Orbiter/External Tank Mate Simulation

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ABSTRACT- *The scope of this project was to complete a simulation (kinematic) of the space shuttle Orbiter/External Tank (ET) Mate. This simulation represents a horizontal and vertical transfer of the Orbiter through the Vehicle Assembly Building (VAB) and movement of major and extensible working Platforms. These simulations were created, as mechanisms, using the Design Mechanism module of Pro/ENGINEER. The Orbiter/ET Mate mechanism assembly was then used to compare and analyze the Orbiter to Platform critical clearance distances using different Orbiter hang angles. It was found that a 15 minute arc angle change in the Orbiter hang angle affected distance at the platform critical spots as much as .550 inches. A Moving Picture Experts Group (MPEG) film clip of the Orbiter/ET Mate was developed, as a training aid, using Windows Movie Maker. The film clip may be viewed using Windows Media Player.*

I. INTRODUCTION

The scope of this project was to complete a "kinematics" simulation of the (space shuttle) Orbiter/ET Mate per Operational Maintenance Instruction (OMI) S0004. Pro/ENGINEER (a parametric, feature based) software was used to create all parts, assemblies, mechanisms and film clips.

II. MAIN TEXT-DESCRIPTIVE INFORMATION

Mechanism simulation is possible using the Mechanism Design Extension module of Pro/ENGINEER (kinematics driven)[1]. This module uses Pro/MECHANICA motion type "connections." These connections are used for component assembly and placement. Each connection limits mechanism component motion. Movement is obtained by selecting drag or defining servo motors and their velocity. A motion analysis may be run to simulate assembly motion and verify design requirements.

Pro/ENGINEER's Pro/Mechanica Motion may be used to analyze velocity and acceleration of components in a mechanism. Springs, dampers, contact, and friction are used to make the mechanism work as intended. Solid model designs may be checked for strength to qualify designs. It may be tested using loads (forces/torque). Engineers may analyze motion of the mechanism.

The VAB model was revised to reflect a bigger door opening (to accept entry for the shape of the Orbiter). Structural steel framing; and major and extensible Platforms were added to the VAB interior to create a realistic VAB environment. A simplified representation of the VAB was created. This representation was created to manage and reduce computer file size. See Figure 1.

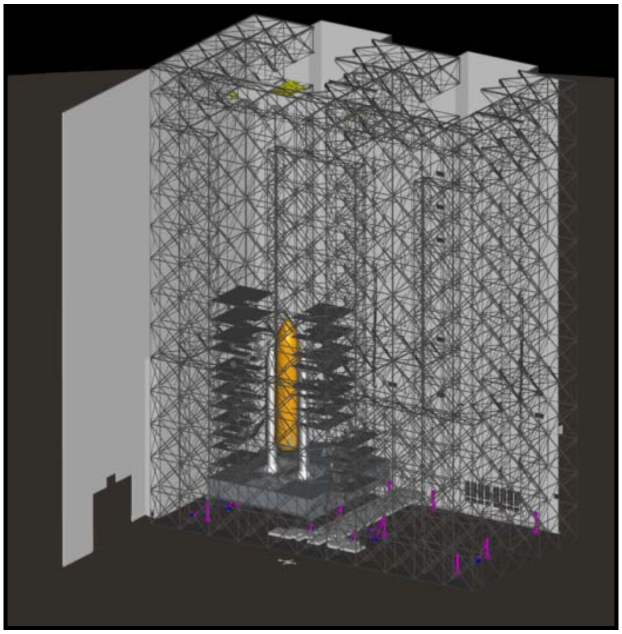

Figure 1. VAB As A Simplified Rep (Including Structural Steel, Major, and Extensible Platforms).

Four major Platform structures (B, C, D, and E), comprising VAB High Bay 3 Platforms, were modeled. There were 13 levels to the structures of the major Platforms. These structures extend or retract. Sixty-six small extensible Platforms that folded up or down were attached to the major Platforms. Approximately 132 servo motors were installed and their velocity determined to create the motion required to extend, retract, fold up or down each small working Platform. See Figure 2.

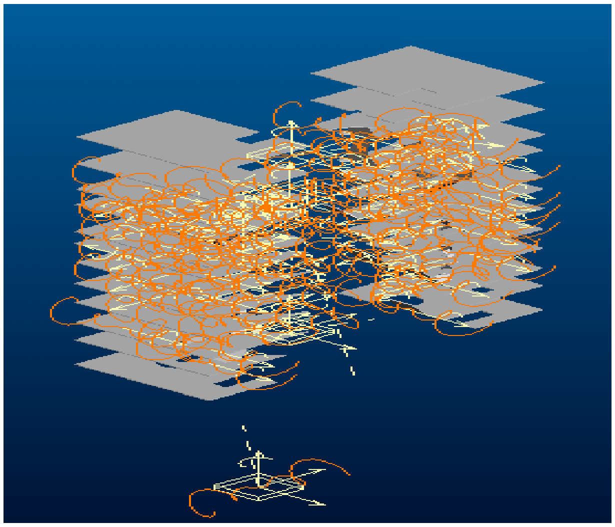

Figure 2. Extensible Platforms (Showing Servo Motors).

