Enabling Crew Launch on Atlas V and Delta IV

Jeff A. Patton[1], Andrew J. Aldrin[2], and Vernon L. Thorp[3]
United Launch Alliance, P.O. Box 277005, Littleton, Colorado 80127

and

Steven F. Duschl[4]
United Launch Alliance, P. O. Box 9009, Cape Canaveral, FL 32920-9009

On February 20, 1963, John Glenn flew to orbit atop an Atlas rocket which had been converted from an Intercontinental Ballistic Missile. A key component of the human rating of Atlas was the addition of an emergency detection system called the Abort Sensing and Implementation System (ASIS). This simple system monitored a handful of key measurements to provide an abort command should the flight go seriously wrong. Given the history of Atlas flights up to that time, this concern was not unfounded. The Atlas performed as designed on all four Mercury Atlas flights, so the ASIS was never called upon to save a life.

Subsequently, NASA issued a report entitled "Launch Vehicle Man Rating" (NASA 410-24-13-1) which identified two key elements to "man-rate" a launch system;

- **"Implementation of design, quality assurance, and checkout procedures to achieve as high a level of vehicle reliability as feasible"**
- **"Design of emergency-detection and abort-implementation systems to assure crew safety in the event of a vehicle malfunction"**

ULA has been involved in understanding Human Space Flight requirements and their impact on the Atlas V and Delta IV launch systems since these launch systems were base-lined by NASA in 2002 to launch the Orbital Space Plane (OSP). Our efforts in support of Commercial Human Space Flight continue today as we assess compliance to NASA National Performance Review (NPR) 8705.2B "Human Rating Requirements for Space Systems." We believe that a human rated system should be comprised of three primary elements, the combination of which provides a common-sense, system-level approach to accomplish the goal of safe, reliable human transportation to Orbit.

1. **Launch vehicle reliability**
2. **Addition of an Emergency Detection System**
3. **Intact abort capability.**

We have made significant investments in studies and analyses to help understand the impacts of these key elements on our launch vehicles for a Commercial Crew Program.

Unlike 1963, Atlas V and Delta IV are mature, reliable launch vehicles. Like 1963, though, Atlas and Delta will require an Emergency Detection System (EDS) to monitor critical systems, interface with the crew, and issue an abort command. Just like NASA in 1963, we have been focused on ensuring that our systems achieve as high a level of reliability as practical, and to design an EDS to assure crew safety in the unlikely event of a vehicle malfunction. We have worked closely with the Federal Aviation Administration Office of Commercial Space Transportation (FAA-AST) to incorporate their requirements. We have

[1] Manager, Business Development and Advanced Programs, United Launch Alliance, P.O. Box 277005, MC U9115, Littleton, Colorado 80127, AIAA Senior Member.
[2] Director, Business Development and Advanced Programs, United Launch Alliance, P.O. Box 277005, MC U9115, Littleton, Colorado 80127, AIAA Senior Member.
[3] NASA Program Manager, Customer Program Office, United Launch Alliance, P.O. Box 277005, MC U5001, Littleton, Colorado 80127.
[4] Advanced Programs Lead Engineer, CCAFS Engineering and Infrastructure, United Launch Alliance, P. O. Box 9009, MS CX41RR, Cape Canaveral, FL 32920.

coordinated with the 45th Space Wing to implement changes in our Flight Termination System to account for the presence of crew on our system.

Our comprehensive Development Plan for Commercial Crew on Atlas or Delta includes not only the incorporation of these key elements, but also the modifications for crew ingress and egress at our launch sites. We have created detailed plans to accommodate these unique requirements in a dedicated Atlas V SLC-41 Vertical Integration Facility (VIF) and Mobile Launch Platform (MLP). An equivalent implementation has been planned for Delta IV at LC-37A. The entire effort to human rate an Atlas V or Delta IV or Commercial Crew and launch the first crewed mission is expected to take approximately 4 years. This includes a full scale uncrewed demonstration flight.

Our highly reliable launch systems and our approach to human rating has been recognized and endorsed by many commercial, entrepreneurial, and traditional aerospace companies. Atlas V was baselined by several companies as their launch vehicle during the NASA Commercial Orbital Transportation System (COTS) procurements. We continue to work closely with a number of traditional Aerospace companies, in addition to many entrepreneurial firms, all of whom have the same goal: to provide safe and reliable Earth to Orbit transportation.

I. Introduction

NASA is at a crucial juncture as it plans the future of Human Spaceflight. ULA strongly supports the Administration's bold new initiative to rely on commercial companies to provide human access to Low Earth Orbit (LEO) while focusing on the more technologically challenging aspects of Exploration. This initiative will make a foundational investment in a capability for crew launch that meets NASA's stringent safety standards while enabling an emerging commercial spaceflight market. NASA will benefit from the efficiencies of a commercially operated system, which will be enhanced as the newly enabled commercial market grows. We also believe that it is in the best interest of our Nation to expand the use of the Florida Launch Range through a more robust launch tempo for NASA Crew Launch, Robotic Precursor and Flagship Technology Missions. Increased flight rate is the single, most important benefit for all companies.

NASA and ULA studies have confirmed that use of existing launch vehicles offer tremendous advantages to meet Human Spaceflight needs. The changes to Atlas V and Delta IV are straightforward. First, our existing launch pads will require accommodations to allow for ingress and egress to and from a crewed spacecraft. Second, we require the addition of an Emergency Detection System (EDS) to monitor the health of the launch vehicle, detect anonomolous conditions, safe the launch vehicle, and to trigger an abort.

We continue to work with a number of commercial providers who share the common belief that using existing, flight-proven launch vehicles significantly reduces the risk for crew access to LEO, thus allowing them to focus on the development of the crewed space vehicle.

Our ongoing efforts to provide human space flight on Atlas and Delta have recently been focused on two primary areas. First, there are programmatic enablers that are key to establishing this capability and to ensure the success of the Program. These enablers include the NASA acquisition approach, how NASA will exercise Insight and Oversight, and the investment that will be made in the common capabilities benefitting all users of Atlas and Delta. Second are the options for improving and exploiting physical launch infrastructure at the Florida Launch Range. ULA has studied many of these potentials and believes that there are a variety of approaches that may improve operations and throughput at our existing facilities, and leverage KSC-unique capabilities.

II. Commercial Human Space Flight

The Commercial Crew Transportation RFI (May 2010) was the first step towards enabling the Commercial Crew Transportation capability. However, the NASA Commercial Human Rating Plan (CHRP) represented a "business as usual" approach that was inconsistent with Commercial practices. The process did not provide a fixed set of requirements, yet required a fixed price procurement approach. The traditional NASA Program that loosely defines requirements, subject to Insight/Oversight interpretation and provisions, will result in cost overruns, and schedule slips. It is unrealistic to believe that a Commercial Crew Program will be successful if those models are followed. This initiative will require a paradigm shift in the acquisition approach to achieve affordable yet safe crew transport. Instead of traditional Program constructs NASA should look towards other successful USG/Industry Development Program initiatives as models, such as the US Air Force Evolved Expendable Launch Vehicle (EELV) Development Program. The Space Act Agreement (SAA) provides a similar framework, and the success of the Commercial Crew

Development (CCDev) Emergency Detection Prototype SAA so far with NASA insight is encouraging evidence that the SAA process can work effectively.

