

Dual Spacecraft System

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At the AIAA Space 2008 Conference & Exposition, we presented a paper on the development of the Dual Spacecraft System (DSS)⁴. The DSS structure enables the launch of two independent payloads on a single United Launch Alliance (ULA) Atlas V launch vehicle. A dual mission increases manifest flexibility and allows for additional spacecraft deployments given the same number of actual launches. The DSS makes extensive use of existing components with well understood capabilities, and it is poised to take advantage of the need to launch a smaller class of payloads. These are small-to-medium class payloads—too big to be considered secondaries, but smaller than the typical Atlas 400-class spacecraft. The DSS offers significant cost savings to this class of payloads.

In this paper, we discuss our group's progress on the DSS design and development over the past year. We took the DSS through a System Requirements Review in June 2008 and a Preliminary Design Review in September 2008. Both of these reviews were very well received with strong design concepts presented and wide customer participation. Currently we have scheduled a Critical Design Review for November 2009. A significant portion of the design already exists, since the DSS is based on existing hardware, but there are several new, important systems that will require additional design effort. The team is currently working the detailed designs and analysis of these systems in support of the Critical Design Review. We discuss details of these designs and analyses here.

Another focus of our design group has been on producibility. In keeping with our philosophy to coordinate with manufacturing early in the design process, we held a very successful Kaizen event at the ULA production facility in Harlingen, TX. This site builds the Centaur Forward Adapter (CFA), the underlying structural component of the DSS. The event identified many potential improvements to the design, tooling, and manufacturing processes which will increase producibility and decrease nonrecurring tooling costs associated with the DSS. We held a second successful Kaizen event at the Cape Canaveral Launch Site, focusing on Ground Support Equipment and Launch Operations. We present descriptions and results from both of these events. The paper concludes with a discussion of our planned future work and schedule.

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⁴ Andrulis, C. and Colvin, B., "Dual Spacecraft System (DSS)," AIAA 2008-7658, *AIAA Space 2008 Conference & Exposition*, San Diego, CA, 2008.

I. Description

The Dual Spacecraft System (DSS) is based on our existing Centaur Forward Adapter (CFA). See Fig. I-1. The cylindrical and conical sections of the CFA are skin and stringer assemblies, joined together with a shared ring. The CFA is a structurally tested and flight-proven component. In order to create a DSS, two CFAs are taken and all non-essential and non-structural components are removed creating what are called canisters. These two canisters are then joined together to form a clamshell. See Fig. I-2. If more volume is required by the lower spacecraft, it is possible to insert up to four stub adapter plugs between the two canisters. The stub adapter is the two-foot cylindrical portion of the CFA and can be seen in Fig. I-1. More details pertaining to the payload envelopes available can be found in the “Dual Spacecraft System (DSS)” paper presented at the AIAA Space 2008 Conference & Exposition⁵.



Figure I-1: The Centaur Forward Adapter (CFA) is the structural basis for the DSS

