

# Commercial Crew Development Environmental Control and Life Support System Status

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**The National Aeronautics and Space Administration (NASA) Commercial Crew Development (CCDev) Project was a short term Project that was managed within the Commercial Crew and Cargo Program Office (C3PO) to help develop and demonstrate a small number of key human spaceflight capabilities in support of moving towards a possible commercial crew transportation system to low earth orbit (LEO). It was intended to foster entrepreneurial activities with a few selected companies. The other purpose of the Project was to try to reduce some of the possible risk with a commercial crew transportation system to LEO. The entrepreneurial activities were encouraged with these few selected companies by NASA providing only part of the total funding to complete specific tasks that were jointly agreed to by NASA and the company. These joint agreements were documented in a Space Act Agreement (SAA) that was signed by NASA and the company. This paper will provide an overview of the CCDev Project and it will also discuss in detail the Environmental Control and Life Support (ECLS) tasks that were performed under CCDev.**

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## I. Introduction

THE Commercial Crew Development - 1 (CCDev - 1) effort was a National Aeronautics and Space Administration (NASA) Project conceived to try and stimulate the United States (U.S.) private sector in developing and demonstrating safe, reliable, and cost-effective commercial human spaceflight capability to low-Earth orbit (LEO). To accomplish this goal NASA decided to use \$50 million dollars of its American Recovery and Reinvestment Act (ARRA) funds to award multiple competitive Space Act Agreements (SAAs) to try and stimulate this new capability. To select the companies that NASA would award the SAAs to, they solicited ideas from U.S. private industry with a request for proposal (RFP) in August 2009 with the proposed awards originally being planned to be announced in November 2009. The RFP requested proposals to mature the design and development of the U.S. commercial crew spaceflight concepts and associated technologies and capabilities. With this new Project NASA hoped to try and reduce the gap in U.S. human spaceflight capability to LEO with the coming retirement of the Space Shuttle.

Out of all of the proposals that NASA received from their RFP, NASA selected five companies. These five companies that were officially announced in February 2010 instead of the planned date of November 2009 were Blue Origin, Paragon Space Development Corporation, Sierra Nevada Corporation, The Boeing Company, and United Launch Alliance.

Blue Origin was awarded \$3.7 million to develop their pusher launch escape system and a composite crew module pressure vessel for structural testing. These tasks were to further their launch vehicle concept called the New Shepard, which is a vertical take-off and landing vehicle that is similar to the old NASA DC-X concept.

Paragon Space Development Corporation was awarded \$1.4 million to develop an Environmental Control and Life Support (ECLS) Air Revitalization Subsystem (ARS) Engineering Development Unit (EDU) and to further their design concept to a Preliminary Design Review (PDR) level.

Sierra Nevada Corporation was awarded \$20 million to further their vehicle concept, called Dream Chaser (DC). Their vehicle is proposed to launch seven crew members on top of an Atlas V 402 launch vehicle to LEO. It is based on NASA's HL-20 lifting body concept. The agreed to tasks for Sierra Nevada were to build an "Engineering Test Article (ETA), define integrated structural loads, develop software algorithms, develop their Software Assurance Plan, design their Guidance, Navigation, & Control system, build & fly a Dream Chaser scale model for

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approach & landing tests, build & test their Orbital Maneuvering System (OMS) motor, build & test their Reaction Control System (RCS) thruster prototype that uses non-toxic propellant, conduct Thermal Protection System (TPS) trades, mature integration of their vehicle to the Atlas V launch vehicle, and build a DC/Atlas V 402 wind tunnel model for testing.” (2)

The Boeing Company was awarded \$18 million to develop their commercial crew space transportation vehicle through System Design Review (SDR). The Boeing Company’s vehicle is a seven crew member sized vehicle that is similar in shape to the Apollo vehicle. In addition they agreed to perform an Abort System hardware demonstration, base heat shield fabrication demonstration, Avionics Systems Integration Facility demonstration, Crew Module (CM) Pressure Shell fabrication demonstration, Landing System demonstration, Life Support demonstration, Autonomous Rendezvous and Docking (AR&D) Integrated Guidance, Navigation, and Control (GNC) demonstration, and a CM Mockup demonstration.

