CATIA V5 Virtual Environment Support for Constellation Ground Operations

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This summer internship primarily involved using CATIA V5 modeling software to design and model parts to support ground operations for the Constellation program. I learned several new CATIA features, including the Imagine and Shape workbench and the Tubing Design workbench, and presented brief workbench lessons to my co-workers. Most modeling tasks involved visualizing design options for Launch Pad 39B operations, including Mobile Launcher Platform (MLP) access and internal access to the Ares I rocket. Other ground support equipment, including a hydrazine servicing cart, a mobile fuel vapor scrubber, a hypergolic propellant tank cart, and a SCAPE (Self Contained Atmospheric Protective Ensemble) suit, was created to aid in the visualization of pad operations.

Nomenclature

CATIA	=	Computer Aided Three-dimensional Interactive Application
DMU	=	Digital Mockup
DVG	=	Design Visualization Group
GN2	=	gaseous nitrogen
GSE	=	ground support equipment
MLP	=	Mobile Launcher Platform
SCAPE	=	Self Contained Atmospheric Protective Ensemble
VAB	=	Vehicle Assembly Building

I. Introduction

THIS summer I worked in the Boeing Design Visualization Group (DVG). The purpose of the DVG is to work with customers and provide them with visualizations of their products and processes. I used CATIA V5, an advanced computer modeling software, and my tasks mainly involved contributing to or creating models for various ground operations for the Constellation program, specifically at launch pad 39B. I made some modifications to existing equipment on the MLP and the launch tower, and I also created new models of various ground support equipment.

II. CATIA Software

I have had previous experience with CATIA, however it had been several months since I last used it, so I began by working through some tutorials. CATIA has a variety of capabilities, and is organized into different design modes, called workbenches. The most commonly used workbenches are Part Design, Assembly Design, Sketcher, and Wireframe and Surface Design. The first tutorial I completed was the Digital Mockup (DMU) Kinematics workbench, which was helpful during later tasks which required animation. I was also introduced to two new workbenches: Tubing Design and Imagine and Shape. My job was to become familiar with the workbenches and present them to my coworkers in the form of a "lunch and learn" session.

A. DMU Kinematics Workbench

The DMU Kinematics workbench allows the user to apply kinematic relationships between the parts in a model. Most of the tutorials involve assembling simple parts using the Assembly Design and Part Design workbenches, and then using the DMU Kinematics workbench to simulate moving parts. The first step in creating an animation from an assembly is to choose which parts will be fixed. All other parts will move relative to the fixed part. In order for two parts to move with respect to each other, there must be a joint linking them. Some commonly used joints are: prismatic, revolute, cylindrical, planar, and rigid. A prismatic joint is shown in Fig. 1, where the small block is

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constrained to move back and forth along the fixed base block. A revolute joint allows a part to rotate about an axis, such as the arm rotating about the cylinder center in Fig. 2. Like the revolute joint, a cylindrical joint allows rotation about an axis, however the rotating part is also free to translate along the axis of rotation. A planar joint restricts an object to motion along a single plane, and a rigid joint fixes two parts in relation to each other.

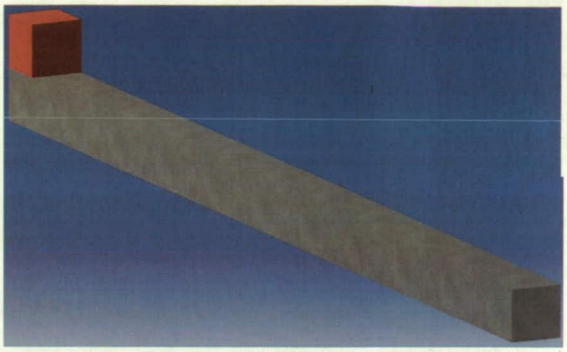

Figure 1. Prismatic joint.

There are two ways to apply joints to an assembly. One way is to create the assembly and apply all necessary constraints in the Assembly Design workbench. DMU Kinematics can then convert those constraints into joint relations using the Assembly Constraints Conversion command. This method was used to create the animation for the slider crank mechanism shown in Fig. 3. The base block is fixed, and there is a cylindrical joint between the base and the crank. A revolute joint is not used in this case because it requires two planar faces to be in contact. Instead, a cylindrical joint is applied, allowing the hole at the end of the crank to rotate about the cylinder on the base block. At this point, the cylindrical joint also allows the crank to translate along the axis of rotation, however this degree of freedom will be eliminated with the addition of subsequent joints.

