would have been in the procurement process prior to the Orion System level PDR, thus increasing the likelihood that incorrect or unnecessary parts would be purchased. This was judged to be a non-achievable plan. Several alternatives were investigated to mitigate this early procurement challenge. The most promising alternative was to move the Orion 1 launch to within 3 months of the Orion 2 launch, regaining 3 months on the front end of the schedule. This proposal was not incorporated in this study as it did not provide enough time in between the flights for necessary data analysis.

4.2 Option 3 -Ares Overview

The assessment by the CxAccel Ares subteam of the adjustments and modifications to the Ares development, qualification, and manufacturing timeline resulted in identification of unrealistic compression of hardware qualification and manufacturing schedules. Key program milestones (i.e., IOC/Orion 2) could no longer be supported. Specific areas of concern include:

4.2.1 Option 3 - First Stage Element:

The Static Test schedule could not be safely compressed further than in Option 2. First Stage hardware certification cannot be completed to support a first crewed flight in March 2013.

4.2.2 Option 3 - Upper Stage Element:

The Upper Stage Element cannot accelerate DCR prior to April 2013 due to the need to complete qualification and Integrated Stage Test Article (ISTA) testing and analysis prior to DCR. Upper Stage hardware certification is not complete until July 2013 and cannot be completed to support a first crewed flight in March 2013.

4.2.3 Option 3 - Upper Stage Engine Element:

The Upper Stage Engine Element would require that Test Stand A-2 be made available for J-2X no later than July 2009. Additionally, in order to accomplish the two-part certification test series in the time required, the current RS-68 Test Stand B-1B being used by the DoD would need to be available for handover to the CxP no later than April 2009 to enable J-2X testing by October 2011. All engine deliveries, including development, certification, and production engines would be significantly accelerated.

The sequence of events to accomplish Option 3 would be extraordinarily success-oriented, and exhibits high and unacceptable technical and programmatic risk.

4.3 Option 3 - EVA Overview

In order to attain the 18 month acceleration, the EVA Project will develop and certify an ISS transition suit comprised mainly of heritage hardware, modified to be compatible with Orion interfaces and to meet Constellation requirements. This heritage suit will provide basic launch/entry/abort and crew survival protection and short term unpressurized survival capability. It is not upgradeable for lunar capability. This suit will not support microgravity EVA and could not be upgraded to do so. A separate suit will need to be developed for the lunar mission; the lunar suit system, with both Configuration 1 and Configuration 2 suits, will have to be developed concurrently as part of the lunar capability development cycle. Therefore, there will be no commonality between the heritage-based ISS suit and Configuration 1 of the lunar suit system. Option 3 was not considered feasible by the CxP; therefore, costs were not analyzed for this option. Option 3 has a substantially decreased capability for ISS missions, completely sacrifices commonality between the ISS and lunar phase, and requires an entirely new suit for the lunar mission.

4.4 Option 3 - Ground Operations Overview

Option 3 requires an even more aggressive approach to accelerating the baseline. Although Ares I-Y is removed, due to the single string architecture and launch spacing, the complete operational capability is still required for the first launch of Orion-1; accelerated 6 months earlier than Option 2. Early funding limits, an even greater dependence on shuttle infrastructure transition, and remaining flight design ambiguities limit opportunities to accelerate ground development and operations schedules.

To accomplish Option 3, more aggressive funding and development acceleration would be required. Standalone ground system projects, with additional funding, could likely be accelerated. However, dependencies on flight system products preclude significant GSE development and final Operational Readiness of the Ground Systems.

4.5 Option 3 - Mission Operations Overview

This option is not supportable due to vehicle design hardware and software products being unsupportable.

5.0 Conclusions

The CxAccel Study found that the current baseline, PMR08 Rev 1, is clearly at high programmatic risk and not achievable on the current content, cost, or schedule due to an insufficient funding profile and the lack of adequate Program reserves in 2009 and 2010, in conjunction with the effect of two Continuing Resolutions. The CxP has had to defer development of facilities, equipment, engineering development units, tooling, ground testing and wind tunnel testing. The flight test program had to be minimized to an aggressive success oriented program with no room for test failures. These changes effectively resulted in the deferral of a large portion of the development phase of the program.

Option 1 (September 2014) is achievable at a decreased programmatic risk posture from the baseline (high to medium) because of increased funding and reserves, the more robust test program, and acceleration of ground and flight tests.

Option 2 (September 2013) is achievable at a similar high risk posture as the baseline, but with adequate funds to execute, and requires an aggressive schedule with no margin available for test failures. Technical risk is increased relative to the baseline primarily because of the deletion of the Ares I-Y flight test.

Option 3 (March 2013) was found to not be achievable because it requires initiating long lead procurement of over 50% of Orion components prior to PDR and Upper Stage and Upper Stage Engine cannot deliver hardware in time to support Orion 1. As a result, Option 3 was not costed in this study.

Table 1 provides a delta cost by option from PMR08 Rev 1. In order to quantify the total current funding requirements associated with each option, the option costs distinguish acceleration costs from current baseline shortfalls to PMR08, Rev 1 and technical baseline changes instituted since PMR08 Rev 1. Additionally, Program Reserve was added at 20% for DDT&E and 10% for production

Table 1 – Delta Costs by Option from PMR08, Rev 1

Project	Option 1 (\$M)		Option 2 (\$M)	
	FY 09-10	FY 09 - 15	FY 09-10	FY09 - 15
Orion (w/o design simp.)	636	463	826	631
Ares 1	468	787	505	791
Ground Ops	52	41	245	293
Missions Ops	0	0	167	220
EVA	0	0	(3)	(20)
PI	38	100	38	100
Subtotal Acceleration	1194	1391	1778	2015
Reserves	545	451	549	541
Current Baseline Shortfall	307	1154	307	1154
Technical Baseline Changes	446	804	388	683
Total	2491	3801	3023	4393

Figure 4 is a graphical representation of the phasing of the baseline and Options 1 and 2. The graph illustrates how budget reductions in FY09 and FY10 shift technical content to later years, and thus defer mitigation of risks too late in the Program. Both Options 1 and 2 provide a funding profile similar to a classical development program and allow for risk mitigation early in the Program.