A. Program Construct and Procurement Approach

If NASA wishes to have a "commercial" procurement for these services, ULA strongly recommends that NASA establish a baseline a set of simplified system-level performance and capabilities requirements that are well know and not subject to interpretation for a Crew Transportation Program. NASA should also develop a clearly defined Insight and Oversight governance model that incorporates and adequately funds a Change Process to assess and incorporate customer-driven requirements changes throughout the development of the Program.

Human rating requirements, insight/oversight, investment, risk allocation and acquisition cannot be considered in isolation. There needs to be a comprehensive strategy which balances risk between the government and industry. The problem we have had with much of the historical debate has been that opinions tend to get polarized into either purely commercial perspectives, which force too much risk on the contractor, or purely government arsenal-type arguments in which the contractor takes none of the risk. Figure 1 offers one means of considering these questions along several dimensions.

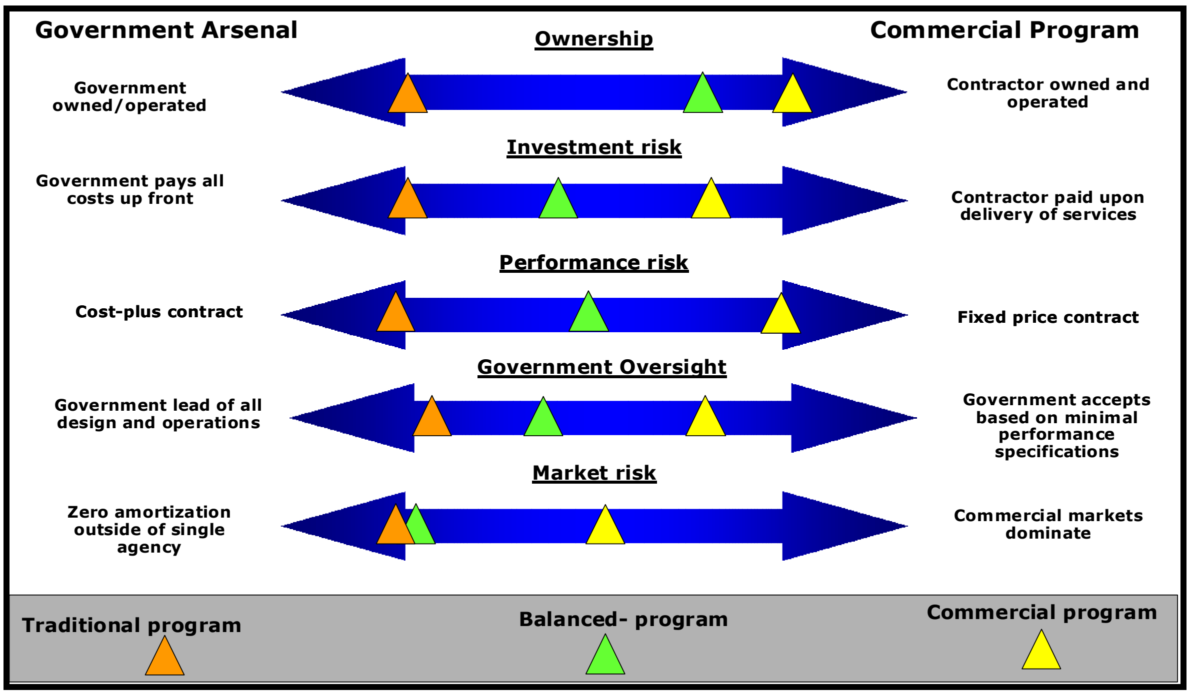


Figure 1. Crew launch program acquisition considerations. *NASA's Acquisition Strategy should be comprehensive and strike a balance between the risks associated with traditional government acquisitions and those of commercially procured systems.*

The first dimension is ownership. We believe that the appropriate balance of risk would put ownership in the hands of industry. However, due to the fact that government crew safety and potential damage to the International Space Station are virtually uninsurable risks, there must be some level of government indemnification.

In Section II.D of this Paper, we will explore the appropriate level of investment risk. Our position is that given fact that the USG is the only viable market, and the potential impact of financing costs, NASA should fully fund the development of this capability, and not rely on private investment predicated on a nascent commercial market.

Along the third slider, we consider performance risk. In a low technical risk program with stable requirements, we could envision the entire program conducted as a fixed price contract. Indeed the vast majority of launch services are contracted on a fixed cost basis. However, the requirements for human rating commercially owned and operated space systems are extremely fluid, as demonstrated in the CHIRP. Therefore, we would suggest that the requirements be simplified and stabilized, and that a robust change process be implemented. The alternative is to return to cost-reimbursable contracting.

We will deal with the question of government oversight in some detail in Section II.B of this Paper. But we believe that the current NASA Launch Services Program offers a very useful model for managing government risk.

Finally, in a functioning commercial market, the commercial buyer sets the market requirements, and the government purchases the same services. The human space launch market is dominated by government requirements. Therefore, we would suggest that the government must pay the cost for maintaining the infrastructure, and the commercial market should be allowed to purchase additional capacity at marginal pricing. This is similar to the model currently employed with the EELV program.

B. Insight/Oversight

NASA KSC's Launch Services Program (LSP) has an existing and proven process for meeting insight and oversight requirements for critical missions. This process has been in place in its current form since the formation of LSP in 1998, and it is built on decades of development oversight and operational launch experience. For high-value and critical missions, LSP achieves results equal to other effective U.S. Government insight/oversight models for a fraction of the cost. The LSP model should be considered as a starting point for commercial crew transportation services.

There are several elements of LSP's insight/oversight model that contribute to its effectiveness. These include close technical partnership with contractor engineering teams, on-site resident offices, acknowledgement and acceptance of contractor processes, and alignment of technical decision making and risk management processes.

1. Technical Partnership: The LSP model emphasizes good communication between contractor and NASA management and technical personnel. As relationships develop, and as contractors learn from experience that they can share information freely with NASA without fear of it being misused, a reinforcing cycle begins that results in greater NASA access to information, and minimized cost impacts to the contractor. The trust and communication that are key to this partnership can result in highly efficient and effective NASA insight.
2. On-Site Resident Offices: These groups of embedded NASA (and support contractor) employees accelerate the development of the trust and technical partnership described above, and they provide a very efficient and effective method for obtaining detailed insight on a continuous basis. Resident Office personnel are typically plugged into a contractor's IT systems and have access to all available technical information. This includes design, analysis, quality, test, production, and supplier data. By virtue of their fluency with contractor systems, these personnel can provide data and status to their home office colleagues without the need for continuously requesting data from individual contractor employees (which would increase cost). Resident Office personnel also have access to technical meetings and reviews, and have the ability to engage in direct conversations with contractor personnel whenever required. On-Site Resident Offices are one of the most powerful tools available to NASA for obtaining insight and increasing familiarity with all technical aspects of a contractor's work.
3. Acknowledgement and Acceptance of Contractor Process: It is incumbent upon a contractor to demonstrate that its processes are robust and effective in ensuring successful missions. Methods for demonstrating this include AS9100 certification and compliance with NASA's requirements for launch vehicle certification. Both of these methods are required by current NASA Launch Service (NLS) contracts managed by LSP. The NLS contract Statement of Work (SOW) defines additional requirements intended to ensure reliability and mitigate risk. A contractor must meet these requirements and demonstrate to NASA's satisfaction that they have robust and effective engineering, production, launch processing, and technical decision-making processes. Once they have done so, it is important for NASA to acknowledge and accept these processes. If NASA directs a deviation from or an addition to these processes, the deviation or addition should be subject to additional contractual direction and funding. This approach to oversight makes it compatible with Firm Fixed Price contracting. Although rare, these oversight issues do occasionally occur, typically when NASA desires additional testing of a component or system beyond what is planned by a contractor.
4. Alignment of Technical Decision-Making and Risk Management Processes: Alignment of these processes between NASA and a contractor (along with an emphasis on maintaining clear and open communication) enhances government insight, allows for early identification of potential issues, and allows for faster resolution of technical issues. Specific examples of alignment include:

    - Compatible Engineering Review Board processes (which can allow joint boards to reduce time required to reach decisions)

- NASA IV&V activities performed on the same schedule as a contractor's related activity (to allow immediate identification of issues instead of having them come to light months or years after the contractor activity has been completed)
- Sharing of risk tracking and risk resolution plans

The insight/oversight approach described here could be implemented with a prime contractor via their contract directly with NASA, or could be implemented with a major subcontractor by flowing the appropriate SOW and other requirements down through the prime contract. This approach was used for the GOES N, O, & P procurement recently managed by NASA GSFC, in which the spacecraft and launch services were procured via a single delivery-on-orbit contract with the spacecraft manufacturer. To ensure adequate launch service insight, the prime contract required flowdown of NASA technical and insight requirements to the launch service subcontractor.

C. Investment in Common Capabilities

ULA would provide launch services to a Commercial Crew Transportation (CCT) Company in support of their Crew Launch system. We believe that there are "human rating" elements that must be added to our proven launch vehicles that are common, regardless of the unique space craft configuration. As such, we strongly recommend that NASA fund the development of these capabilities directly with ULA to benefit ALL users of these existing, flight-proven launch vehicles. This allows each CCT Company to focus their limited resources on the development of the spacecraft while they rely on NASA and ULA to provide the common elements to fly on Atlas or Delta. Not only does this allow a standard approach for these elements, but it has the added benefit of allowing NASA to fund these once, rather than funding multiple companies to come up with unique solutions. The elements are summarized below:

1. <u>Dedicated processing and launch facilities for Crew Launch</u> – Our current processing and launch facilities at SLC-37B and SLC-41 were not built to accommodate crew launch. Due to the unique nature of human spaceflight, ULA recommends that dedicated facilities be built for either Delta IV on LC-37B or Atlas V on SLC-41. These dedicated facilities would integrate crew ingress and egress requirements unique for either launch system. These facilities have the added benefit of being able to take advantage of the experienced workforce for ongoing launch operations, and also be available to reduce the manifest congestion associated with our on-going launch manifest, increasing availability of launch slots for NASA Exploration Missions.
2. <u>Atlas Dual Engine Centaur (DEC)</u> – DEC offers significant LEO performance improvements over our current design, and has been baselined by all CCT Companies that we are currently working with.
3. <u>Human Rating</u> – Includes the launch vehicle Emergency Detection System (EDS) design and qualification, launch site modifications to accommodate crew ingress and emergency egress, any spacecraft unique analysis, software, system testing and analysis, and modifications to the existing Flight Termination System (FTS). ULA is making significant progress on an EDS prototype which is currently being demonstrated as part of the CCDev Program.

D. Investment Risk

ULA and its predecessor companies invested over $4.5 billion of company funds in the development and facilitization of the EELV family of vehicles ($2.7B for Delta IV and $1.8B for Atlas V). Total US government investment in these vehicles was $1.2B including funding for the initial Delta IV heavy demonstration mission. This puts the USG share of investment at 20% for Delta IV and 22% for Atlas as the vehicles are currently configured. Using the human rating cost estimates above, and assuming that the government provides 100% of the investment in human rating, the share of USG investment total system would range from 33% to 39% for Atlas V, and 42% for Delta IV.

Our assumption that NASA must invest 100% is driven by two factors. First, there is insufficient certainty regarding markets to justify investment. The commercial passenger travel market remains in its embryonic stages, and by itself does not warrant investment. Even the USG market for crew delivery services suffers from significant uncertainty. Secondly, given the fact that NASA is the primary market, the life cycle costs of a NASA investment scenario are considerably lower than one in which industry provides the up-front investment.

There is very high uncertainty over the size of the commercial space passenger travel market. To begin with there is a relative dearth of studies on the size of the commercial passenger travel market. Among the few, one study from Futron suggests that the market could be as large as $300m/yr. Other private studies suggest it could be larger. However, the current market served by Soyuz averages less than that by an order of magnitude. By aerospace standards, this is not a large market. By way of comparison, the business cases for many of the launch systems of the 1990s were built on assumptions of markets an order of magnitude larger than the Futron estimates. More importantly perhaps, there was a plethora of studies projecting such high launch rates, perhaps most notably those sponsored by the Federal Aviation Administration. As erroneous as it turned out to be, there was a broad consensus that the commercial launch market was in excess of 40 launches a year. Given this level of uncertainty, it is extremely difficult to justify an investment in the commercial side of the human space flight market.

The situation with NASA is different. Assuming the space station continues to remain healthy, there appears to be a clear requirement for 2-4 crew launches a year. But even here, uncertainty remains. First, how many providers will share this market? All indications are that NASA would like to support two providers. So this reduces the market to 1-2 launches a year for each provider. Moreover, the risk remains that the ISS will not remain healthy, or that an additional provider (perhaps a government provided vehicle) will enter the market as well. Finally, there is the risk that the Commercial Crew Transportation program could be cancelled in future budgets. Given this level of uncertainty, we believe it would be necessary for NASA to provide 100% termination liability for all investments, including the cost of money.

So a logical business is left with the proposition of creating a risk-adjusted investment model. The conclusion here is fairly clear as well. Given the fact that investors (including company shareholders) demand a return on investment, it will be more cost effective for NASA to provide the up-front investment itself, rather than paying the investors for the cost of money. Assuming a conservative ROI of 15%, for the launch portion alone NASA would pay a life cycle cost premium of 25% if there are two guaranteed launches a year. If the NASA launch rate drops to 1 launch a year that premium jumps to over 100%.

ULA has been intimately involved with a number of companies interested in developing a mutually beneficial commercial space market for our respective products. We have worked together to understand the commercial space market and the enablers for that market to gain a foothold. These on-going relationships have provided us with unique insight into the potential non-NASA market for access to space. As such, it has become clear to us that the non-NASA market is directly dependant upon the decisions made by NASA today. There will be no commercial market with a viable commercial crew transportation system. The USG is in a unique position as an anchor tenant to develop a commercially-viable space transportation system that could facilitate a commercial space market. Without this commitment, we have determined that a commercial market will not exist in the timeframe required for a reasonable Return on Investment.

