Commercial Crew Development: Enabling Launch on EELV

Michael Holguin,
United Launch Alliance (ULA)
9100 E. Mineral Avenue
Centennial, CO 80112

Abstract

The building momentum surrounding the emerging market for Commercial Human Spaceflight is exciting, and United Launch Alliance plays a pivotal role as a key launch service provider to several of the candidate crew spacecraft. In order to enable commercial human spaceflight, there are a handful of capabilities that must be developed in order to augment the highly reliable flight proven EELV launch vehicle family. ULA has been working in partnership with NASA using an unfunded Space Act Agreement under the Commercial Crew Development initiative to develop these capabilities.

I. Introduction

Over the last decade, ULA has been involved in human rating studies that have provided a solid foundation for the human rating effort that we are currently engaged in for Commercial Crew. This effort made significant progress during the OSP program, in that ULA and NASA worked very closely to understand the upgrades required to meet the approach under consideration at that time to fly humans on Atlas (and Delta). Numerous studies have been conducted over the last decade and cooperative agreements between NASA and various members of the spacecraft community have been performed to further increase this confidence. A summary of this effort is illustrated in Figure 1.

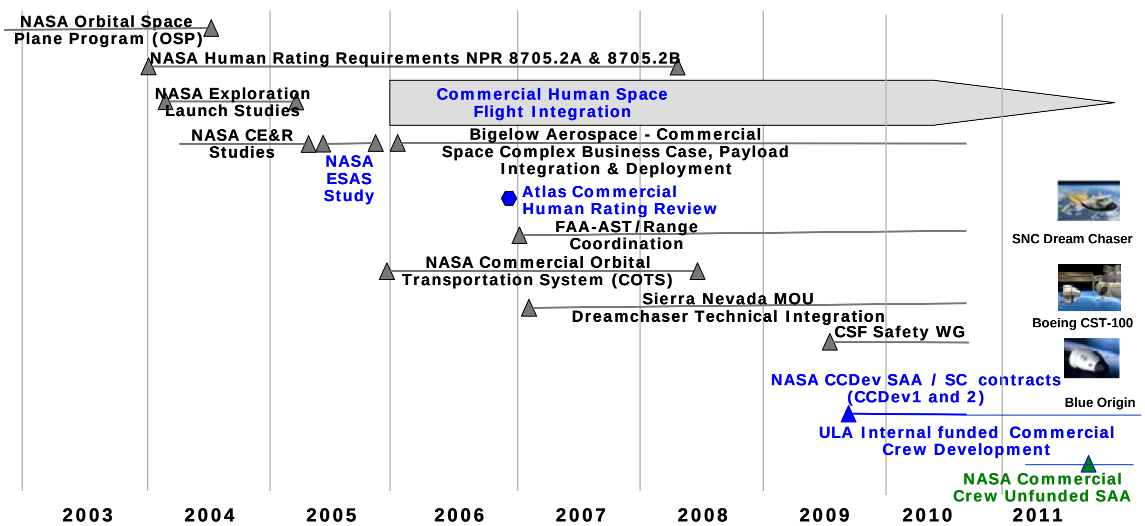

Figure 1: Atlas Human Spaceflight requirements and design previous efforts
* Images courtesy of Boeing, Sierra Nevada, and Blue Origin

In 2010 ULA was awarded a CCDev1 Space Act Agreement to develop a prototype Emergency Detection System (EDS) that would enable the crewed spacecraft to abort in case of a launch vehicle or spacecraft failure, in addition to early integration subcontracts with various spacecraft providers. ULA successfully demonstrated the abort capability during the final demonstration effort performed in December of 2010. At that time ULA not only established that this capability was feasible using existing systems but was actually “flown” in a high fidelity Systems Integration Lab with various spacecraft configurations and various failure modes.