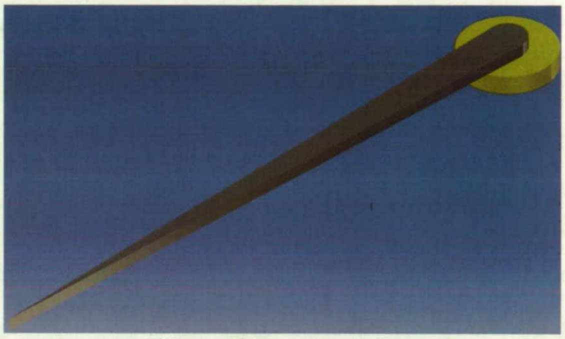

Figure 2. Revolute joint.

A revolute joint exists at each end of the connecting rod to allow it to rotate with respect to both the crank and the sliding block. The sliding block is then constrained by a cylindrical joint to move in one direction along the base. This is not the only joint configuration that allows the assembly to simulate the slider crank motion; for example, another method could involve a prismatic joint between the sliding block and the base, as in Fig. 1. However, these joints were assigned based on the way the assembly was constrained. The second way to apply joints to an assembly is to manually select each joint from the Kinematic Joints toolbar in the DMU Kinematics workbench.

B. Imagine and Shape Workbench

The Imagine and Shape workbench allows the user to create more abstract parts than could be created using Part Design or other workbenches. It has many features and options, but for most of the parts that I designed with it, the basic idea was to start with a simple sphere or circle and then modify it by pulling points around until I ended up with a suitable part. One disadvantage to this workbench is that once a change is made, it is hard to take it back. The "undo" command still works, but if you want to revert to a version of the part that you had before your last save, you cannot simply delete each modification, as you can in Part Design. The DVG will find the Imagine and Shape workbench useful when creating flexible covers for equipment, however the workbench is not suitable for most structure-related work.

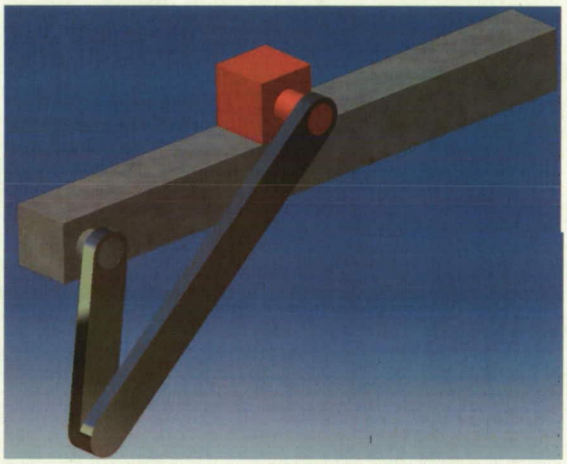

Figure 3. Slider crank mechanism.

C. Tubing Design Workbench

Tubes and pipes can be modeled in the Part Design workbench, however the Tubing Design workbench makes it a much simpler matter to add tubes to an assembly

III. Launch Pad Operations

Launch Complex 39 has been in use since the Apollo program, and will continue to provide access to space in the future. This summer, much of the DVG's work has involved simulating operations at Pad 39B, from which the Ares I rocket will launch during the Constellation program.