The simulation of the Orbiter/ET Mate (S0004) involves a hoist and structural mate of the Orbiter to the ET. Approximately 50 servo motors were used to simulate this motion. The space shuttle control documents Operational Manual Instruction (OMI) <u>S0004 Orbiter/ET Mate</u> and <u>Shuttle System/Launch Platform Stacking and VAB Servicing ICD-2-0A001</u> were used to document the simulation. The S0004 Simulation Assembly (major assembly) includes a simplified representation of the VAB assembly, a simulated ground/floor, a 76 wheel OTS, a KSC Orbiter, and a VAB Platform assembly. Additional shrinkwrap assemblies concluded the major assembly. These assemblies were the KSC shuttle stack, Orbiter sling, and VAB High Bay 3 structural steel. The KSC shuttle stack includes: the Mobile Launch Platform (MLP), ET, and two Solid Rocket Boosters (SRB's).

The simulation begins by transporting the Orbiter, using the Orbiter Transporter System (OTS), to inside the VAB. The Orbiter is centered in the transfer aisle. See Figure 3.

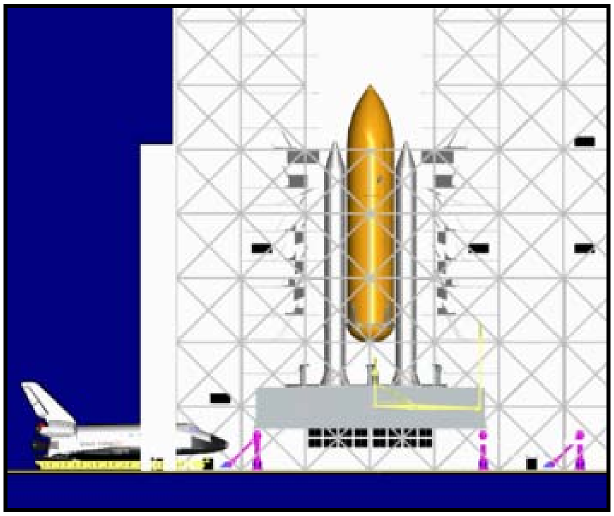

Figure 3. Orbiter And Transporter (OTS) Entering VAB.

Two bridge Cranes (250/325 and 175-ton) are used to lift and translate the Orbiter sling and spreader beams. The Orbiter sling is positioned and attached at Orbiter aft adapters then forward adapters. The Orbiter sling will flex at its connections. The Orbiter is lifted from the OTS. The OTS is moved forward to clear a "suspended load." The Orbiter is positioned and rotated to the vertical position using both bridge Cranes. See Figure 4.

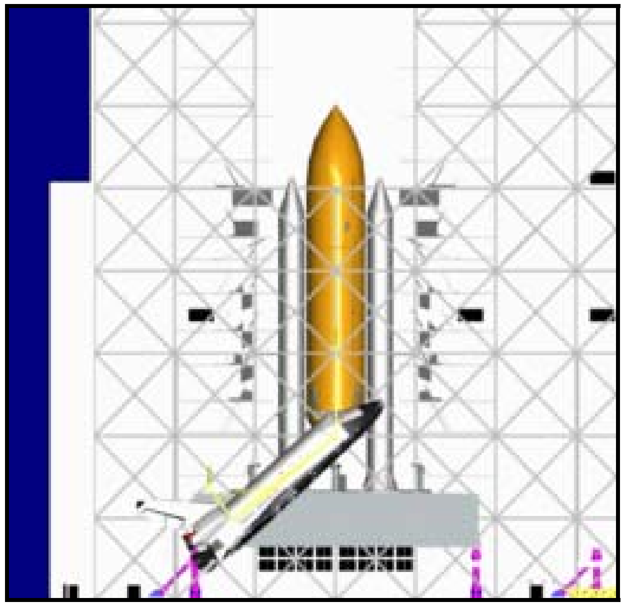

Figure 4. Orbiter Being Rotated To A Vertical Position.

The aft spreader beam is removed from the Orbiter sling assembly and stored in the transfer aisle. The Orbiter hang angle is determined and corrected. The Orbiter is rolled 45 degrees from a top view. This rotation allows the Orbiter to clear steel structure in High Bay #3. See Figure 5.