In 2011, ULA was selected by three of the four CCDev2 (Commercial Crew Development) spacecraft awardees to integrate the Atlas V launch vehicle - Boeing, Sierra Nevada and Blue Origin chose the Atlas V to provide launch services for their spacecraft. In addition, ULA elected to continue in parallel, the development of a few key elements to facilitate crewed space transportation. NASA also partnered with ULA under an unfunded SAA/MOU to follow the design and certification efforts and provide guidance and expertise from the Commercial Crew Program Office (CCPO) against the Crew Transportation System (CTS) 100 series requirements set. The elements ULA continues to develop include the EDS as the key enabling technology to allow humans to safely fly on Atlas; NASA certification of the existing Atlas for human spaceflight taking advantage of the Atlas V CAT3 certification as a springboard; performance improvements to the launch vehicle to enhance abort capabilities; and provisions at the launch site for accommodations such as crew access and emergency egress. This paper will describe these elements under development and the status of each activity.

II. Approach to Crew Safety

A. Historical Context

Two key fundamental tenets of Human Space Flight are crew safety and mission success. This was true from the time John F Kennedy announced that the US would put humans on the moon and return them safely, and the same is still true today. In the beginning of human spaceflight within the United States, the Atlas once safely carried astronauts like John Glenn to orbit with the simplest of upgrades to the launch vehicle, primarily a system for detection of launch vehicle anomalies that would signal an abort to the crew capsule. This is referred to as the Abort Sensing and Implementation System (Reference AIAA Space 2011 Paper by ULA entitled "Evolution of Abort Management of Crewed Launch Vehicles from Mercury ASIS to Commercial Crew EDS"). During 2010, ULA demonstrated an Emergency Detection System prototype to NASA as part of the Space Act Agreement for CCDev1. This EDS Demonstration & Development effort ensured that the approach we used was consistent with Human Spaceflight principles. EDS is the key technology to be implemented that will enable the existing flight proven Atlas V to fly crew, a key component in achieving Atlas V human space flight (HSF) certification.

B. Heritage

The Atlas V and Delta IV fleet have proven themselves in 44 successful flights to date since the launch of the first EELV. EELV has its heritage in over 50 years worth of process maturation, years of evolution of systems and subsystems that increased performance and incorporated fault tolerance, reliability improvements, and the latest technology. Adding EDS to this flight proven system along with an intact abort capability minimizes risk to crew safety to the maximum extent possible. Figure 2 illustrates the main characteristics of a System-Level Crew Safety approach using the existing EELV fleet.

Figure 2 - Main characteristics of a system-level crew safety approach using the existing EELV fleet.

III. Human Space Flight Certification

A. Flight History is Key to Confidence

As a flight proven system, the EELV can minimize risk associated with NASA's Human Spaceflight certification of the overall LV/SC system vs. a newly developed spacecraft with a completely new non-flight proven stack. Figure 3 shows the number of flights that have occurred during the period that human rating efforts have been studied within ULA.

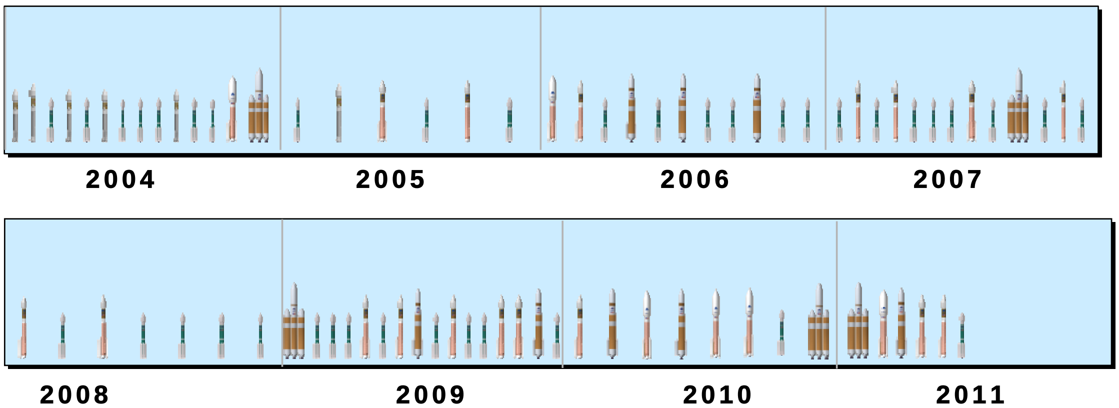

Figure 3: ULA's ongoing flight rate provides a large database of flight vehicle characteristics and experience