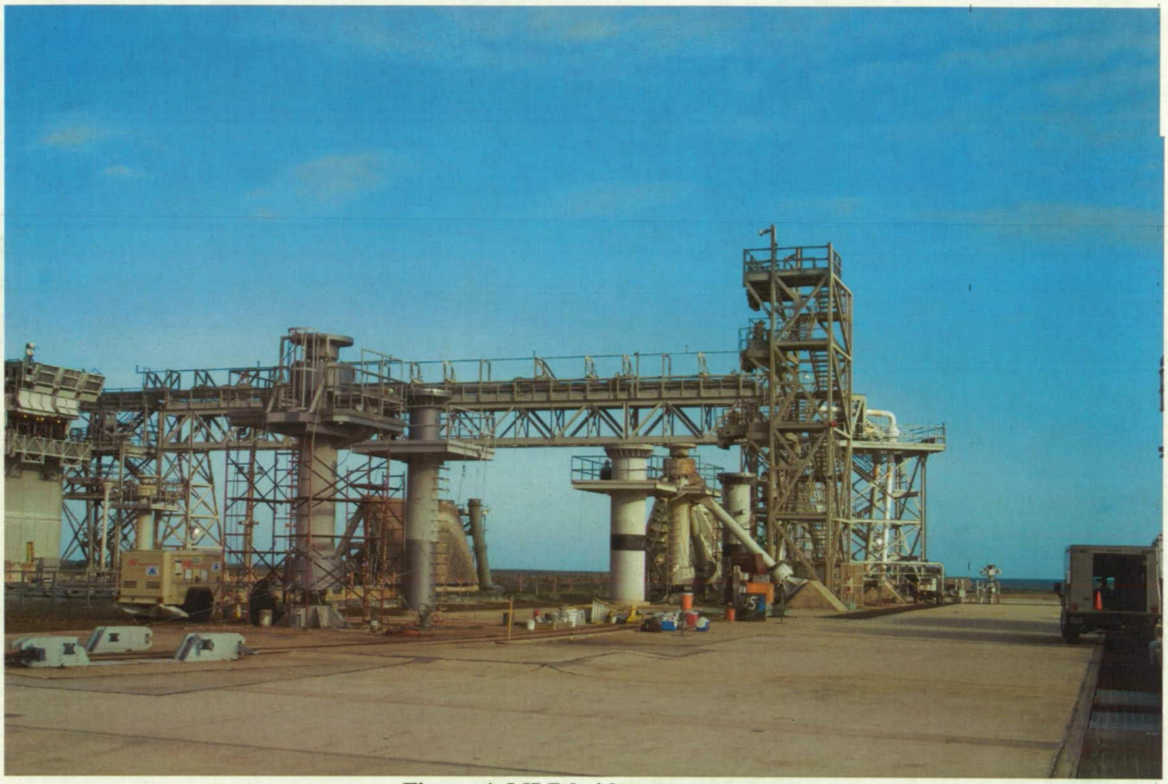

Figure 4. MLP bridge structure.

A. Mobile Launcher Platform Interfaces

The Mobile Launcher Platform (MLP) is currently used, along with the crawler-transporter, to transport the Space Shuttle from the VAB to the launch pad. The current MLPs were originally used to transport the Saturn V rocket, and new ones will be built to carry the Ares I and Ares V rockets for the Constellation program. The new MLPs will include a launch tower, so the existing service structures for the Shuttle will be torn down. However, some of the structures that serve as an interface between the pad and the MLP will be the same. To show how these interfaces will be used for Constellation, DVG has created models by scanning the existing structures using a 3D scanner. The scanned data points were then used to create detailed and accurate models in CATIA. I have contributed to some of these models by adding water piping, hypergolic propellant piping, and various other parts.

Figure 5. Pipe detail.

1. Bridge Piping

There is currently a bridge structure at Pad 39B, which is shown in Fig. 4. The structure crosses over the flame trench and is used to access various parts of the

Figure 6. MLP bridge pipes.