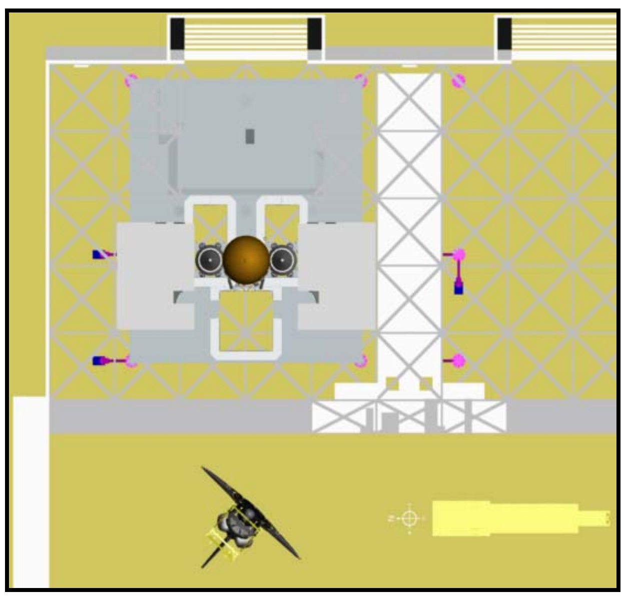

Figure 5. Top View Of Orbiter Showing 45-Degree Roll.

The Orbiter is positioned in the center of High Bay #3. The Orbiter is elevated to a level above the tower Catwalk. The Orbiter is moved into High Bay #3. The Orbiter is rolled back 45 degrees. See Figure 6.

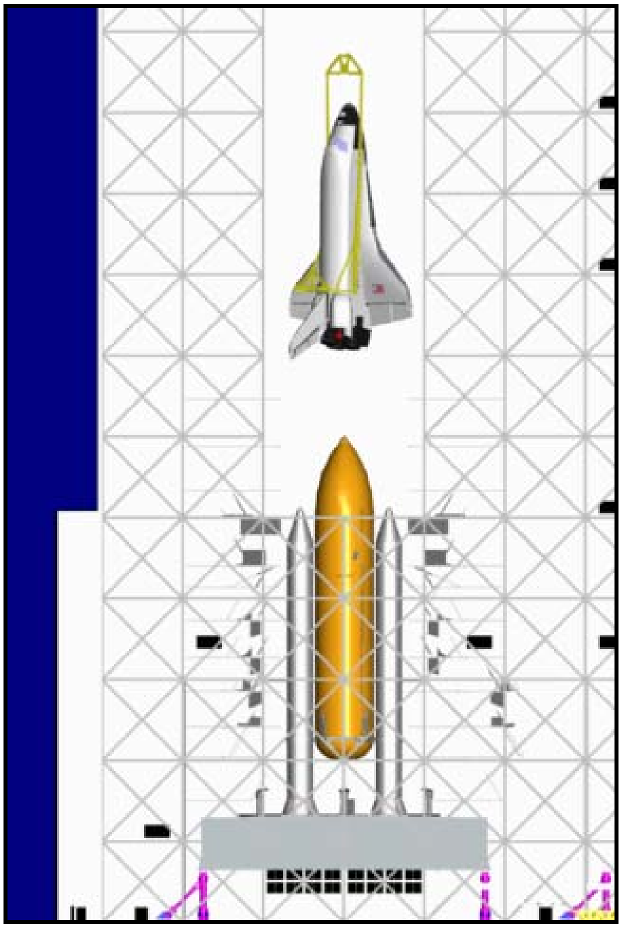

Figure 6. Orbiter Being Moved Into High Bay #3.

The Orbiter is pinhole positioned in High Bay #3. The Orbiter is lowered until wing tips are level with C-Roof Platform scales. Orbiter wing tips are misaligned 4 inches to allow for crane cable twist. The Orbiter is lowered until the ET ball-fittings align with the Orbiter aft ET attach points. The Orbiter is soft and hard mated to the ET at aft attach points (E/O 2 & 3). The Orbiter is soft and hard mated to the ET at forward attach position (E/O 1). The Orbiter sling is removed from the Orbiter and stored in the transfer isle. This completes the Orbiter/External Tank Mate (S0004). See Figure 7.