As a result of this ongoing significant flight rate and historical database, the characteristics of a flight proven system are well known: A) the operating conditions have been validated against design margins after each flight to ensure that the vehicle operates within family and any unknown conditions are accounted for and well understood, B) manufacturing, inspection, testing and launch ops processes are well honed, and C) rigorous technical review and corrective action processes are tightly integrated with our customers processes. Because a wide variety of missions from LEO to interplanetary have been flown on the Atlas V, and it has flown in many different configurations flying through an expansive range of environments – a significant body of evidence is available to the HSF community. The NASA HSF certification team and all of our customers have enjoyed access to this body of evidence as proof that the vehicle continues to deliver on its promise of mission success. Part of the proof of our customers trust in Atlas V can be found in NASA's Category 3 certification of Atlas V, and the only US launch vehicle with approval to fly nuclear payloads.

B. Atlas V Category 3 Certification Depth of Insight Provides Body of Evidence for Human Spaceflight

Atlas V has been certified to the highest levels of reliability and mission success by NASA as part of the qualifications required to fly the most important NASA science missions. Since these are "one of a kind" missions and extremely expensive and valuable scientifically, NASA policy dictates an extensive certification process. This highest level of certification is referred to as Category 3 and is based on a combination of successful flights and access to the body of evidence including design, test and flight data. NASA Launch Vehicle Certification is part of a comprehensive Mission Assurance process that is based on decades of experience and lessons learned over hundreds of missions. The Certification process is executed by NASA's Launch Services Program at KSC, with support from other NASA organizations. The Mission Assurance elements include:

- Launch Vehicle Certification
- Insight & Approval (NPD 8610.23)
- Engineering Review Process / Board
- Flight Anomaly Resolution
- Mission Analysis
- Verification Process
- Resident Offices
- Reviews
- Safety & Flight Assurance and Risk Management
- Launch Readiness Reviews
- Launch Operations
- Lessons Learned Process

Top level certification requirements are owned by NASA SOMD (now HEO) and defined in NPD 8610.7D: Launch Services Risk Mitigation Policy for NASA-Owned and/or NASA-Sponsored Payloads/Missions. This policy defines payload classes and required launch vehicle certification levels for each. The certification process itself is owned and performed by the Launch Services Program (LSP) at KSC in accordance with LSP-PLN-324.01: Expendable Launch Vehicle Certification, which defines the criteria to be used to certify any LV configuration under contract to LSP. It is important to note that because NASA and ULA have been flying together for many years, synergies have emerged and the resident office has become deeply knowledgeable not only of the current vehicle configuration but is also engaged in the ongoing upgrades and improvements to the vehicle in order that the vehicle continues to maintain its certification. As such, NASA processes parallel and complement ULA processes throughout the product lifecycle.

Per NPD 8610.7D, the policy is applied to *"balance launch risk for individual missions with demonstrated launch vehicle history, flight anomaly, and mission failure resolution, if any, and NASA technical penetration consistent with overall mission risk… This policy addresses three levels of launch vehicle risk: high, medium, and low. NASA's approach to determine launch vehicle risk Category and mitigate the risks across Category alternatives are through a launch vehicle certification process…. (4) Payloads which are classified as* ***Class A, and, in some cases, Class B payloads*** *pursuant to NPR 8705.4, shall be launched on* ***Risk Category 3 launch vehicles*** *that have a more robust demonstrated successful flight history. . . . certified by any of three alternative methods*"

These alternatives are summarized below:

Alternative	1	2	3
Demonstrated Flight Record	14 consecutive successful flights of a common LV configuration (i.e., 95 % demonstrated reliability at 50 % confidence level), instrumented to provide design verification & flight performance data	6 successful flights (that include a minimum of 3 consecutive successful flights) of a common LV configuration instrumented to provide design verification & flight performance data	**3 successful flights (that include a minimum of 2 consecutive successful flights) of a common LV configuration instrumented to provide design verification & flight performance data**
Additional Requirements	Evaluation of subject documentation	Completion of a NASA Design Certification Review, NASA-conducted IV&V of launch vehicle analyses, and audits and evaluation of subject documentation	**Completion of extensive NASA technical penetration, audits, and evaluation of subject documentation**
Post Flight Ops Anomaly Resolution Process	√	√	√
Flight Margin Verification	√	√	√
Design	NASA assessment of LSC design reliability	NASA assessment of LSC design reliability	**NASA assessment of LSC design reliability**
MFG and Ops systems eng.	None	NASA Audit	**NASA Audit**
System Safety	Demonstrated compliance with applicable Range Safety reqmnts.	Demonstrated compliance with applicable Range Safety reqmnts.	**Demonstrated compliance with applicable Range Safety reqmnts.**
Test and Verification	None	NASA Design Certification Review	**Comprehensive Acceptance Test results**
Quality Systems Processes	None	NASA Audit	**NASA Audit**
Flight Hardware and SW Qual	None	NASA Design Certification Review	**Series of NASA Engineering Review Boards on vehicle subsystems**
LV Analysis	None	NASA IV&V	**NASA IV&V**
Risk Management	Risk Plan, Mitigated and Accepted Technical and Safety Risks	Risk Plan, Mitigated and Accepted Technical and Safety Risks	**Risk Plan, Mitigated and Accepted Technical and Safety Risks**
Integrated Analysis	None	None	**Full Vehicle Fishbone**
Launch Complex	None	NASA Design Certification Review	NASA Engineering Review Board

Category 3 certification provides a significant springboard for NASA to leverage of for Human Space Flight Certification. NASA has invested significant time and resources over the years providing an independent technical and risk assessment of the Atlas V which has provided mission success for every planetary mission launched, and Atlas V has launched most interplanetary missions. As illustrated in Figure 2, the body of evidence and technical penetration by the LSP's multi decade risk assessments after years of cooperative efforts between NASA and ULA is substantial. Beyond that, the additional documentation and technical assessments required for Nuclear Certification form a solid basis for HSF certification and allows NASA to provide a requirements and processes gap assessment for HSF. This is a significant advantage of using flight proven vs. "fresh off the paper" rocket, and can alleviate much of the burden on the NASA Commercial Crew Program Office (see figure 4).

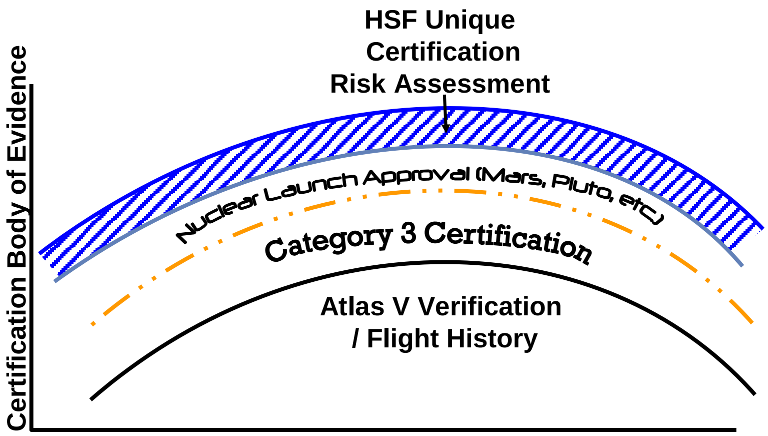

Figure 4: The Existing Body of Evidence from Previous NASA Category 3 and Nuclear launch approval efforts provides a significant dataset for Human Spaceflight Certification of Atlas V

C. Safety vs. Reliability

ULA has also initiated a subcontract to provide a probabilistic risk assessment (PRA) for the launch vehicle portion of the CTS. The requirements for nuclear missions necessitate a PRA against launch vehicle hazards for personnel and public safety. For crewed missions this PRA will be updated with hazards to crew as the accident outcome condition and will be integrated with various spacecraft PRA's for a total Loss of Crew (LOC) risk assessment. The significant understanding that the NASA community has gained in flying Atlas for previous science missions once again provides a springboard for human space flight. It should be understood that there is a significant difference in safety vs. reliability. While reliability provides for mission success, crew safety is dependent upon reliability of the system and a thorough hazard analysis including systems interactions within the LV system, and between the spacecraft and the launch vehicle system as well. The hazard analysis baseline established previously is being updated to provide a basis for the total CTS stack analysis.

D. Requirements Assessment

The NASA Human Spaceflight CTS-1100 series requirements provide a basis for evaluation against the existing launch vehicle design. Each requirement is being taken at face value, with assessments being performed at every level of the system. Where a "meets intent" clause is specified, the risk that the requirements is intended to mitigate is evaluated against the controls and design criteria used on the as built and flown launch vehicle. Having a significant amount of flight data provides a basis for evaluation of environments and margins is extremely valuable in predicting whether sufficient margin exists to guard against unknown unknowns.