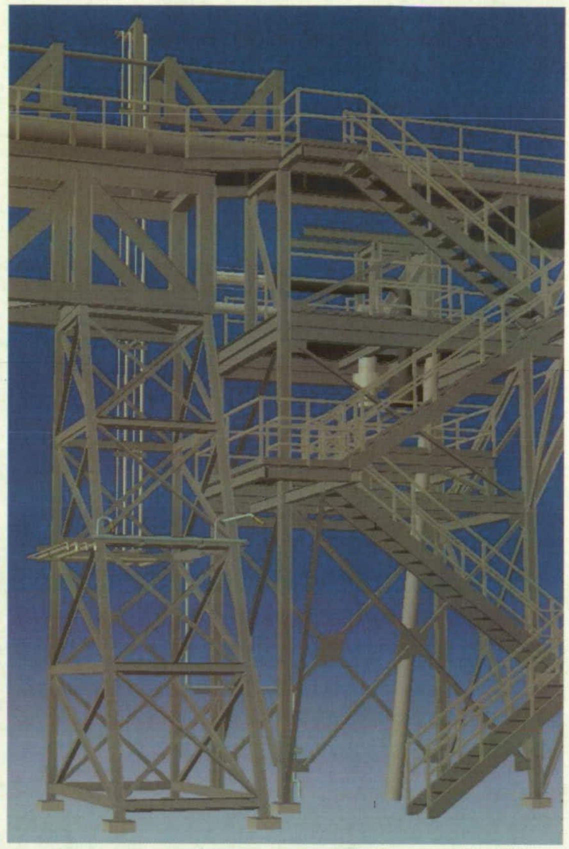

Figure 7. MLP bridge pipes CATIA model.

MLP. According to blueprints for the Constellation launch pad, there will be water and hypergolic propellant piping along the bridge support, and my job was to model the pipes and show them in the CATIA model of the bridge structure.

A close-up view of the water pipe nozzles is shown in Fig. 5. The nozzle is not shown in great detail, however it was important to show the correct angle and position of the pipes, which were given in the blueprints. A photo of the actual structure is shown in Fig. 6, and the CATIA model is shown in Fig. 7.

2. Access Tower

There is an access tower with a movable platform at the pad that provides several connections, including gaseous nitrogen (GN2) pipes. The pipes are arranged on swinging arms so that they can easily be maneuvered and connected to the MLP. The tower is shown in the left half of Fig. 8, and its deck, with the movable pipes, is shown in Fig. 9. The first thing I did with the tower model was add minor details, including bulkhead plates, pipes, the rope fence, swing arm base plates, and the stopper that keeps the movable platform in the horizontal position. I used the DMU Kinematics workbench to simulate the motion of the moving pipes, one of which is shown in detail in Fig. 10. The pipe

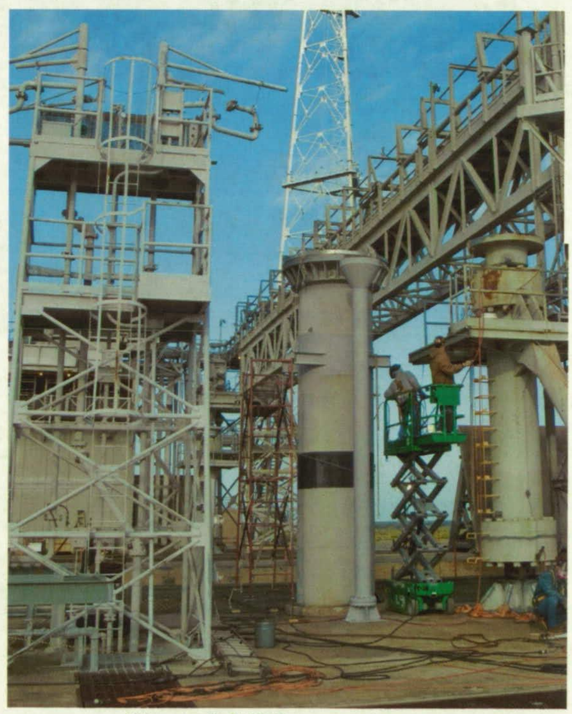

Figure 8. MLP access tower.