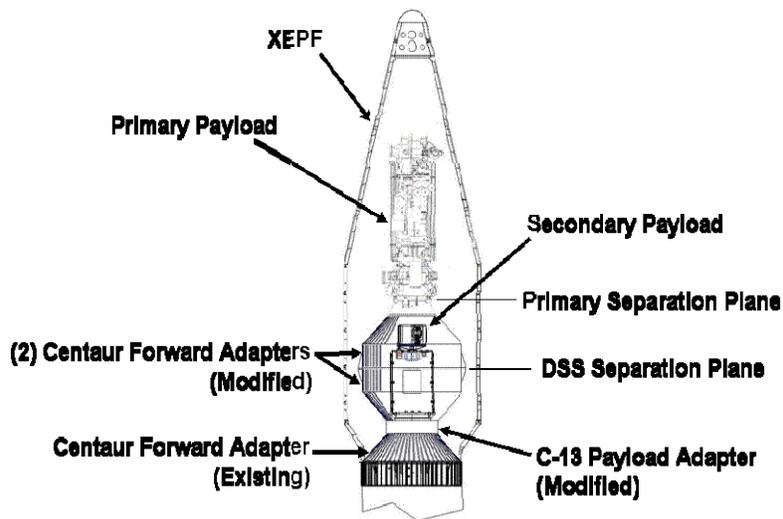


Figure I-2: The DSS with two payloads inside the Atlas 4m fairing

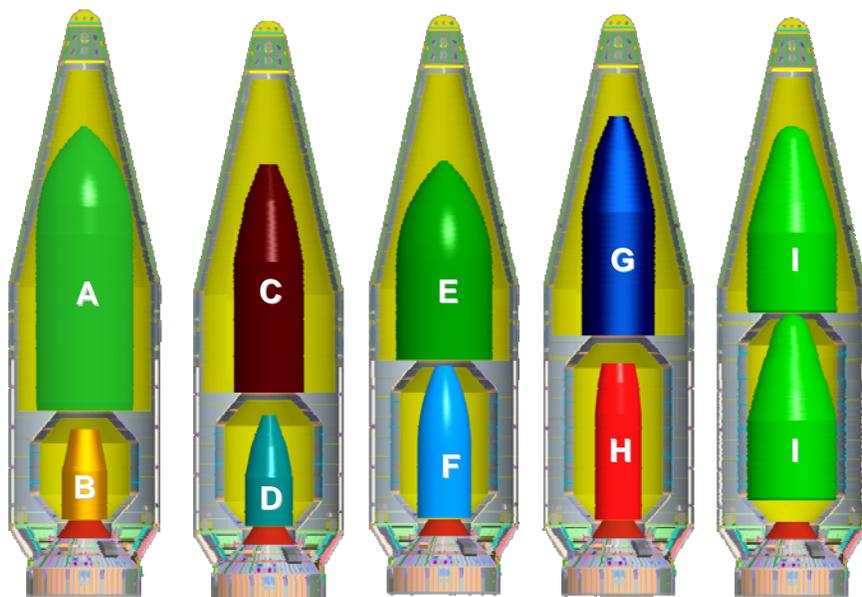
The DSS concept successfully went through a Preliminary Design Review (PDR) in September 2008. The preliminary design of the DSS was presented before ULA management and potential DSS customers and was approved to proceed to a Critical Design Review which is planned for November 2009. Additionally, two separate Kaizen events were held. In October of 2008, the team went to Harlingen, TX to coordinate with Manufacturing in

⁵ Andrulis, C. and Colvin, B., “Dual Spacecraft System (DSS),” AIAA 2008-7658, *AIAA Space 2008 Conference & Exposition*, San Diego, CA, 2008.

an effort to increase the producibility of the DSS. In June of 2009, the team went to the Cape Canaveral Launch Site to identify any potential roadblocks that may arise with the processing of two separate payloads. As we are not under contract for any specific missions yet, the review and Kaizen events were performed for generic payloads.

II. Advantages to the DSS

There are numerous advantages to using the DSS. Since the DSS will be using existing, flight proven components, the hardware is well understood, qualified and tested. This simplifies development and reduces nonrecurring costs and risks when compared to a brand new development. The DSS will give Atlas a dual payload capability, thus increasing manifest flexibility and allowing additional spacecraft deployments for the same number of actual launches. The DSS will not only have significant customer cost savings but also will create the potential to combine government and commercial payloads. The DSS can accommodate several other launch vehicle payload envelopes including Delta II 9.5' PLF (I) and 10' PLF (A and E), SpaceX Falcon 1 (D) and 1e (F), Taurus 92 (C) and 63 (H), Minotaur IV 92 (G) and Pegasus 38 (B), as shown in Figure II-1.



**Figure II-1: Various Launch Vehicle Payload Envelopes with 0-4 Plug DSS Configurations
(Atlas 4m XEPF fairing)**

Note: Envelope sizes were taken from various mission planners guides and are subject to change.