E. Summary

Over the decades of the continuous product evolution and upgrades, the Atlas system has undergone a series of Design Equivalency Reviews (DER) against an evolving set of requirements from the various customer communities. Our current assessment of the Commercial Crew requirements to date has found no significant shortfall of the existing rocket to meet the requirements outlined in CTS 1100 series of documents. Our certification baseline package and forward plan will be presented at our tailored System Requirements Review (SRR) in December 2011 for our NASA and customer community.

IV. EDS Overview and Forward Progress

A. Emergency Detections System Overview

The Emergency Detection Systems (EDS) job is purposely straightforward; monitor the LV, detect anomalous conditions that will result in a crew safety critical situation, and send a signal to the crewed spacecraft in sufficient time for the spacecraft to abort and get safely away. The system also allows the crew to initiate an abort on the spacecraft side of the interface. In each case the EDS will also shut down the RL-10 or RD-180 engines on the LV to provide a safe abort environment. In addition, the crew can inhibit an abort if the ground and flight crew identify a situation warrants it. EDS monitors only those potential LV events that are Criticality 1 crew safety hazards based on a predetermined set of thoroughly investigated failure modes and assessment of the criticality of the event. Because the LV is expendable, complex engine monitoring algorithms and maintenance-related LV prognostication or redundancy management in the form of LV reconfiguration are not a required function of EDS. Because the existing LV design is single fault tolerant, redundancy management and reconfiguration functions are already designed into the current system and subsystem architecture. As such EDS is not required to manage those interactions, keeping the system simpler and more reliable. EDS takes advantage of the fault tolerant technology that exists within the current LV. EDS will take the following actions upon detection of a critical anomaly:

1) Notify the crew of an impending or occurring degrading condition as soon as detected
2) Issue an abort signal to the spacecraft
3) Initiate LV engine shutdown prior to spacecraft separation.

EDS must be able to distinguish a false abort condition and/or determine false indications of a degrading system (such as sensor failure). The EDS philosophy is to always have fault tolerance in the form of a corroborating set of measurements to validate failures or degradations. If you have to abort due to a system failure, isn't a great day, but an abort off a perfectly good rocket is worse, a redundant systems architecture is critical to providing protection against both situations. The Abort Sensing and Implementation System (ASIS) for Mercury primarily used high-level sensors as high level indicators (i.e., attitude, rates, acceleration, etc.) as they offer broad fault coverage and address numerous failure modes. Sensors closer to the component may be required to provide earlier awareness and timing margin. Existing sensors were preferred wherever possible as their data are based on previous flights and they have known performance. Anomalous trends are easier to detect with known sensor performance. As the EDS is critical for human safety, it must be a minimum of single fault tolerant (including transducers/sensors, transmission paths, processing, etc.). This level of fault tolerance matches the existing Atlas V architecture. This includes single fault tolerance for issuing a false abort signal as well as single fault tolerance against preventing initiation of a valid abort signal. Thus, failure detection by sensors is expected to be corroborated via separate, independent measurements as much as possible. Existing design standards, practice, and experience are being used to development the EDS, which leverages proven design-to-production engineering and manufacturing processes.

Using a well understood Atlas V to determine the fault set critical to be monitored and associated timing and failure characteristics minimizes the risk of missing an important parameter or systems interaction. The EDS is designed to be integrated into the Atlas (and potentially Delta) system architectures to maintain the integrity of our flight-demonstrated reliability. A key attribute of using the flying EELV system is that the operation of EDS can be validated over many flights if it is flown in passive mode, piggybacking on non-crewed EELV flights. The risk to existing missions flying this in piggyback mode is made inconsequential by integrating the EDS into the existing architecture with minimal intrusions, not disturbing the guidance and control system of the nominal flight operations of the launch vehicle.

Figure 5: EDS Prototype Avionics and High Fidelity Systems Integration Lab Test Bed

B. CCDev1 Emergency Detections System Prototyping

During CCDev1 the ULA team developed a prototype EDS avionics box, loaded it with a set of algorithms developed to detect a defined of failure modes, integrated it into our Systems Integration Laboratory which provides a flight like avionics suite, and demonstrated the ability of the system to detect these failures and send the abort signal in a timely manner (Figure 5).