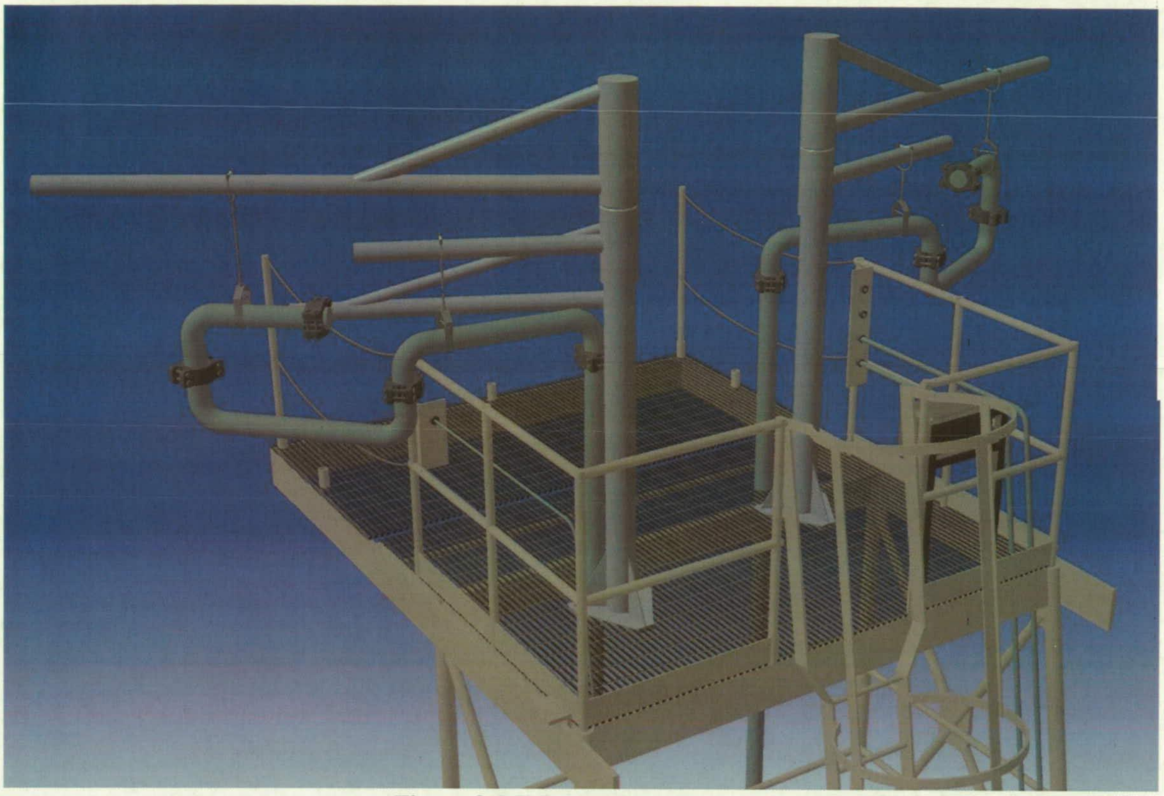

Figure 9. MLP access tower deck.

assembly has a revolute joint at each clamp, and each slider is free to move along its swing arm, and each swing arm rotates about the center tube. I encountered many errors, but in the course of applying the correct kinematics, I learned a lot more about the DMU Kinematics workbench.

B. Launch Tower

The launch tower for Ares I will be fixed to the MLP and one of its roles will be to provide access to various parts of the rocket. Tower designers utilize DVG to show realistic views of the tower and to see how the structure accommodates other hardware, including the rocket and ground support equipment. One of the most noticeable features of the launch tower is a series of access arms that reach from the main structure to the rocket. I was involved in modifying and creating some access arm features.

1. Internal Access

At the end of each access arm there is an access hatch that opens into the interior of the rocket. I created models of internal access platforms, shown in Figs. 11-13, at three different areas: the Instrument Unit, the Interstage area, and the Forward Assembly. Each platform assembly has similar components, a step, a plate with padding, a frame that protects the hatch, and two covers. The hard cover provides more protection and structure, while the soft cover is more easily removable and is used when there is frequent access to

Figure 10. GN2 pipes.

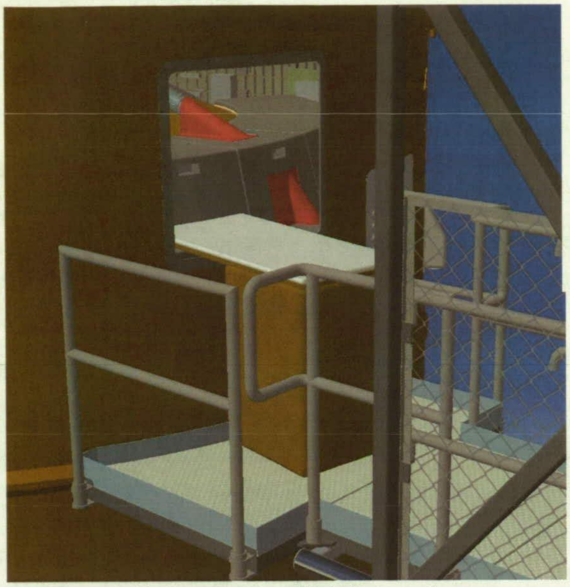
Figure 11. Instrument Unit internal access.