III. New and Updated Design Details

Since the PDR in September 2008, the team has made significant progress in the design and analysis of the DSS. Updates to the various analysis groups are discussed below. The groups not specifically discussed below have been steadily progressing their designs and analyses and will provide updates in the CDR in November 2009. These groups include: GSE, Launch Operations, Safety, Systems Engineering, Mass Properties, Production Operations, EMI/EMC/ESD, and Thermal Analysis.

Structures:

Since PDR, the canister and plug designs have been simplified to reduce design and manufacturing costs. The overall structure remains similar to our current Centaur Forward Adapter and Stub Adapters but various modifications including common stringers and removing certain holes and non-structural avionics equipment has been incorporated into the design.

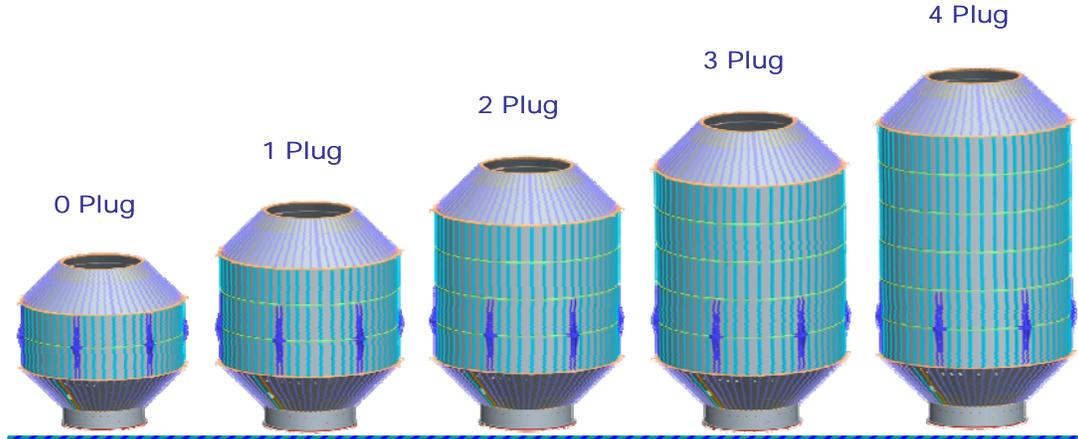


Figure III-1: 0-4 Plug DSS Configurations

The team has developed and incorporated a structural access door into the design of the DSS. The door is 30” x 20” and is located in the aft canister and will provide full body access to the lower spacecraft. This door can also be placed in any of the plugs and located between any of the fittings if necessary. The door is shown in figure III-2.

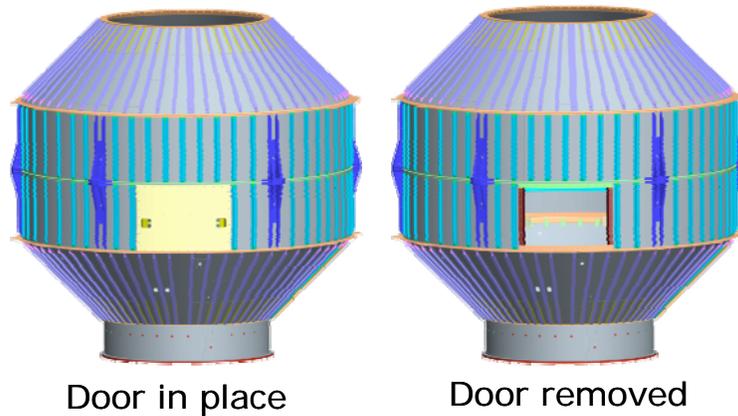


Figure III-2: DSS Access Door Design

The design of the Environmental Control System (ECS) has progressed to the design shown in Figure III-3, including the interfaces to the payload fairing and DSS structure and access doors for disconnect duct installation. Preliminary Aerophysics review and approval has been completed on this design.