III. Launch Site Accomodations

Crew launch offers many opportunities to utilize existing facilities at CCAFS or at NASA/KSC, all of which have been studied since the Orbital Space Plan Program. This Paper highlights ten potential approaches to accommodate Crew Launch using Atlas V or Delta IV and existing facilities at SLC-39, SLC-37, and/or SLC-41. We believe that the use of existing launch facilities and launch vehicles provides a cost effective interim Commercial Crew launch capability as the market expands and other dedicated facilities are readied. This approach leverages the demonstrated reliability and inherent safety of existing, flight-proven launch systems, while allowing NASA to focus on launch of Orion and HLV launch from SLC-39. However, there may be viable alternatives that allow Commercial Crew launch from SLC-39, but this is highly dependant upon the business case considerations detailed in Section II of this Paper.

Due to the flexibility inherent in our launch systems, we are confident that we can expand our existing infrastructure to meet NASA's needs, in addition to using the NASA/KSC VAB and SLC-39 to integrate, test and launch Atlas V and Delta IV. This flexibility was demonstrated in ULA's support of the successful Ares I-X test flight. ULA avionics and ground systems were used to integrate, test and launch the Ares I-X vehicle. NASA may want to consider upgrading the KSC Ares 1-X ground control system to enable Atlas and Delta launches from SLC-39B. Figure 2 depicts some options for accommodating the increased flight rate that we envision for Crew Launch, Robotic Precursor and Flagship Technology Missions, along with accommodating the needs of our existing National Security Space customers.

The NASA KSC Vertical Assembly Building (VAB) and SLC-39 can be used to process and launch Atlas V and Delta IV. We are still investigating the specific technical details, but this appears to be an attractive option. However, it is predicated on the specific Concept of Operations and Acquisition Strategy that NASA would employ. For example, for a Commercial Crew Launch Program, NASA KSC offers the inherent benefits of accommodating the needs of crew ingress, egress and crew safety and quality processes. However, it is unclear at this time if NASA will be able to provide the modifications and recurring operations at a cost that is viable to a Commercial Company. It is also unclear if the NASA/KSC facilities could be available as soon as existing or expanded facilities at SLC-37 and/or SLC-41.

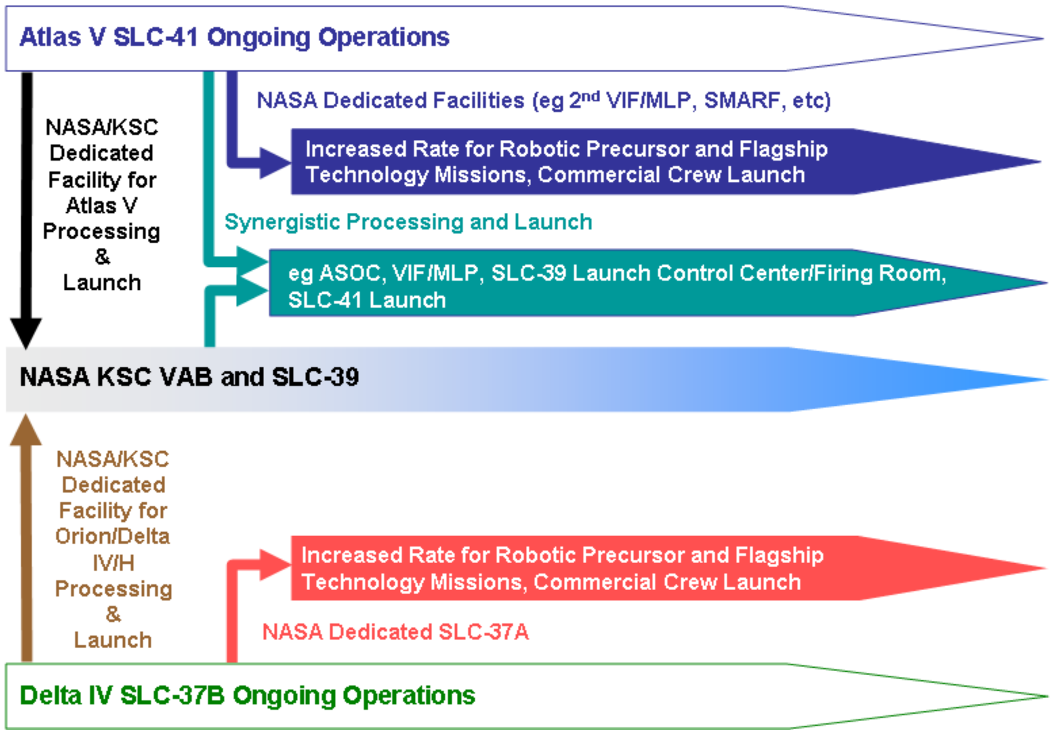


Figure 2. Considerations for accommodating increased flight rates. *Existing launch infrastructure can be utilized and expanded to accommodate NASA launch needs for Crew Launch, Robotic Precursor and Flagship Technology Mission.*

We feel that an attractive option would be to accommodate more traditional operations at NASA facilities, such as making the necessary modifications to process and launch the Orion Crew Exploration Vehicle (CEV) on a Delta IV-Heavy. This provides the mutual benefits of transferring lessons-learned between ULA and NASA as we transition to using NASA engineers, operators and technicians to assemble, integrate, test and launch Delta-IV. This also provides a path to enable NASA's need for a Heavy Lift Launch Vehicle in the future.

At the same time, current Atlas V and Delta IV processing and launch facilities could be expanded to meet NASA's needs. For Atlas V, a second VIF/MLP could be constructed and nearly double our current flight rate (with an increase in manpower to support parallel processing). Other facilities such as the SMARF offer similar benefits. For Delta IV, we recommend that a duplicate of the existing SLC-37B be constructed and dedicated to NASA missions.

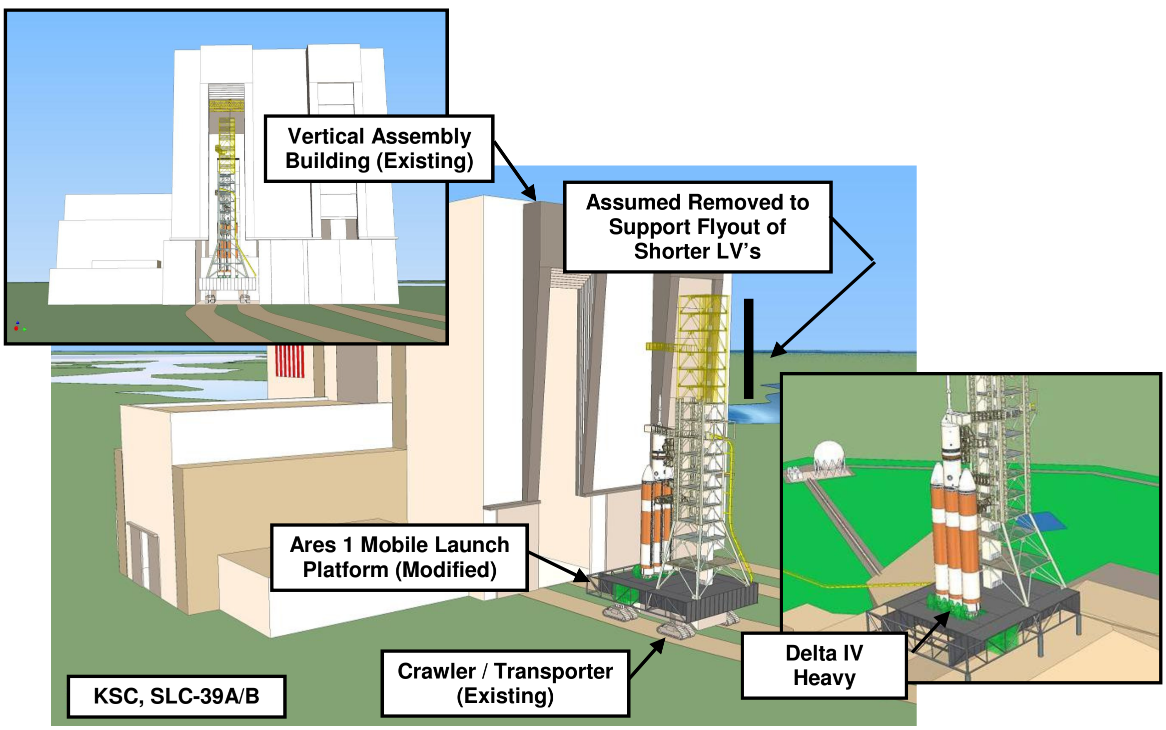
There are a variety of approaches that can leverage both NASA and CCAFS capabilities. For example, parallel EELV/NASA operations at SLC-41 or SLC-37 could be accommodated by modifying one of the KSC LCC Firing Rooms to be a remote control center. This concept is similar to the launch ops concepts used for the Ares 1-X test flight.