Figure 12. Interstage internal access.

internal areas. I modeled the soft cover using the Imagine and Shape workbench.

The step and entrance platform can be seen in Fig. 11 at the Instrument Unit access arm. Inside the hatch, wedge-shaped platforms are visible, which lay on top of the central tank and provide a working surface. The soft hatch cover can be seen at the Interstage arm in Fig 12. To the right of the hatch in Fig. 12, there is a smaller frame, which protects several valves. This frame also has a soft cover. The hard door is shown at the Forward Assembly arm in Fig. 13.

The three access arms in Figs 11-13 are each a few feet below the access hatch. A step as tall as the one in Fig. 11 is unsafe since it puts the worker at a level above the handrails. Since the only purpose of the access arms is to

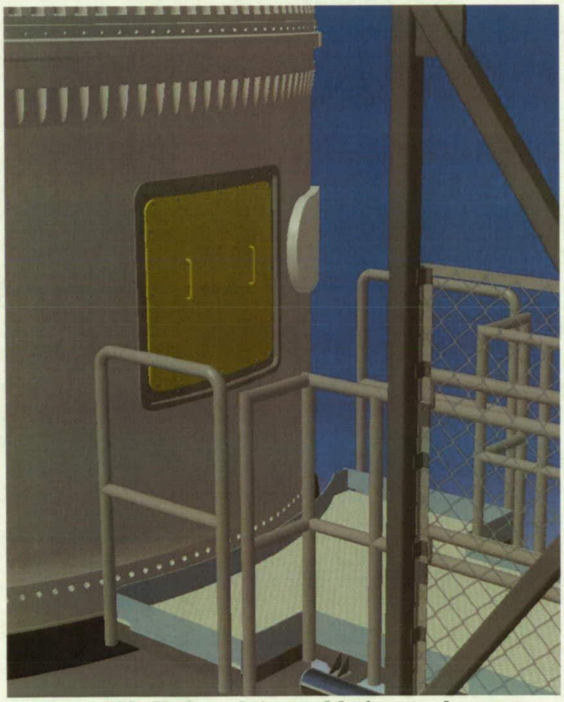
Figure 13. Forward Assembly internal access.


Figure 14. Frustum access ladder.