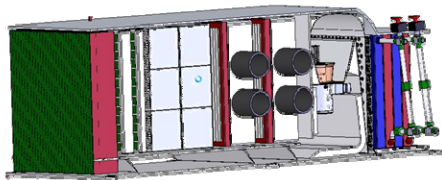
The final award was to United Launch Alliance. They were awarded “\$6.7 million to mature a modular Emergency Detection System (EDS) for their Atlas V and Delta IV launch vehicles.” (2) This System will provide real time health monitoring of the booster to provide the earliest time notification of a possible catastrophic booster failure to allow for commanding of the crew launch escape system to be initiated. This is similar in concept to what was done for the Titan launch vehicle for the Gemini Program.

These five SAAs that were awarded by NASA for CCDev – 1 were set up so that NASA only partially funded the development of their jointly agreed to tasks. It was the responsibility of each of these companies to provide the balance of funding to help leverage the taxpayer investments. Since, NASA did not provide all of the funding for the project one of the agreements that was made with the companies was that the engineering data rights would belong to them and not NASA. Due to this agreement this paper will only talk about these projects from a qualitative point of view instead of a quantitative point of view.

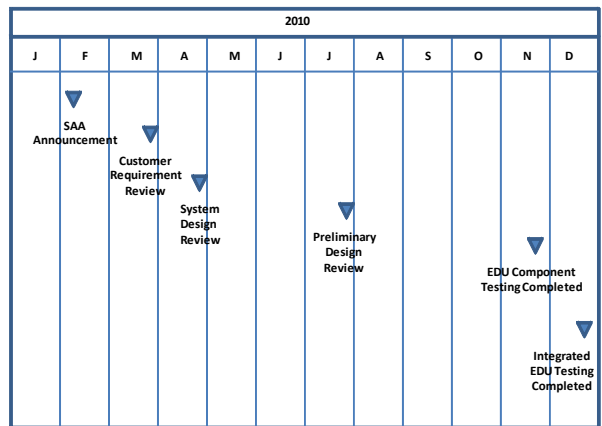
Out of these five SAAs only two of the SAAs involved active thermal and life support hardware. These two were the Paragon Space Development Corporation and the other was the Boeing Company. The Paragon Space Development proposed a novel air revitalization system up to the PDR level and the Boeing Company proposed a complete capsule design, including a proposed concept for an active thermal and life support system, up to the SDR level.

## II. Paragon Space Development Corporation CCDev Overview

The Paragon Space Development Corporation was responsible during CCDev -1 to develop a commercial crew transportation ARS EDU that included the following capabilities - cabin level air filtration, trace contaminant control hardware, post fire recovery hardware, carbon dioxide removal hardware, humidity control hardware, cabin air circulation hardware, and a sensible heat exchanger to remove cabin air heat loads. All of this hardware also needs to fit in a modular reconfigurable package, as shown in Figure 1. The schedule for this hardware was very



**Figure 1. – ARS EDU Hardware Layout**  
(picture credit: Paragon Space Development Corporation)



**Figure 2. – Paragon Space Development Corporation High Level CCDev -1 Schedule**

aggressive, since the SAA announcement was made in early February 2010 and Paragon Space Development Corporation had agreed in their SAA with NASA to have a Customer Requirements Review (CRR), a SDR, a PDR, perform EDU Component Testing, and perform an Integrated EDU Subsystem Test all before the end of the year, as shown in Figure 2.

At the start of the project NASA quickly recognized that the most challenging part of Paragon’s design was with their humidity control hardware. It was also recognized that Paragon would also have a few smaller challenges with their carbon dioxide removal hardware design and their hardware performance due to their limited packaging volume. After the initial kickoff meeting, Paragon was able to move their design from a design concept up to a PDR level with limited input and comments from NASA experts in the field of Air Revitalization and ECLS System Architecture. To collect some performance data to show that their concept was viable, Paragon tested their hardware in two different stages. In the first stage, they tested the components in a standalone configuration. After successfully passing the component testing they then moved on to the second stage. The second stage was an integrated test where they inputted heat, water vapor, and carbon dioxide into the test chamber that contained their development unit to see how well the design would perform. Based on the results of their component and integrated testing it showed that their design is potentially a viable design solution to provide air revitalization in a small spacecraft. Since this design only went to a PDR level, additional work would be required by Paragon to get it flight certified. Also, some changes to their design may have to be made to accommodate each unique vehicle interface and packaging constraints. Overall this design was interesting and good for NASA, since it helped to push a novel way to solve the Air Revitalization function for a small spacecraft.