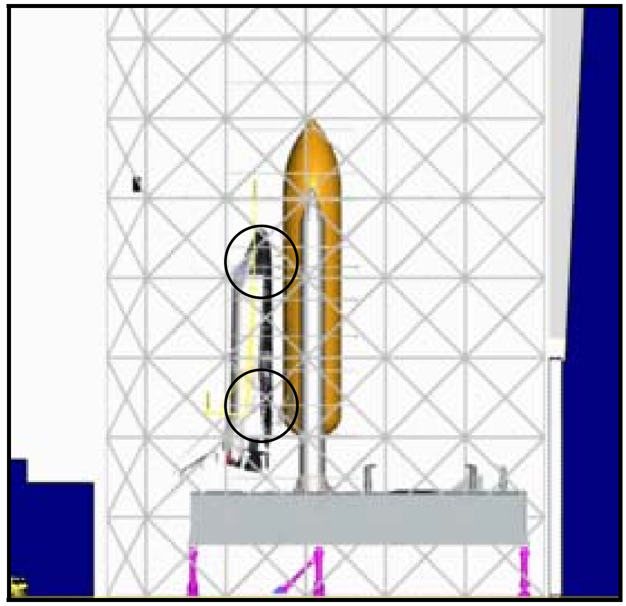

Figure 7. External Tank/Orbiter Mate At E/O 1, 2, & 3.

III. MATHEMATICAL PRESENTATIONS

Table One shows clearance distances, using different Orbiter hang angles, at places where “clearance issues” exist between the Orbiter and major or extensible Platforms. Clearance issues exist in High Bay 3 at the D2 (a Post), D3, E-main, and B-2 positions. Distances were measured with the Orbiter positioned horizontally 24 inches from a hard mate at E/O 2 &3. This distance included a 10” horizontal move, to the start of the soft mate position, and a 14” horizontal move to a hard mate at E/O 2 & 3 using the turnbuckle. The D2 postposition was not modeled and could not be measured. The distances at D3 and B-2 changed very little. The distance at E-Main differs by .550 inches per each 15-minute change in Orbiter hang angle. A change in Orbiter hang angle may be a factor at the E-Main position. See Table I.

Orbiter/Extensible & Platform Clearance Issues – High Bay #3				
	Orbiter Hang Angle			
Location	89° 15'	89° 30'	89° 45'	90°
D2 (Post)	-	-	-	-
D3	3.426	3.323	3.222	3.120
E Main	3.717	4.268	4.820	5.370
B-2	1.540	1.538	1.537	1.535

Table I. Clearance Issues.

There are a number of places where "crane rotation issues" exist, using different Orbiter hang angles, between the Orbiter and major or extensible Platforms. To account for this rotation, Wing tips are offset 4 inches to account for a cable twist factor that would mis-position the Orbiter as it is lowered. This offset allows for a correction so that Orbiter and ET attach points are square at E/O 2 & 3. Crane rotation issues exist in High Bay 3 at the D2/D3 Level (AP-65) North Side/Upper LH wing, E-Main South/Upper RH wing, and B-2 South/Upper RH wing levels. These places are listed in Table One and will be aggravated or removed depending upon wing tip being relocated north or south. Figure 8 is a 2-D drawing showing the dimension of 1.538 inches at the B-2 critical clearance position.

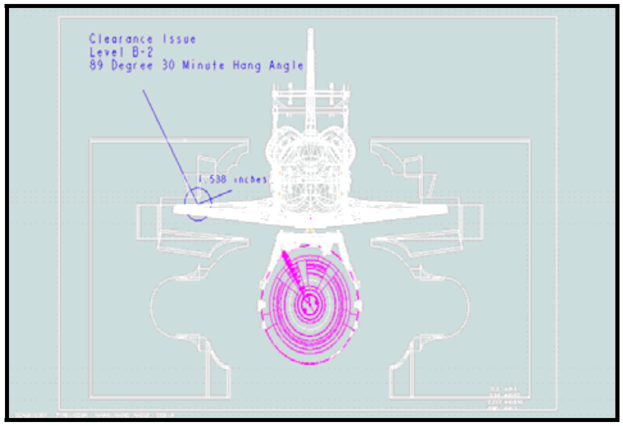

Figure 8. Drawing Showing Clearance at B-2.

IV. RESULTS

It was found that a 15 minute arc angle change in Orbiter hang angle affected distance at the platform critical spots as much as .550 inches.

V. CONCLUSIONS

Translation of "solid" models is best attempted by exporting and importing a STEP file.

Parts, assemblies, and drawings may be viewed and manipulated using Pro/INTRALINK.

ProductView Express 2.0 or Pro/ENGINEER will enable engineers to create, view, manipulate and revise parts, assemblies, and drawings.

A single reference or survey "benchmark" should be established in the VAB.

VI. REFERENCES

1. Gagnon, Yves (2003). PRO/MECHANICA WILDFIRE, Elements and Applications Series, PART 1: IDEALIZATIONS. Schroff Development Corporation.