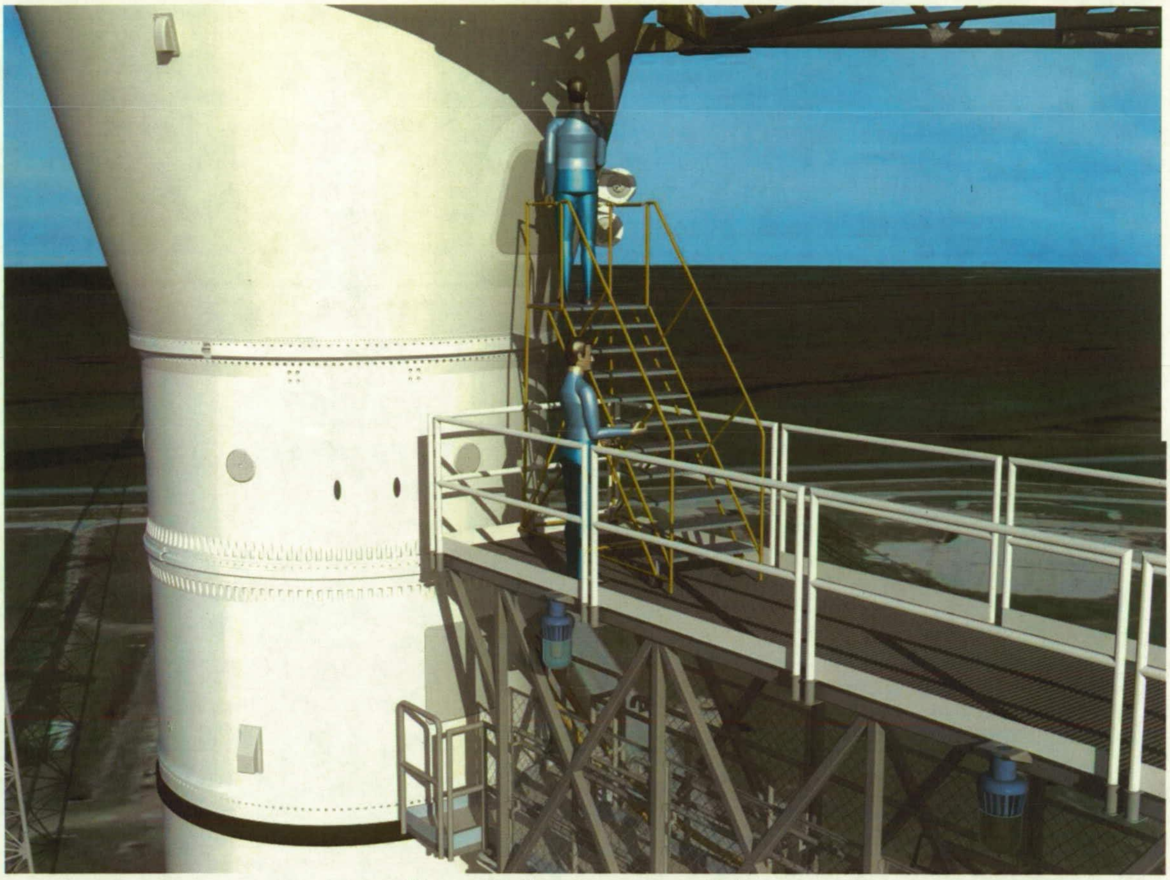

Figure 15. Frustum access deck.

access the hatch, the DVG will recommend that the design be changed so that the deck of the arm is inches from the hatch. This would eliminate the safety hazard and the need for an extra step.

2. Frustum Access

The frustum is the section of the Ares I rocket between the lower and upper stage where the diameter changes noticeably. It is necessary to access the frustum while the rocket is at the launch pad, and DVG was asked to create some options for frustum access, where the main idea was to utilize the existing access arm just below the frustum. One option was to have a ladder near the end of the access arm that goes to a small platform at the frustum level, as shown in Fig. 14. When shown this option, the designers said that the ladder was too narrow and must be as wide as possible. I modified the ladder to maximize its width while avoiding interference with any other parts. I then modeled another option, which involved having a deck on the top of the existing arm with removable handrails and a rolling ladder. This configuration is shown in Fig. 15.

Figure 16. Hydrazine servicing cart.

IV. Ground Support Equipment

A. Hydrazine Servicing Cart

Since the Ares I will use the same type of Solid Rocket Booster segments as the Space Shuttle, much of the servicing equipment will remain the same, including the hydrazine servicing cart, shown in Fig. 16. I created this model using a set of blueprints for the existing cart. The model will be used in ground processing animations.

Figure 17. Hypergolic propellant tank cart.

B. Hypergolic Propellant Tank Mover

At the launch pad there will be hypergolic propellant tanks that can weigh up to 1700 pounds. As a part of pad operations, DVG will show how those tanks will be moved from the ground to their position on the launch tower. To show this, I found a powered cart that can carry up to 5000 pounds, and made a CATIA model of it. The cart is shown in Fig. 17, with the hypergolic propellant tank and a scale on its bed.

C. Mobile Scrubber

I was an intern with DVG during the summer of 2008, and one of my tasks then was to model a fuel scrubber based on a small-scale wooden model. I used a 3D scanner to scan the wooden model, and then made a CATIA model from the scanned points and used a 3D printer to create a plastic model of the scrubber. This summer the scrubber will be used in a simulation, and I created an assembly that includes a truck and trailer carrying the scrubber, shown in Fig. 18. Since the original scrubber was only a few inches, I increased the scale so that it was 8 feet per side and modified an existing trailer model to fit the requirements.

