

Ground and Range Operations for a Heavy-Lift Vehicle: Preliminary Thoughts

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Luis Rabelo
University of Central Florida

Jorge Bardina
NASA Ames Research Center

Yanshen Zhu
University of Central Florida

Jeppie Compton
NASA Kennedy Space Center

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ABSTRACT

This paper discusses the ground and range operations for a Shuttle derived Heavy-Lift Vehicle being launched from the Kennedy Space Center on the Eastern range. Comparisons will be made between the Shuttle and a heavy lift configuration (SLS-ETF MPCV - April 2011) by contrasting their subsystems. The analysis will also describe a simulation configuration with the potential to be utilized for heavy lift vehicle processing/range simulation modeling and the development of decision-making systems utilized by the range. In addition, a simple simulation model is used to provide the required critical thinking foundations for this preliminary analysis.

INTRODUCTION

Simulation modeling is one of the most important areas for exploration. The NASA Office of Chief Technologist (OCT) [6] has stated that “Simulation focuses on the design, planning, and operational challenges of NASA's distributed, long-lived mission systems.” We agree that a model represents the features of a system from a dimensional or multidimensional viewpoint. On the other hand, simulation is the execution of a model which has the possibility (if the model is able to capture appropriately the features up to certain level of fidelity) to represent its behavior. In addition,

OCT states [6] that “Through the combination of the two, we can make better decisions and communicate those decisions early enough in the design and development process that changes are easy and quick, as opposed to during production when they are extremely costly and practically impossible.” There are several principles with complex systems such as “emergent behavior” which can be discovered with simulation. Simulation modeling has some interesting benefits and features:

- 1. It helps to understand complex problems from different viewpoints:** We have to understand the system and its structure, goals and objectives. We have to view complex problems from different dimensions. It is usual a multidisciplinary effort.
- 2. Basic theory can be combined with experiments and expert opinions:** A simulation model can fused data and information from first-principle models, empirical, and expert opinions.
- 3. Ontologies will be very important to increase agility and interoperability:** This will support the development of knowledge discovery mechanisms and the potential automation of generating simulation models.
- 4. A map of models is important:** A map of “models” (analytical and empirical) from the different points in the

lifecycle of a system is an important endeavor in order to determine gaps.

5. Find an appropriate technology platform for the simulator (e.g., distributed, cloud computing, hybrid, etc.) that makes sense and it is scalable and supports the different types of users: It is important to have configuration management and concept of operations documentation.

6. Knowledge discovery and predictive modeling are part of the simulation modeling effort: Develop different models, verification, validation and testing. Then, the discovery of relationships, according to the goals/objectives of the analysis task can be found... sometimes during the construction of the simulator many relationships are discovered.

7. Simulation has different outputs and visualization is one of them: Visualization of simulation models is very important to understand and communicate. However, scripted visualization (even it is the most advanced 3D projection) is just that "a movie". Scripted visualization is not simulation.

Indeed simulation modeling will be very important for the planning and validation of future NASA missions. This paper is just a starting point to discuss the ground and range operations for a Shuttle derived Heavy-Lift Vehicle being launched from the Kennedy Space Center on the Eastern range.

CASE STUDY: ENVIRONMENT

The NASA's Space Shuttle was the first orbital spacecraft that was a reusable launch vehicle. At launch, it consisted of the External Tank (ET), the Solid Rocket Boosters (SRB), and the orbiter (Figure 1) [2,7]. The NASA Shuttle program ended this year (2011).



Figure 1. The NASA Space Shuttle and its main elements. Photo credit: NASA

The Shuttle launch processing was very labor intensive and consisted of three separate element flows that came together in the Vehicle Assembly Building (VAB). These flows required unique facilities and ground support equipment (See Figure 2).



Figure 2. The Vehicle Assembly Building at KSC. Photo credit: NASA

1. The Solid Rocket Boosters (SRB) were the largest solid rockets ever designed. Each was 149 feet high and 12 feet in diameter and produced 2.65 million pounds of thrust at liftoff. Each booster consisted of four solid motor segments also called solid rocket motors, vertically stacked with a nose cone on top and the aft skirt at the base of the booster, on which the entire vehicle weight rested prior to launch. Stacking, or assembling the reusable solid rocket motors into the booster, began with transferring the aft skirt from the Rotation, Processing and Surge Facility (RPSF) to the VAB. The SRB processing flow, began when SRBs from a previous launch were retrieved from the ocean by two NASA retrieval ships and returned to Hangar AF at Cape Canaveral Air Force Station (CCAFS). Here the SRBs were disassembled and parts were returned to the vendor and other parts were refurbished for the next launch. After the SRB forward extension and aft segment were built up, they, along with the SRB segments are transferred to the VAB (See Figure 3).



Figure 3. Built up Aft Segment leaving the RPSF on its way to the VAB, Photo credit: NASA

2. The External Tank (ET), after arriving by barge from their assembly plant in Louisiana, were inspected and stored in either High Bay 2 or 4 until they were needed ([Figure 4](#)).



Figure 4. The External Tank rolls from the barge docked in the turn basin to the VAB. Photo credit: NASA

3. The orbiter itself was processed in the Orbiter Processing Facility (OPF). In the OPF initial access and safing was accomplished, post-flight hardware problems were resolved, thermal protection system maintenance was performed, system/component replacement and repair was conducted and Space Shuttle Main Engine (SSME) removal and installation was completed. Payload bay operations and Orbiter modifications were completed and the vehicle prepared for roll over to VAB for Vertical Operations. ([Figure 5](#)).



Figure 5. Shuttle Orbiter rolling over from the OPF to the VAB. Photo credit: NASA

Once a Mobile Launch Platform (MLP), a two-story tall, nine-million-pound steel structure that serves as the launch base for the integrated Shuttle stack was in place in the high bay, SRB stacking began and required approximately three weeks. This was accomplished by hoisting the Solid Rocket Motors onto the MLP in either High Bay 1 or 3 and the segments individually mated to form two complete SRBs. Once the SRB stacking was complete, ET mate and closeout, which requires approximately two weeks, was completed ([Figure 6](#)).



Figure 6. SRB/ET stack in VAB High Bay 1. Photo credit: NASA