C. Summary

Over the next few months, the EDS team will focus their efforts on continuing to develop the design of the EDS avionics box and integrated system, including further refinement of the fault data set. This fault data set includes consequences of the failure, critical timing analysis, and sensor suite recommendations. NASA and Spacecraft community participation in the effort will provide the set of requirements that will define the overall architecture and capabilities of the system. Experience evolving multiple generations of Atlas and Delta LV and associated flight experience, combined with upgraded sensors and technology (as appropriate) provides a robust and minimal risk approach to providing a crew transportation system focused on crew safety.

V. Improved Atlas V Performance

A. Background

The commercial crew program places primary emphasis on crew safety. The Dual Engine Centaur (DEC) effort proposed for the commercial crew development program improves performance and provides additional margin for black zone mitigation. The DEC configuration has flown over 160 times starting with AC-1 in 1962 and has a long and very successful flight history and has been a staple in the ULA family of vehicles for decades (See figure 6). The detailed DEC implementation roadmap is planned so that DEC can be implemented to support a 2015 ILC.

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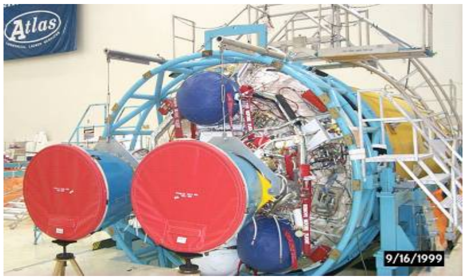

Figure 6: DEC in the factory

B. Dual Engine Centaur Heritage

Because of the significant flight heritage, DEC is largely an implementation effort rather than a development effort. One of the key upgrades the DEC implementation will benefit from is the incorporation of the latest Centaur system upgrades into this configuration. The development risk is considered low based on very successful flight heritage with DEC on Atlas II and III vehicles and the use of the same Centaur tank for DEC on Atlas V. Atlas V currently flies the Centaur III in the single engine configuration (SEC). The Centaur III dual engine configuration (DEC) successfully flew on the Atlas IIIB vehicle (AC-204) in Feb, 2002. Atlas IIIB and V configurations use the "stretched" Centaur (Centaur III), which has increased propellant tank storage capability to support longer burn duration Atlas V missions. Atlas IIIB successfully flew both the single & dual engine Centaur III configurations. Both the SEC & DEC configurations were in production simultaneously until the decision to use only SEC configurations was made due to the fact that the performance increase for Atlas V did not require the additional thrust of a DEC. Variations in hardware between the two engine configurations were kitted for both engine configurations which easily allowed Centaur's to be reconfigured between SEC and DEC. In fact, AC203 reconfigured between a DEC and SEC demonstrating the compatibility and flexibility in assembling and testing various vehicle configurations.

C. Black Zone Mitigations

NASA classifies black zones as a condition that occurs when a spacecraft reentry produces accelerations on the crew greater than allowed in NASA HSF requirements specifications. While black zones can be satisfied with the SEC configuration, DEC provides additional margin against those acceleration limits. With the increased thrust of the DEC upper stage phase, the trajectory is flattened minimizing the "lofting" required to establish the energy required to achieve orbit. In the unlikely event of a crew abort situation, this minimizes the angle and speed of re-entry for crew spacecraft resulting in a safety benefit.

D. Low Risk Approach

The existing Centaur III DEC (CIIID) was a design requirement for implementation on the Atlas V vehicle, so the incremental effort to complete addition of the DEC to the Atlas V fleet has been assessed several times over the last decade by a technical and operational teams across the Atlas program. The CIII DEC was designed and qualified with Atlas V in mind already, so the primary implementation tasks for DEC are as a result of Atlas V unique configuration differences and vehicle upgrades which have occurred since the last CIII DEC flight in 2004 on the AC-204 vehicle.

DEC effort has been ongoing since 2008 consisting of trade studies, system level requirements definition and preliminary design and analyses. Preliminary system level requirements and preliminary design concepts and feasibility analysis results for DEC designs were held at ULA engineering review boards with NASA attendance.