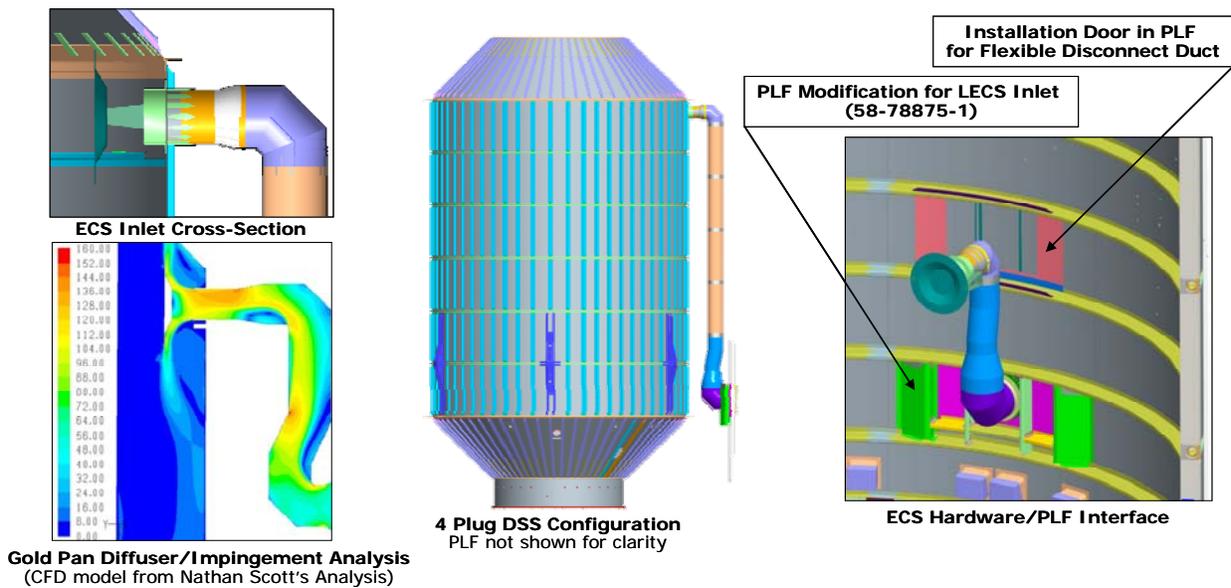


Figure III-3: DSS Environmental Control System

Aerophysics:

A Computational Fluid Dynamic (CFD) model has been developed to characterize the velocities a spacecraft could experience in the DSS with a goldpan diffuser. Flow field simulation was performed for the maximum ECS flow rate of 100 lbm/min with flow velocities being reported from 0-20 ft/s. The CFD analysis indicates adequate flow dispersal and impingement velocities for both the lower and upper spacecraft.

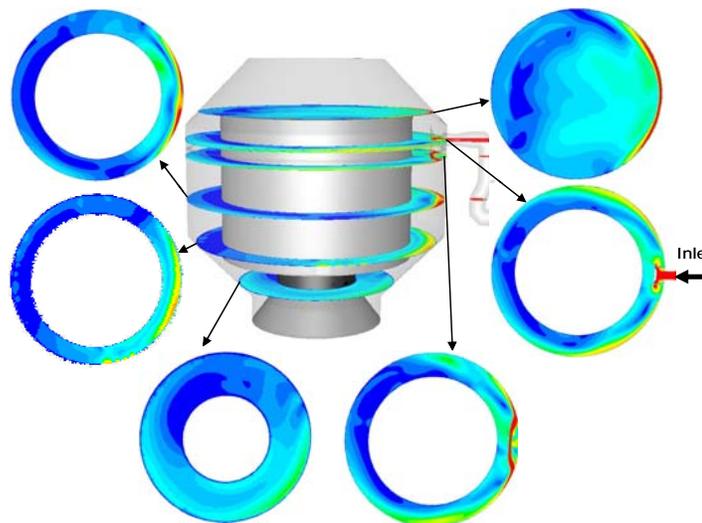


Figure III-6: CFD Model for DSS ECS Flow Analysis

Stress/Strength:

The system finite element models have been completed for all DSS configurations. A 10,000 lb upper payload and a 5,000 lb lower payload in a zero plug configuration as well as a 5,000 lb upper payload and 8,000 lb lower payload in a 4 plug configuration have been reviewed and preliminary analyses show positive margins of safety. These weights should be considered preliminary targets, not necessarily maximums or limits, as the analyses have not been finalized. The exact allowable weights will also depend on the heights of the spacecraft's centers of gravity and may not be limited to the 10,000 lb or 5,000 lb quoted weights. The analysis of the ECS and other secondary hardware is to be completed by CDR in November 2009.

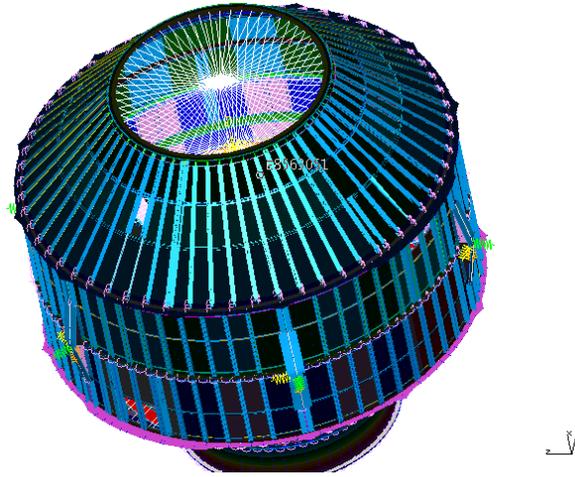


Figure III-4: FEA Model of 0-Plug DSS Configuration

Vibro Acoustics:

Since PDR the team has worked to create more detailed models of rings, stringers, beams and joints. Finite Element Models were generated for low frequency (≤ 140 Hz) analysis and Statistical Energy models were generated for high frequency (≥ 140 Hz) analysis. The preliminary analyses show positive margins.

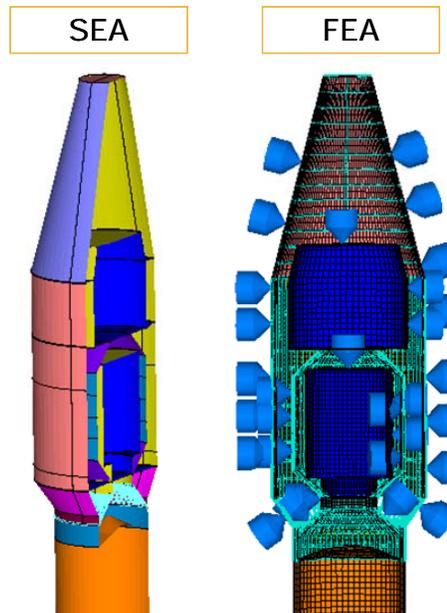


Figure III-5: SEA and FEA Acoustic DSS Models

Loads Dynamics:

The initial design development loads and dynamic clearance loss analyses have been completed. A coupled loads analyses (CLA) of the zero plug configuration was performed with a 10,000 lbm ‘indicator payload’ SV in the upper position and a 5,000 lbm ‘indicator payload’ SV in the lower position. The results show the DSS loads to be within capability and the responses are typical of those seen by Atlas V payloads. A second CLA was performed on the four plug configuration and it used ‘real’ spacecraft in the upper and lower positions for payloads. The results also show that the DSS loads are within capability and the margins are good. A third CLA is in work and is to be completed by CDR in November 2009. This CLA will be performed on a zero and four plug configuration with ‘real’ SVs that have scaled masses and stiffness. It is intended to fully exercise the DSS structures and define critical loads and worst-case clearance losses.