ULA has taken the opportunity to investigate our existing Florida Eastern Range EELV launch sites (SLC-37B for Delta IV and SLC-41for Atlas V) as well as launch site infrastructure at Kennedy Space Center with respect to NASA Crew Launch, Robotic Precursor and Flagship Technology Missions that could fly on an Atlas V or a Delta IV. While that study is ongoing, some determinations have been made concerning the capability of existing facilities to support Crew launch using Evolved Expendable Launch Vehicles. Since the use of one launch site versus another and any modifications that would result are heavily concept dependent, existing infrastructure utilization and/or the need for new infrastructure will be discussed within the context of individual launch processing concepts and what each means for SLC-37, SLC-41 (CCAFS) and/or SLC-39 (KSC).

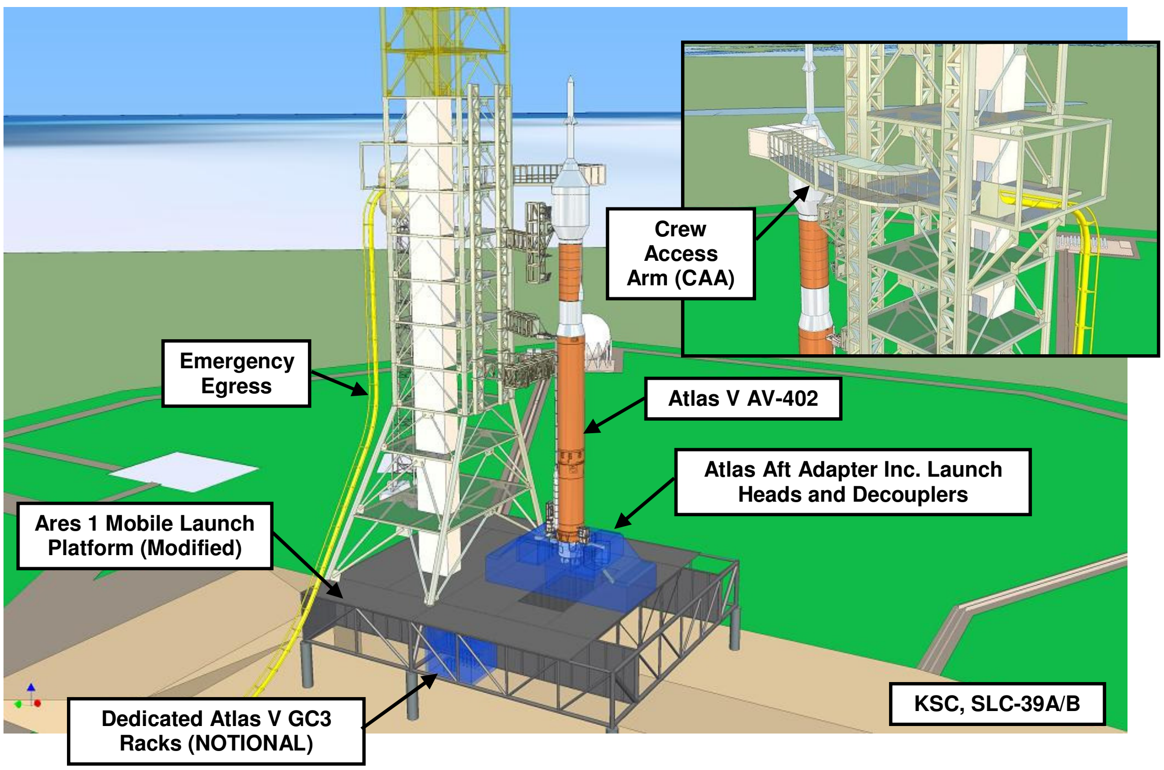
A cross section of concepts that support Crew launch using ULA vehicles from the Florida Launch Range is presented below for your review. The list is not meant to be all inclusive, nor are options presented in order of preference. ULA's intent is rather to demonstrate at a top level what it is technically possible first and foremost, with relative strengths and weaknesses provided to further the discussion. In every case, existing facilities and launch infrastructure are leveraged to the greatest extent possible for a host of reasons, not the least of which is limiting nonrecurring investment. New hardware, equipment and other processing infrastructure will also be required, no matter the concept. Both classes (existing and new) are summarized for your review. The ultimate approach will include not only the technical assessment, but also an assessment of the business considerations detailed in Section II of this Paper.

It is also true that the extent to which facilities are shared can often be correlated to other factors such as time to Initial Launch Capability (ILC) and nonrecurring activation cost. Again, ULA has attempted to give some qualitative insight in to the compromises that are inherent with any given concept. For example, SLC-41 presents potentially attractive options for launching crewed Atlas V missions – relatively low initial cost, early launch availability – but with potential constraints associated with sharing facilities with other USG and commercial customers.