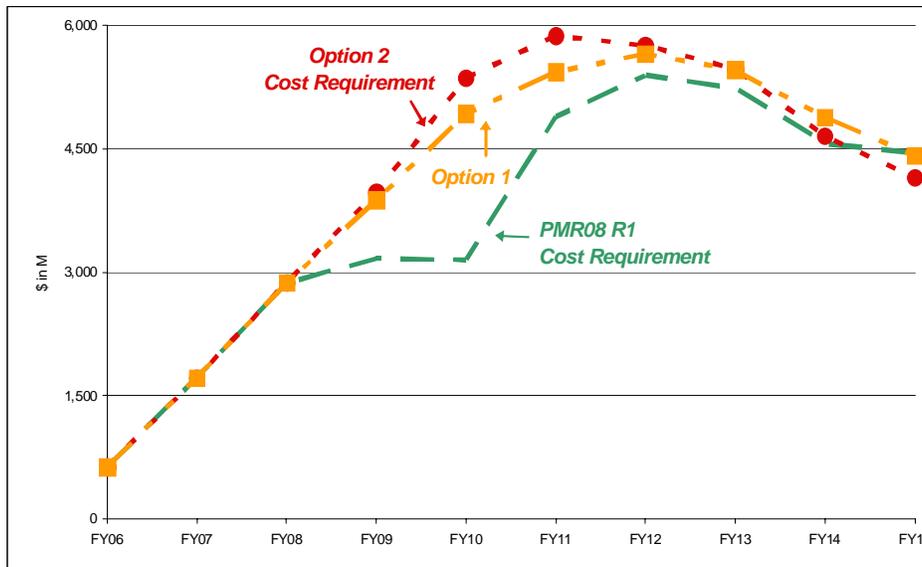


Figure 4 – CxAccel Study Phasing Plan

Figure 5 is a notional illustration of IOC versus acceleration cost, versus programmatic risk. For example, study Option 1 has the same IOC as the PMR08 Rev 1; however, PMR08 Rev 1 lacks adequate funding and is higher risk as illustrated on the shift on the risk contour line. Option 2 accelerates IOC by 12 months but because of the compressed schedule is at a similar high risk posture as PMR08 Rev 1. It should be noted that there is a continuum of possible IOC dates, between Option 2 and 1 with reduced risk as you move from left to right. Option 3 has the highest risk of all of the options, and was not consider achievable.

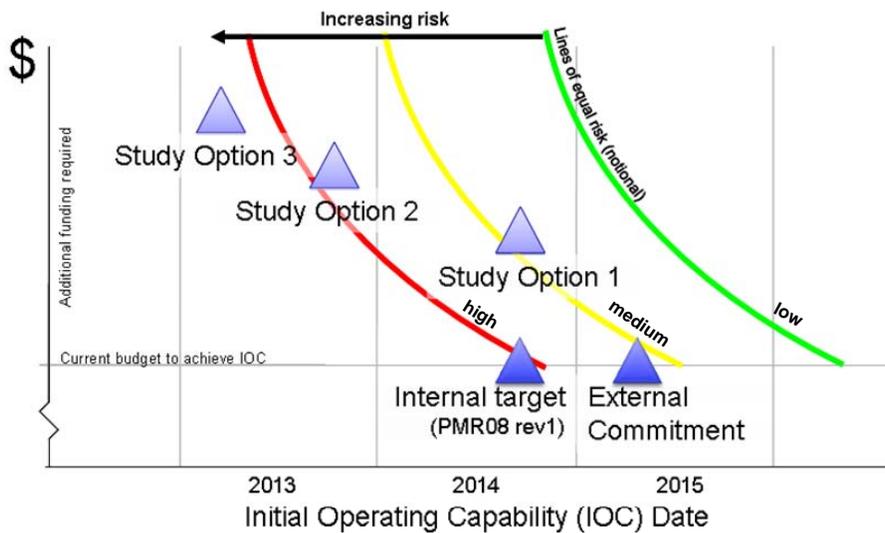


Figure 5 – IOC versus Costs versus Risk

It is recognized that additional funding may not be available and therefore to achieve the external commitment of March 2015, the CxP should implement all no-cost and cost avoidance strategies as soon as possible including: design simplifications, software scrubs, assembly integration and test improvements, incremental qualification of hardware, and flight test optimization. Additionally the CxP should review scope and content for additional acceleration ideas, adjustment, and phasing.

The CxAccel Study results are based on a single point in time and the baseline may change between this report’s release and approval to accelerate. Upon authority to proceed, the CxP will need to determine the best use of funding to buy down the most risk. In addition, there are programmatic decisions that can be made from a program lifecycle perspective that may result in an increased risk to realizing acceleration but they are deemed to be necessary from a broader program perspective. The opportunity for acceleration is a limited window. Because of the need to initiate long lead item procurements, any delay in an acceleration decision beyond mid-2009 would preclude any significant acceleration.