Production fabrication techniques for the Atlas IIIB and V Centaur tanks are all the same and are independent of vehicle configuration. Launch site facility modifications were also considered during the original Atlas V development. The vertical integration facility (VIF), mobile launch platform (MLP) and mechanical GSE were designed to support DEC during Atlas V development. Some modifications will be required to the integrated fluids software that is used during pre-launch operations (ex. engine chill down system and engine purge flow pressure set points). However, these changes are considered to be a minimal implementation effort. Test procedures were also largely implemented for both configurations with some updates required. First Flight test pathfinder combined with other the launch site accommodations upgrades will provide an opportunity for process proofing. Ground software changes will also need to be implemented for DEC mainly for Electro-Mechanical Actuator (EMA) functional tests and launch limit monitoring. Vehicle processing and test procedures are largely in place for DEC as factory and launch site test requirements were implemented for both configurations during Atlas V development with "use/void" statements for engine #2.

D. Conclusion

Dual engine Centaur provides a robust solution for commercial crew. The previous heritage upgraded to the newer Atlas V technology can provide additional safety margin against black zones. The significant heritage for DEC and database from previous flights provides a low risk development effort for reinstitution of this configuration.

VI. Launch Site Accommodations

A. Background

Crew Ingress and Emergency Egress are key requirements for launch site accommodations for human spaceflight. The Atlas V launch vehicle family uses Space Launch Complex 41 (SLC-41), and it has served Atlas V program customers at Cape Canaveral since the launch site's re-commissioning in 2001. The "Clean Pad" concept employed at SLC-41 starts with processing the launch vehicle horizontally then transporting it to the dedicated Vertical Integration Facility (VIF), integrating the spacecraft onto the vehicle at the VIF, and then using a Mobile Launch Platform (MLP), to move the fully integrated launch vehicle from the VIF to the launch pad immediately before launch. This concept is similar to the Shuttle Transportation System at KSC, but the timeline from move to launch is within a day as the operations at the pad consist of only loading of cryogenic propellants and final checkout,

The "Clean Pad" concept has been a key program advantage as launch complex equipment and facilities are relatively simple yet robust. The incorporation of crew ingress /egress was first studied with NASA during the Orbital Space Plane (OSP) effort in 2004. Since then ULA has continued studying additional concepts from simple to extensive. As a result of these efforts ULA has developed viable concepts for crew access via modification of the existing MLP or a dedicated Crew Access Tower (CAT) and emergency egress using various approaches under consideration as shown in figure 7.