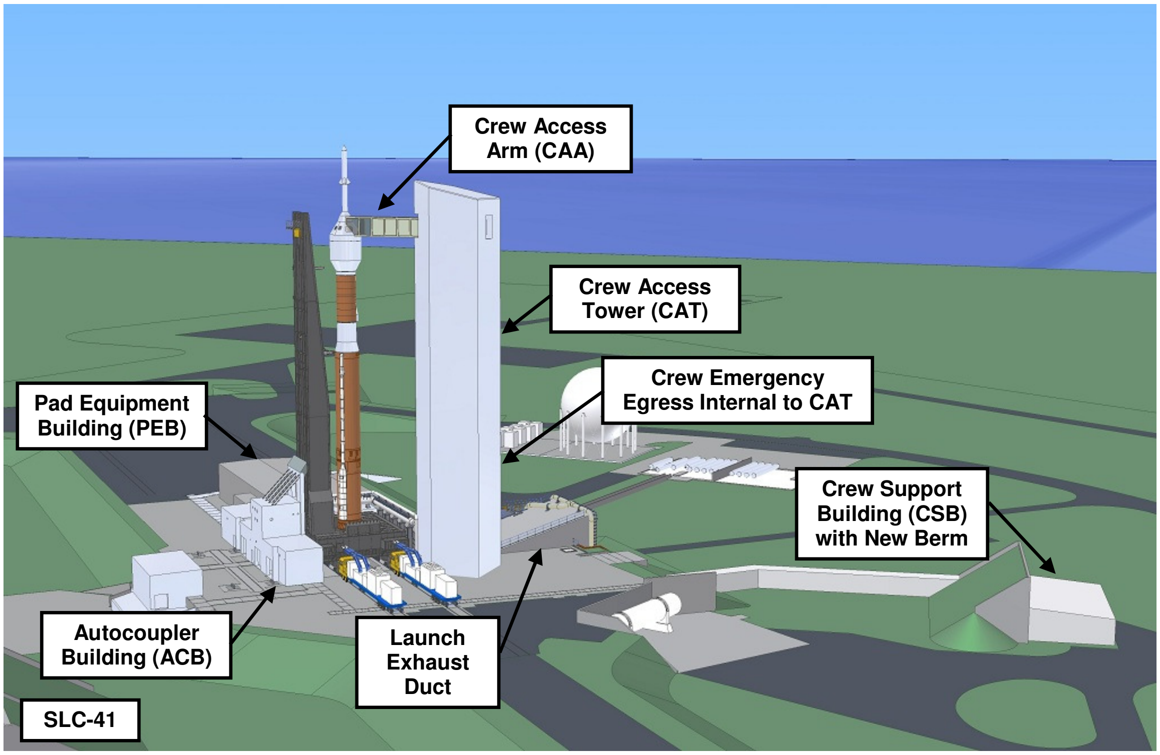
Concept: ULA-K39-01, DIV Heavy Launch from SLC-39B, Shared Infrastructure
Launch Vehicle: Delta IV, Delta IV Heavy configuration
Launch Site: KSC, SLC-39B
Existing Infrastructure: Transportation and Handling GSE; Orbiter Processing Facilities (OPF's), Vertical Assembly Building (VAB), Ares 1-X Mobile Launch Platform, SLC-39B Launch Pad infrastructure (tank farms, etc.); KSC Launch Control Center
New Infrastructure: Equipment for stage level and integrated testing; OPF modifications; VAB work platform modifications; MLP modifications including those for Crew Access; Emergency Egress at SLC-39B, "Human Rated" ground systems; LCC modifications
Potential Concept of Operations: NASA is Launch Services Contractor (LSC); Launch Services Provider (LSP) function is by others (not ULA); Launch Vehicle (LV) stages shipped to CCAFS via barge (Delta Mariner); Boosters (CBC's) and 2nd Stage received at existing OPF; CBC's horizontally integrated in OPF; 1st Stage erected in VAB; 2nd Stage vertically integrated in VAB; Spacecraft and Launch Abort System (LAS) integrated in VAB; roll to Pad; load crew, and launch from SLC-39B
Potential Advantages: Potential for moderate cost; dedicated facilities; guaranteed launch availability; construction decoupled from LV processing
Potential Disadvantages: Unknown maintenance/life cycle costs



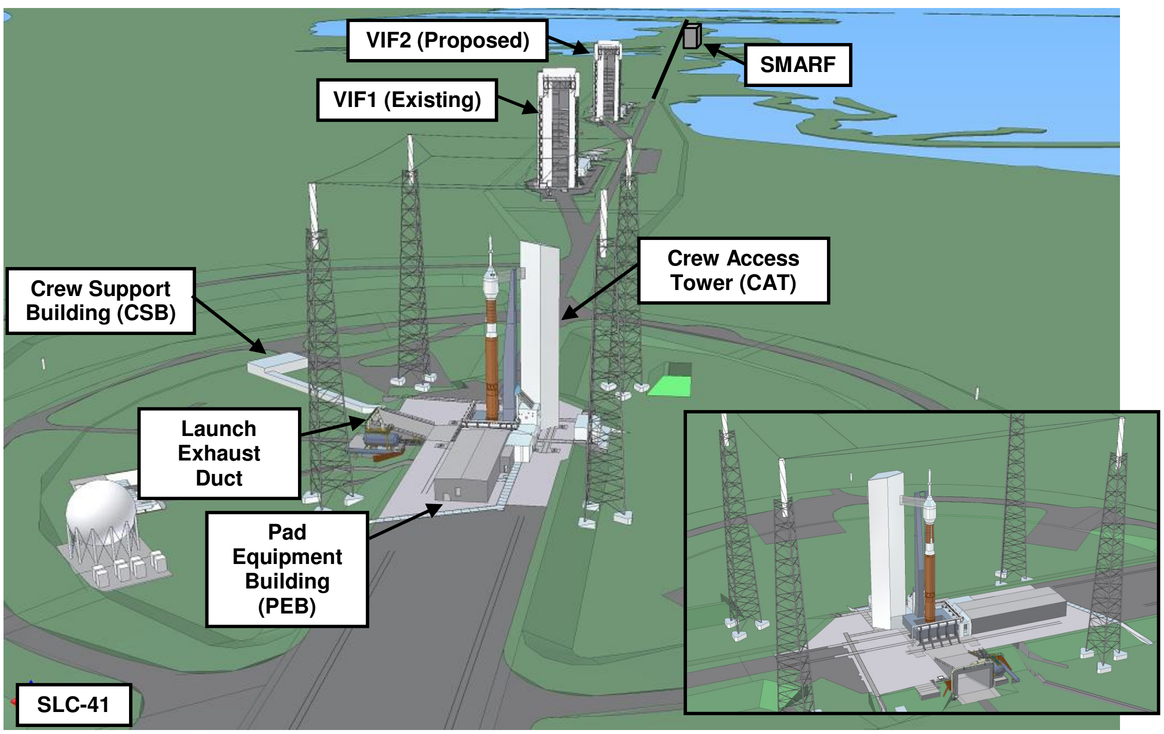
Concept: <u>ULA-K39-02,</u> AV-402 Launch from SLC-39B, Shared Infrastructure
Launch Vehicle: Atlas V, AV-402 configuration
Launch Site: KSC, SLC-39B
Existing Infrastructure: Same as for ULA-K39-01
New Infrastructure: Equipment for stage level and integrated testing; OPF modifications; VAB work platform modifications; MLP modifications including those for Crew Access; Emergency Egress at SLC-39B, RP-1 tank farm and other "Human Rated" ground systems; LCC modifications
Potential Concept of Operations: NASA is Launch Services Contractor (LSC); Launch Services Provider (LSP) function is by others (not ULA); Launch Vehicle (LV) stages shipped to CCAFS via barge (Delta Mariner); Booster (CCB) and Upper Stage received at existing OPF; Booster stage level testing in OPF; Stages vertically integrated in VAB; Spacecraft and Launch Abort System (LAS) integrated in VAB; roll to Pad; load crew, and launch from SLC-39B
Potential Advantages: Potential for moderate cost; dedicated facilities; guaranteed launch availability; construction decoupled from LV processing
Potential Disadvantages: Unknown maintenance/life cycle costs