### III. The Boeing Company CCDev Overview

The Boeing approach to CCDev – 1 was different than the Paragon approach. Their approach was to move forward with a broad multi-system refinement of their old Constellation proposed Crew Space Transportation (CST) – 100 capsule. An external view of their capsule can be seen in Figure 3. Boeing’s schedule was a very methodical list of tasks to move their design to an SDR level so that Boeing could potentially build and fly it as a flight vehicle if they received future CCDev awards. To understand what was done to advance their active thermal and life support design the tasks, only tasks that affected their active thermal and life support design are shown below in Figure 4. To kick off the project, Boeing had an SRR to get joint agreement between Boeing and NASA on the requirements for the proposed CST – 100 capsule. From NASA’s perspective the requirement generation was the best possible requirements to support the CCDev – 1 award but they were way ahead of the NASA requirements generation in support of the starting a new commercial crew transportation contract to LEO and ISS and back to earth. After Boeing completed SRR, they held a couple of Interim Design Reviews (IDRs) to close action items from the SRR and the previous IDRs. During the time covered by this SAA the only ECLS specific task was a development test of their proposed ARS design for removing carbon dioxide, humidity, and heat load by one of their partners. This data was then used to help Boeing refine their proposed ARS design for their capsule for CCDev -1.

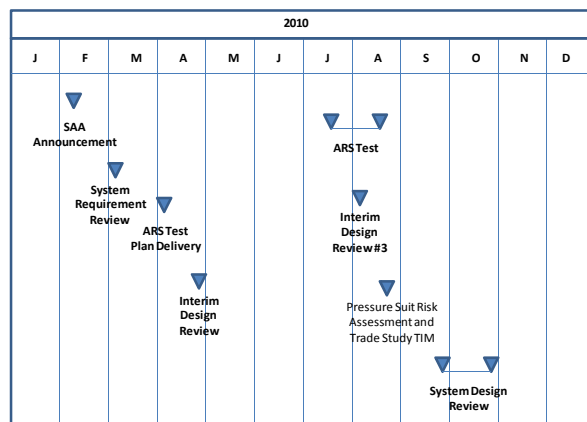


Figure 3. – CST – 100 Vehicle  
(picture credit: The Boeing Company)

Figure 4. – The Boeing Company  
High Level CCDev -1 Schedule

One question that Boeing brought up during this SAA award was NASA's desire for pressure suits for transportation to and from LEO. In support of this question, Boeing held a technical interchange meeting (TIM) with NASA on this subject. At the TIM NASA was not ready to make a decision on the need for a pressure suit to and from LEO so the meeting was held to provide an open discussion on the topic. Since no decision was made this issue that will probably be discussed again sometime in the future.

To close out the Boeing active thermal and life support tasks for CCDev – 1, Boeing held an SDR that documented and summarized their decisions for their CCDev – 1 capsule design based on all of their design and technical interchange meetings and development test during the CCDev – 1 time period.

#### **IV. The Next Step for CCDev**

Near the end of CCDev – 1 NASA decided to kick off the next set of awards under CCDev -2. For CCDev – 2 it was decided to open up the competition to everybody. The tasks from CCDev – 1 had no bearing on what will occur during CCDev – 2.

NASA's first major step for kicking off the start of the CCDev - 2 Program occurred in May 2010 when NASA released a Request for Information (RFI) to industry. The RFI included an initial version of the Commercial Human Rating Plan (CHRP) and it also referenced, but it did not provide a copy of the International Space Station (ISS) crew transportation specification and interface requirement documents.