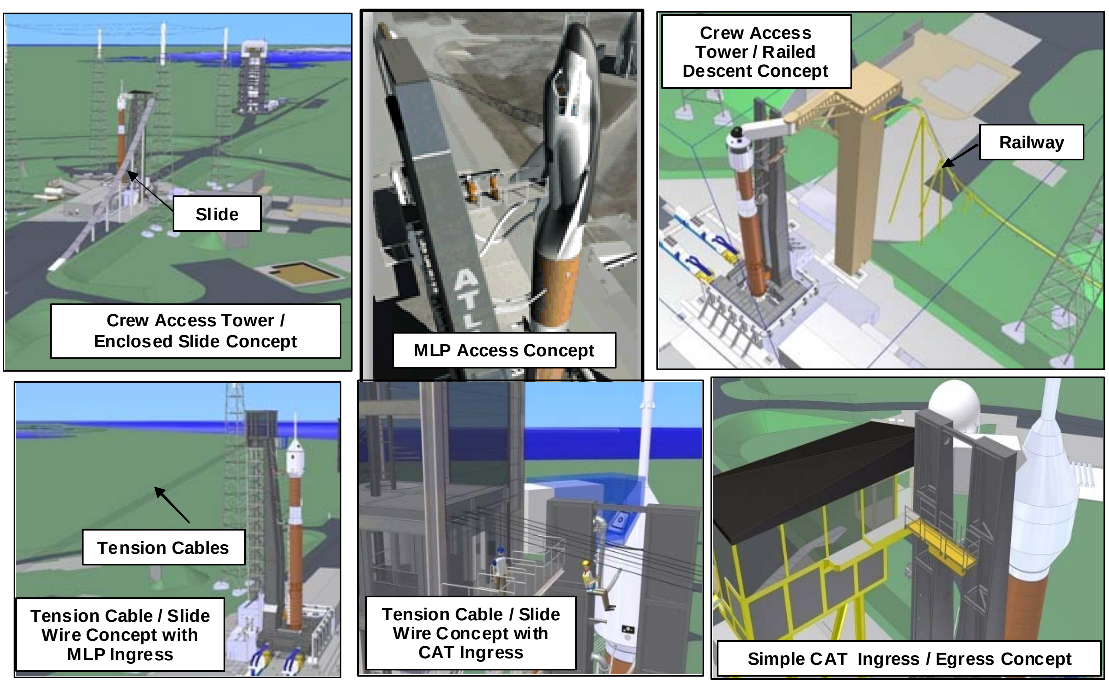

Figure 7 Crew Access & Emergency Egress Concepts
(Dreamchaser image courtesy Sierra Nevada Corp.)

ULA is performing a final trade study with NASA and selected spacecraft providers to determine requirements for access and emergency egress and downselect between the options shown in Figure 2-6, select a baseline from final requirements for Ingress and Emergency Egress at SLC-41. The down-selected crew Ingress concept will also be developed to a tailored SRR in December 2011. The final concept will incorporate key human factors advantages including direct access from grade to the Crew Access Arm and construction advantages that greatly minimize the impact to critical path launch operations.

B. Launch Site Concept of Operations

The Commercial Crew Concept of Operations (CONOPS) plan, processes and procedures are important to the safe and successful integration of crew and spacecraft onto the launch vehicle. ULA is working with the individual spacecraft providers to develop a preliminary launch site CONOPS associated with LV launch processing operations, crew operations and launch operations in partnership with NASA and the Eastern Range. Protocols and procedural steps that facilitate spacecraft integration, day-of-launch crew ingress, and ultimately the successful launch of crew spacecraft commercial missions are being developed in order to facilitate commercial crew spaceflight on Atlas V. A key element of this is crew loading during the stable replenish mode of cryo loading. Hazard analyses are being developed to identify the safety protocols and controls required to ensure that the crew and ops personnel can safely load and close out the crew compartment. Previous hazard analyses have allowed entry to the pad while the vehicle is in a tanked condition.

C. Conclusion

Launch site accommodations need to consider both the spacecraft unique requirements in addition to the NASA overarching requirements set. Beyond that, adapting time critical processes during the final countdown to accommodate loading of crew is of critical importance and being considered in the development of safety protocols and launch site features.

VI. Summary

The Atlas V with the minimal set of additional accommodations identified above provides a system that benefits from an existing infrastructure with significant flight heritage. Human Space Flight Certification benefits from a mountain of evidence already provided to NASA for category 3 certification. Today, with Atlas V’s substantial flight history of 27 successful flights, it would be possible to attain category 3 certification with significantly less NASA technical penetration, but in partnership with our NASA customer, ULA continues to provide access to our technical database and a successful flight program, providing both to substantially reduce NASA uncertainty with respect to flight risk. ULA and NASA maintain a healthy partnership to provide continuous and ongoing detailed penetration and access to design, analysis, test, qualification and flight data for verification purposes, While NASA category 3 certification alternatives provide a path for entrants to achieve Atlas V’s current level of certification with substantially fewer flights, the bar is much higher for technical penetration without a long and successful flight history. NASA has placed a huge trust in ULA to fly its critical science missions on Atlas V and we look forward to the opportunity to fly NASA critical human missions safely and successfully.

EDS is a key component of that safety equation, and is an evolved technology demonstrated on previous Atlas Mercury, Titan Gemini, and Apollo systems. EDS is the key technology to enable a flight-proven, demonstrated, and reliable EELV to provide safe crew transportation to LEO destinations. ULA works in conjunction with NASA and other potential spacecraft providers to demonstrate the ability to detect anomalous conditions on the LV and provide a timely abort signal to the crew. The EDS takes advantage of an existing highly reliable avionics architecture and suite of sensors, with flight proven computing power to provide the most reliable system overall.

The performance improvements achieved with DEC and the accommodations for crewed spacecraft at the launch site are the final puzzle pieces providing our spacecraft customers and NASA with the safest possible ride to orbit for our future commercial crew astronauts.