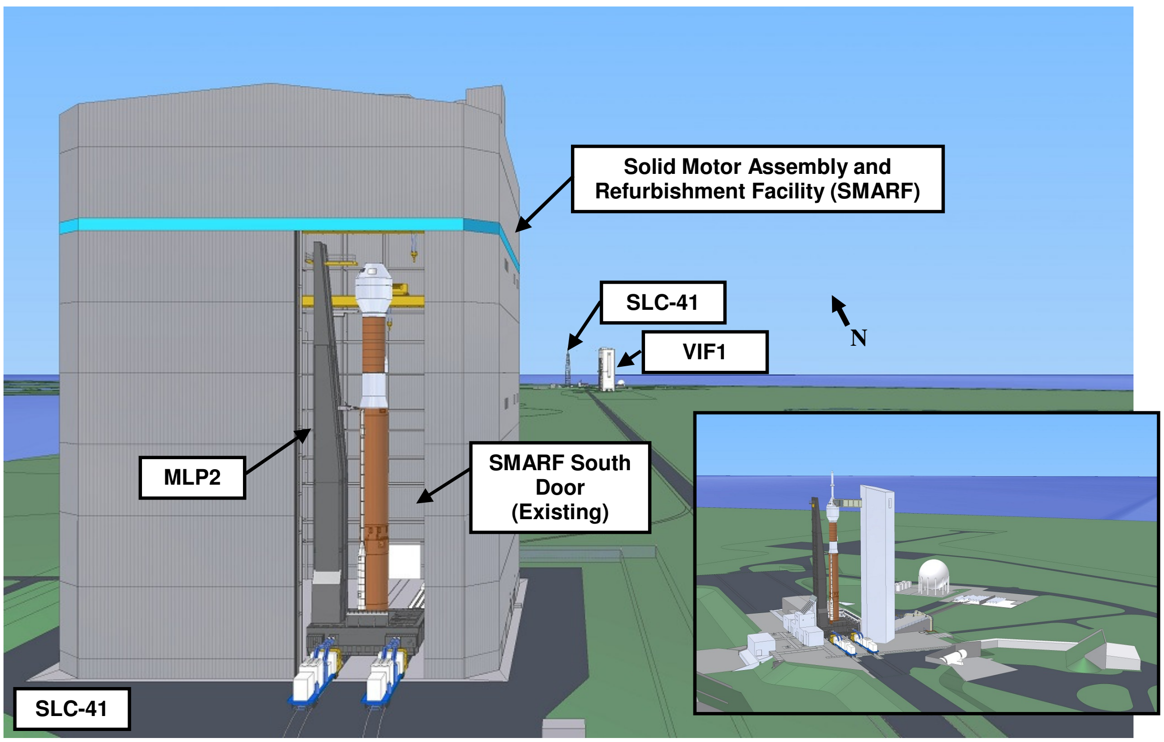
Concept: ULA-C41-01, AV-402 Launch from SLC-41, Shared Infrastructure
Launch Vehicle: Atlas V, AV-402 configuration
Launch Site: CCAFS, SLC-41
Existing Infrastructure: Transportation and Handling GSE; Atlas Spaceflight Operations Center (ASOC); Vertical Integration Facility (VIF); SLC-41 Launch Pad infrastructure (tank farms, etc.); Atlas Launch Control Center
New Infrastructure: Equipment for stage level and integrated testing; VIF work platform modifications, "Human Rated" ground systems; LCC modifications; Crew Access Tower (CAT)
Potential Concept of Operations: NASA is Launch Services Contractor (LSC); ULA is Launch Services Provider (LSP); Launch Vehicle (LV) stages shipped to CCAFS via barge (Delta Mariner); Booster (CCB) and Upper Stage (Centaur) received at existing Atlas Spaceflight Operations Center (ASOC); stages integrated in existing Vertical Integration Facility (VIF); Spacecraft and Launch Abort System (LAS) integrated as for any other Payload; roll to Pad, load crew, and launch from SLC-41
Potential Advantages: Low cost; early launch availability; use of experienced personnel, established processes and available GSE to process LV; low maintenance/life cycle costs; construction largely decoupled from LV processing
Potential Disadvantages: Shared facilities create potential launch availability issues



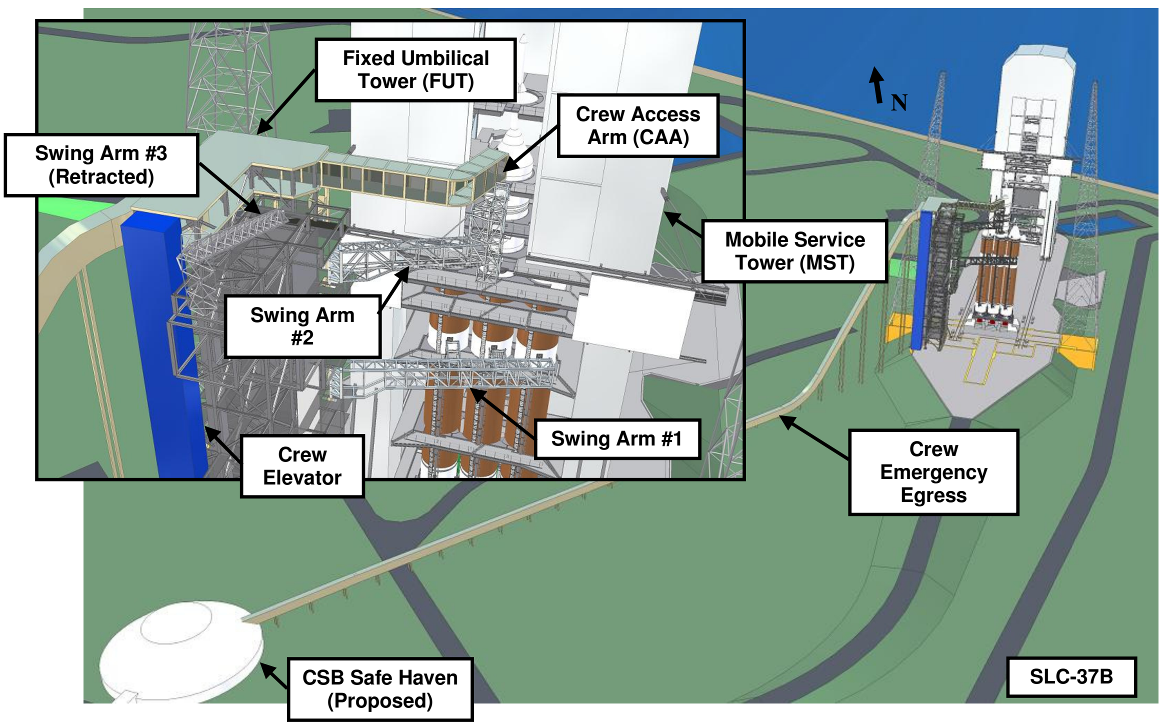
Concept: ULA-C41-02, AV-402 Launch from SLC-41, MLP2 and VIF2
Launch Vehicle: Atlas V, AV-402 configuration
Launch Site: CCAFS, SLC-41
Existing Infrastructure: Same as for ULA-C41-01
New Infrastructure: Same as for ULA-C41-01 less VIF1 work platforms; 2^{nd} Mobile Launch Platform (MLP2 similar to MLP1); 2^{nd} Vertical Integration Facility (VIF2 similar to VIF1)
Potential Concept of Operations: Same as for ULA-C41-01
Potential Advantages: Moderate cost; early launch availability; use of experienced personnel, established processes and available GSE to process LV; moderate maintenance/life cycle costs; construction largely decoupled from LV processing
Potential Disadvantages: Less facility sharing than ULA-C41-01, but more than for ULA-C37-03 or other dedicated KSC options