In August, NASA's Headquarter Exploration Systems Mission Directorate decided to have a meeting to discuss the RFI. This meeting was called the Commercial Crew Planning Status Forum. The objective of this meeting was to discuss NASA's future direction for commercial crew transportation, answer questions arising from the RFI, and to address any additional questions that the commercial companies may have for the next phase of the Program. Another reason for this meeting was that NASA wanted to collect comments from the potential commercial companies to incorporate some of their comments into the next revision of the draft commercial crew transportation requirement documents. During the meeting NASA also stated that the objective for this meeting was to start the follow on work needed to facilitate the develop of a U.S. commercial crew space transportation capability that would provide safe, reliable, and cost effective transportation to and from LEO and the ISS. Once this capability is matured it is expected that NASA could then purchase the commercial services to meet their ISS crew transportation needs from one or more of these commercial service providers. To accomplish this goal, NASA is planning to partially fund the CCDev – 2 companies as they move forward to meet their jointly agreed to milestones. This approach is similar to the process used in CCDev – 1. One of the features of this approach is that it will encourage competition between multiple companies and at the same time it will stimulate non-NASA markets for commercial human transportation services to and from LEO. It will also incentivize performance, supports cost-effectiveness, and eliminates NASA dependence on a single provider in the event of nonperformance.

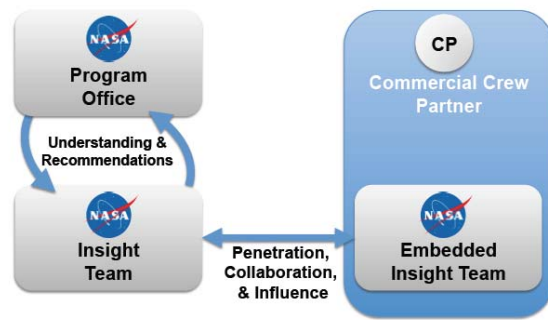
The forum also discussed at a high level a proposed programmatic approach, insight/oversight methodology for this Program, certification and mission certification of flight readiness (CoFR) processes for only the NASA commercial crew transportation missions, liability/indemnification, and usage of NASA facility philosophy and availability. Out of these topics the most interesting ones from a flight system engineering perspective were the interaction between the programmatic approach and the insight/oversight methodology, as shown in Figure 5 and 6. The programmatic approach that was discussed at the meeting was that only the program office will provide direction to commercial partner, manage the requirements, and minimize the number of sub-boards and panels that are needed for this program. On the other hand, the insight teams will be the eyes and ears of the program office. They will participate in discussions with the commercial partners and support milestone reviews to better develop an understanding of the commercial partner's design and how their design meets the program requirements. They will also collaborate with the commercial partners to help them find the best approach to meet the commercial partner's goal to certify their system to fly NASA astronauts to LEO and back.

The RFP for CCDev – 2 was released at the end of October 2010 with the proposals due back to NASA by mid – December 2010. A few days after the RFP was released NASA had a Commercial Crew Development Round 2 Pre-Proposal Conference at Kennedy Space Center (KSC) to review the RFP and to allow the companies to ask questions about the RFP. With the CCDev – 2 RFP NASA also released draft versions of some of the new requirement documents. The goal of these draft requirements documents was “to ensure that the requirements are not overly burdensome and allow our Commercial Partners the maximum flexibility to develop safe and cost effective human space transportation systems.” (8)

Even though the awards were planned to be made in March 2011, the announcements ended up being delayed until the middle of April. In April NASA announced that the companies selected for CCDev-2 were Blue Origin, the Boeing Company, Space Exploration Technologies (SpaceX), and Sierra Nevada.



**Figure 5. – Program Interaction with the Commercial Partner**



**Figure 6. – Insight Team Interaction with the Commercial Partner and the Program Office**

## V. Conclusion

This paper has outlined the CCDev ECLS activities from the start of February 2010 through the start of April 2011. The CCDev – 1 approach allowed for some progress on moving the concept of having commercial companies provide transportation of NASA’s crew to and from LEO and the ISS. CCDev – 2 has been initiated with high hopes for trying to mature this concept even further.

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