Avionics:

The team has a fairly mature harnessing concept with both upper and lower SV electrical interfaces mapped out and shown in figure III-7.

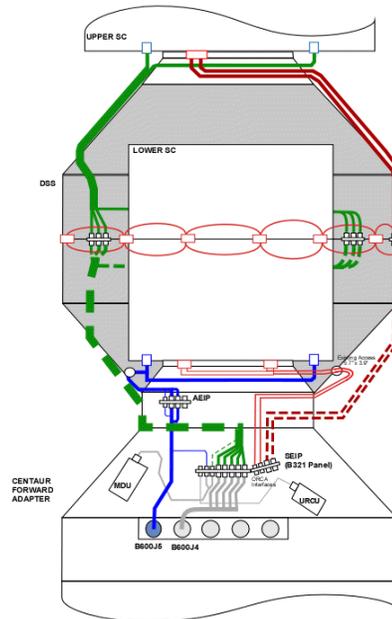


Figure III-7: Avionics Harnessing Overview for 0-Plug DSS Configuration

IV. Kaizen Events

In October of 2008 the team held a successful Kaizen event relating to the manufacturing of the DSS at ULA’s Harlingen facility in Texas. The purpose of this event was to establish a process flow for the build up of the DSS using existing Centaur Forward Adapter (CFA) build processes and DSS stack and assembly build process concepts. Another focus of the event was to cut tooling costs and refine tooling designs wherever possible. The disciplines involved included Structures Design, Business Development and Advanced Programs, the Chief Engineers Office, Production Engineering, Manufacturing Quality and several manufacturing Technicians and Mechanics.

The team identified several improvements to the existing and future state processes while cutting significant costs to the original tooling concept. The team was able to reduce about 260hrs from the build time and about \$400K from the original tooling cost. Throughout this event, the team identified producibility enhancements, standardized tools and parts between the DSS and the CFA that will result in reducing non-recurring and recurring costs to the design, tooling and build processes.

In June of 2009 the team held another successful Kaizen event relating to the Launch Operations at ULA's East Coast Launch Site at Cape Canaveral Air Force Station (CCAFS) in Florida. The purpose of this event was to remove any potential roadblocks from the processing baseline that was presented at the PDR and to streamline DSS processing for the launch site. Many disciplines were represented at this event including Structures Design, Business Development and Advanced Programs, the Chief Engineers Office, Production Engineering, heritage Delta II Launch Operations Engineering and heritage Atlas Launch Operations Engineering and Technicians. Having the many disciplines enabled the team to produce a more detailed launch site flow/timeline for the processing of two separate payloads.

Several improvements to the DSS were identified at the Launch Operations Kaizen. By incorporating lessons learned from dual payload processing with Delta II's Dual Payload Attach Fitting at Vandenberg Air Force Base in California, the team was able to identify the need for new and modified GSE tools and reinforced the need for access to the lower payload through the DSS canister. Minor modifications to the DSS hardware were also identified in an effort to streamline the DSS launch site processing. Through this event, the team was able to provide refined processing requirements and constraints to design groups as well as a preliminary process flow and timeline to take to potential customers.

V. Conclusions and Future Work

With payload envelopes that encompass many different launch vehicle envelopes, the Dual Spacecraft System (DSS) represents a unique opportunity for the small-to-medium class payload market. There are many advantages to using existing, qualified components on a launch vehicle with a proven track record, such as the Atlas. The development of the DSS in late 2008 and thus far in 2009 has proven the DSS concept as a viable and cost effective alternative to launching on a dedicated rocket. ULA is continuing to fund this work internally through a Critical Design Review (CDR), currently scheduled for November of 2009. At that time, we will show the detailed design of the DSS along with the related analyses (coupled loads, separation analysis, venting analysis, etc.) that are unique to the DSS. The DSS is currently slated for an 18 month ILC after a customer contract is awarded.