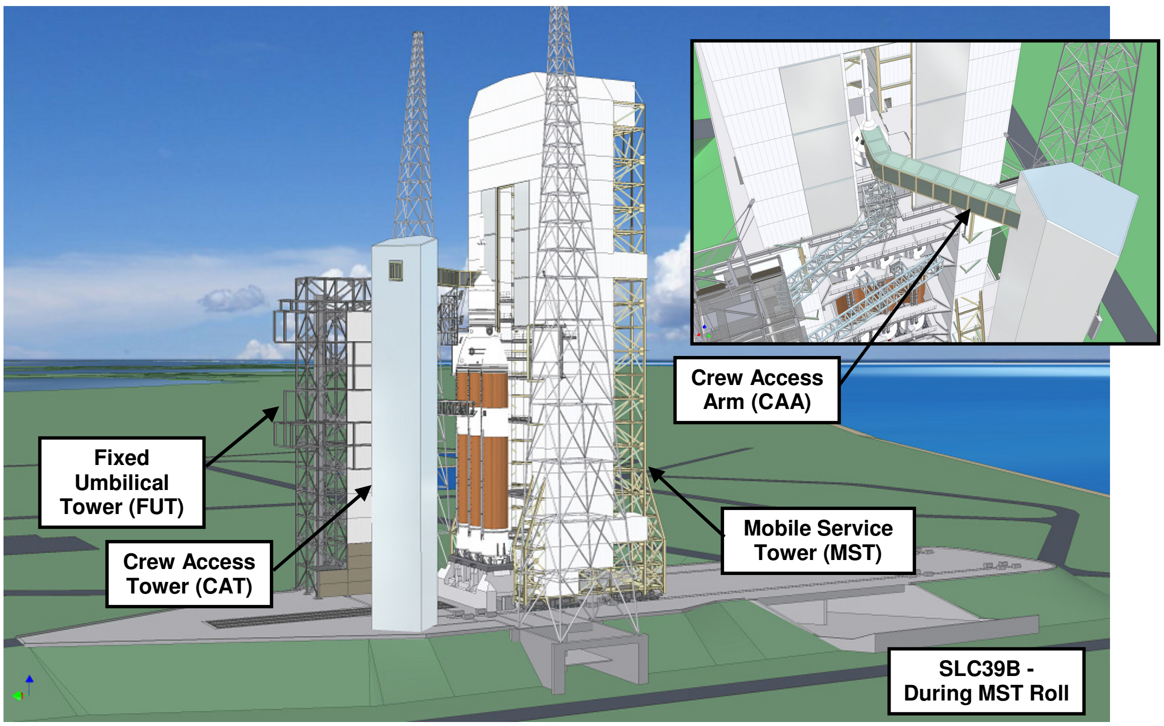
Concept: ULA-C41-03, AV-402 Launch from SLC-41; MLP2 and SMARF Modifications
Launch Vehicle: Atlas V, AV-402 configuration
Launch Site: CCAFS, SLC-41
Existing Infrastructure: Same as for ULA-C41-01; Solid Motor Assembly and Refurbishment Facility (SMARF)
New Infrastructure: Same as for ULA-C41-01 less VIF1 work platforms; 2nd Mobile Launch Platform (MLP2 similar to MLP1); LV vertical integration cell inside SMARF; other SMARF modifications
Potential Concept of Operations: Same as for ULA-C41-01
Potential Advantages: Moderate cost likely less than for ULA-C41-02; early launch availability; use of experienced personnel, established processes and available GSE to process LV; moderate maintenance/life cycle costs; construction largely decoupled from LV processing
Potential Disadvantages: Less facility sharing than ULA-C41-01, but more than for ULA-C37-03 or other dedicated KSC options



Concept: ULA-C37-01, DIV Heavy Launch from SLC-37B, Shared Infrastructure
Launch Vehicle: Delta IV, Delta IV Heavy configuration
Launch Site: CCAFS, SLC-37B
Existing Infrastructure: Transportation and Handling GSE; Delta Operations Center (DOC); Horizontal Integration Facility (HIF); Mobile Service Tower (MST); SLC-37 Launch Pad infrastructure (tank farms, etc.); Delta Launch Control Center
New Infrastructure: Equipment for stage level and integrated testing; MST work platform modifications, Fixed Umbilical Tower (FUT) modifications for Crew Access; Crew Emergency Egress at SLC-37B, "Human Rated" ground systems; LCC modifications
Potential Concept of Operations: NASA is Launch Services Contractor (LSC); ULA is Launch Services Provider (LSP); Launch Vehicle (LV) stages shipped to CCAFS via barge (Delta Mariner); Booster (CBC) received at existing HIF; Upper Stage received at existing DOC; 1st Stage erected in existing MST; 2nd Stage integrated in MST (planned); Spacecraft and Launch Abort System (LAS) integrated in MST as for any other Payload; MST rollback; load crew and launch from SLC-37
Potential Advantages: Low cost; early launch availability; use of experienced personnel, established processes and available GSE to process LV; low maintenance/life cycle costs
Potential Disadvantages: Shared facilities create significant launch availability issues; significant construction in parallel with LV processing



Concept: ULA-C37-02, DIV Heavy Launch from SLC-37B, Crew Access Tower
Launch Vehicle: Delta IV, Delta IV Heavy configuration
Launch Site: CCAFS, SLC-37B
Existing Infrastructure: Same as for ULA-C37-01
New Infrastructure: Same as for ULA-C37-01; Crew Access Tower
Potential Concept of Operations: Same as for ULA-C41-01
Potential Advantages: Moderate cost; early launch availability; use of experienced personnel, established processes and available GSE to process LV; low maintenance/life cycle costs
Potential Disadvantages: Shared facilities create significant launch availability issues; construction in parallel with LV processing



Concept: ULA-C37-03, DIV Heavy Launch from SLC-37A, Dedicated Facility
Launch Vehicle: Delta IV, Delta IV Heavy configuration
Launch Site: CCAFS, SLC-37A
Existing Infrastructure: Same as for ULA-C37-01
New Infrastructure: Same as for ULA-C37-01 less MST work platform modifications; Pad infrastructure including Launch Exhaust Duct (LED) and tank farms; dedicated MST; FUT with integrated Crew Access; Emergency Egress
Potential Concept of Operations: Same as for ULA-C41-01
Potential Advantages: Dedicated facilities; guaranteed launch availability; use of experienced personnel, established processes and available GSE to process LV; low maintenance/life cycle costs; construction decoupled from LV processing
Potential Disadvantages: High construction and maintenance/life cycle costs