D. SCAPE Suit

Part of pad operations includes using SCAPE suits to enter hazardous areas. To model the SCAPE suit, a person wearing the suit was scanned with a 3D scanner and the scan points, shown in Fig. 19, were then used to create an accurate model. I began on this model in my previous summer internship when I modeled the suit's helmet. This

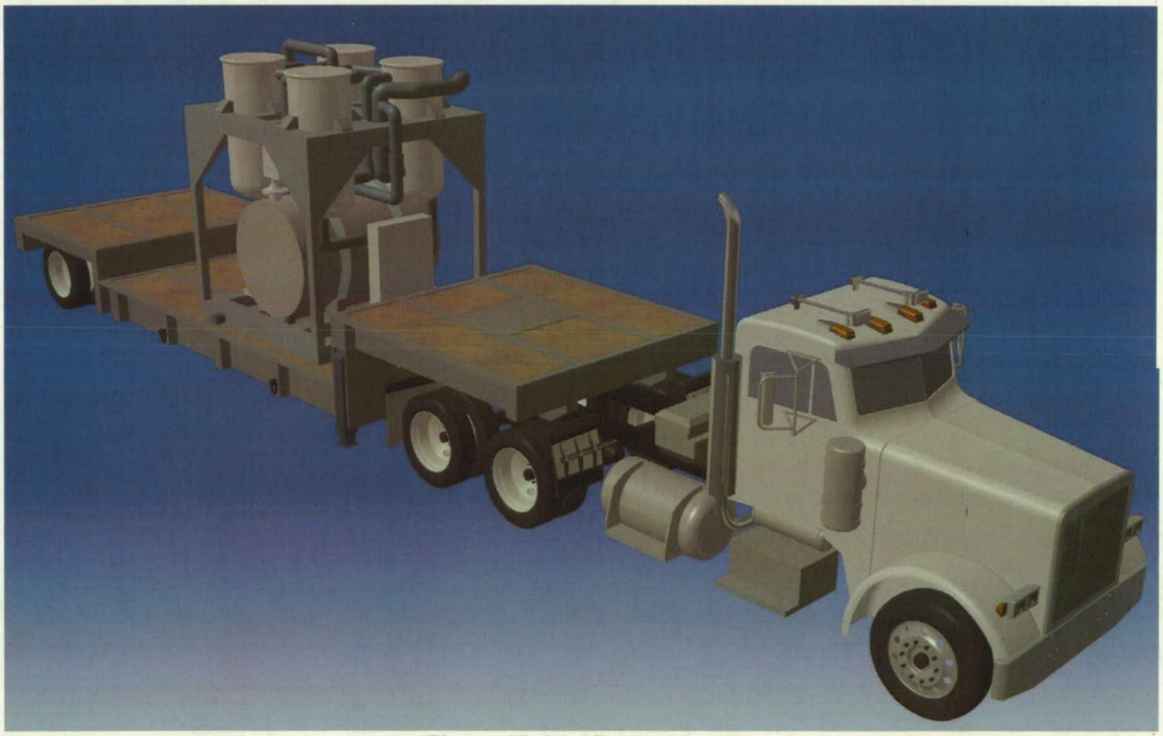

Figure 18. Mobile scrubber.

Figure 19. SCAPE suit scan data.

Figure 20. SCAPE suit.

summer I modeled the rest of the suit, shown in Fig 20, and the Imagine and Shape workbench proved to be quite helpful in making the fabric of the suit look more realistic. CATIA also has an ergonomics workbench, in which the user can manipulate a model of a human and perform ergonomics studies. I attached the SCAPE suit to an ergonomic model, so now the model can be used in an assembly and the suit will move with the model's body, as shown in Fig. 21.

Figure 21. SCAPE Suit.

V. Conclusion

During this internship I learned a lot of useful computer modeling skills. I had the opportunity to learn new workbenches in CATIA and apply my knowledge by creating CATIA models and by teaching co-workers. I learned how DVG aids in the design process, and I enjoyed seeing my models being used in higher-level animations which were then presented to customers. The internship has been beneficial to me by giving me more experience and exposure to the space industry, and it has benefited NASA by providing several models to aid in visualizing the processing of future spacecraft.