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Paper Session I-B - A Virtual Test Bed Environment for Spaceports

Jorge Bardina Ph.D.
NASA Ames Research Center

Luis Rabelo Ph.D.
University of Central Florida / Kennedy Space Center, luis.rabelo-1@ksc.nasa.gov

Barbara Brown
NASA Kennedy Space Center

A Virtual Test Bed Environment for Spaceports

Luis Rabelo, Ph.D.
University of Central Florida
Kennedy Space Center, FL 32899
Luis.rabelo-1@ksc.nasa.gov
lrabelo@mail.ucf.edu

Jorge Bardina, Ph.D.
NASA Ames Research Center
MS 269-1
Moffett Field, CA 94035

Barbara Brown
NASA
Kennedy Space Center, FL 32899

Abstract

Virtual test bed environments are the next S-curve of the computer-aided design (CAD) systems. These "advanced" CAD environments will combine not only the 3D solid modeling capabilities of the current CAD systems but will also seamlessly integrate models that represent the different stages of the life-cycle of a system. Virtual Test Bed environments are more adequate to study complex systems. One interesting characteristic of a complex system is that it is by default a system of systems. This system of systems is non-linear in nature and the interactions among the different components bring interesting emergent properties that are very difficult to visualize and/or study by using the traditional approach of decomposition.

Spaceports are complex systems. Therefore, it seems logical to think that a virtual test bed is needed to host the different models that represent different systems and elements of a spaceport. These models in the virtual test bed will work in an integrated fashion synthesizing in a holistic view and becoming together a Virtual Spaceport. This Virtual Spaceport can be utilized to test new decision-making technologies and new operational processes. This presentation discusses current efforts at Kennedy Space Center (KSC) and Ames Research Center (ARC) to bring the concept of a virtual test bed to reality.

1. Introduction

Virtual test bed environments are the next S-curve of the computer-aided design (CAD) systems. These "advanced" CAD environments will combine not only the 3D solid modeling capabilities of the current CAD systems but will also seamlessly integrate models that represent the different stages of the life-cycle of a system. Therefore, the 3D solid models of the mechanical/physical design will be integrated to the materials models, dynamics models, environmental models, operational models (including operators, crew members), safety models, and other type of models. These virtual environments will go beyond the virtual world attempts of the 90's. The virtual worlds of the 90's concentrated on the look and feel dimensions. However, a virtual environment will go beyond the former cosmetic approach with higher realism and fidelity, with more emphasis on engineering. Virtual test beds will create multi-disciplinary and collaborative design spaces.

From another viewpoint, the current CAD environments **concentrate** only in a single dimensional view of a system but are not adequate for complex systems design. One interesting characteristic of a complex system is that it is by default a system of systems. To be faithful to concurrent engineering principles, you have to study the interactions among the different systems that are elements of the complex systems. This system of systems is non-linear in nature and the interactions among the different components bring interesting emergent properties that are very difficult to visualize and/or study by using the traditional approach of decomposition.

A very interesting outcome of the current CAD systems is that the single view, which they display, have limited them to just being geometric design collaborative environments. For example, to develop a specific product, a CAD system will only serve as a collaborative environment to those members of the design team that only need to know or use 3D Solid Modeling characteristics and/or geometric features. A virtual test bed environment is not only related to geometric design but also includes other properties such as materials, operational behavior, and interactions. A more comprehensive modeling environment such as a virtual test bed will need to have enhanced usability and connectivity capabilities to become an effective collaborative environment.
Spaceports are complex systems. According to Barth [3] "Spaceport technologies must employ a life-cycle "system of systems" concept in which major spaceport systems – launch vehicle processing systems, payload processing systems, landing and recovery systems, and range systems – are designed concurrently with flight vehicle systems and flight crew systems." Therefore, it seems logically to think that a virtual test bed can host the different models that represent different systems and elements of a spaceport. These models in the virtual test bed will work in an integrated fashion synthesizing in a holistic view and becoming together a Virtual Spaceport. This Virtual Spaceport can be utilized to test new technologies, new operational processes, the impact of new space vehicles in the spaceport supply chain, and the introduction of higher schemes of decision-making. A Virtual Spaceport will allow an intelligent visualization of the entire spaceport concept and the implementation of knowledge management strategies.

The Intelligent Launch and Range Operations (ILRO) Program (of the Intelligent Systems Project) at NASA Ames Research Center (ARC) was started to perform initial studies of a test bed with a demonstration. An evolution of the ILRO test bed is the Virtual Test Bed Project. The objective of the Virtual Test Bed (VTB) Project is to provide a collaborative computing environment to support simulation scenarios, reuse, and integration of multidisciplinary models that represent elements of the range and operations at spaceports. VTB will provide several benefits such as a risk management evaluation of legacy and new vehicles framework, a technology pipeline, and a knowledge management enabler. VTB will leverage current technological developments from NASA ARC in intelligent databases to present data and results as usable knowledge with associated security constraints (Developmental Aeronautics Revolutionizing Wind-tunnels with Intelligent Systems of NASA - DARWIN) and methodologies for remote access to research facilities employing interactive and virtual reality interfaces.

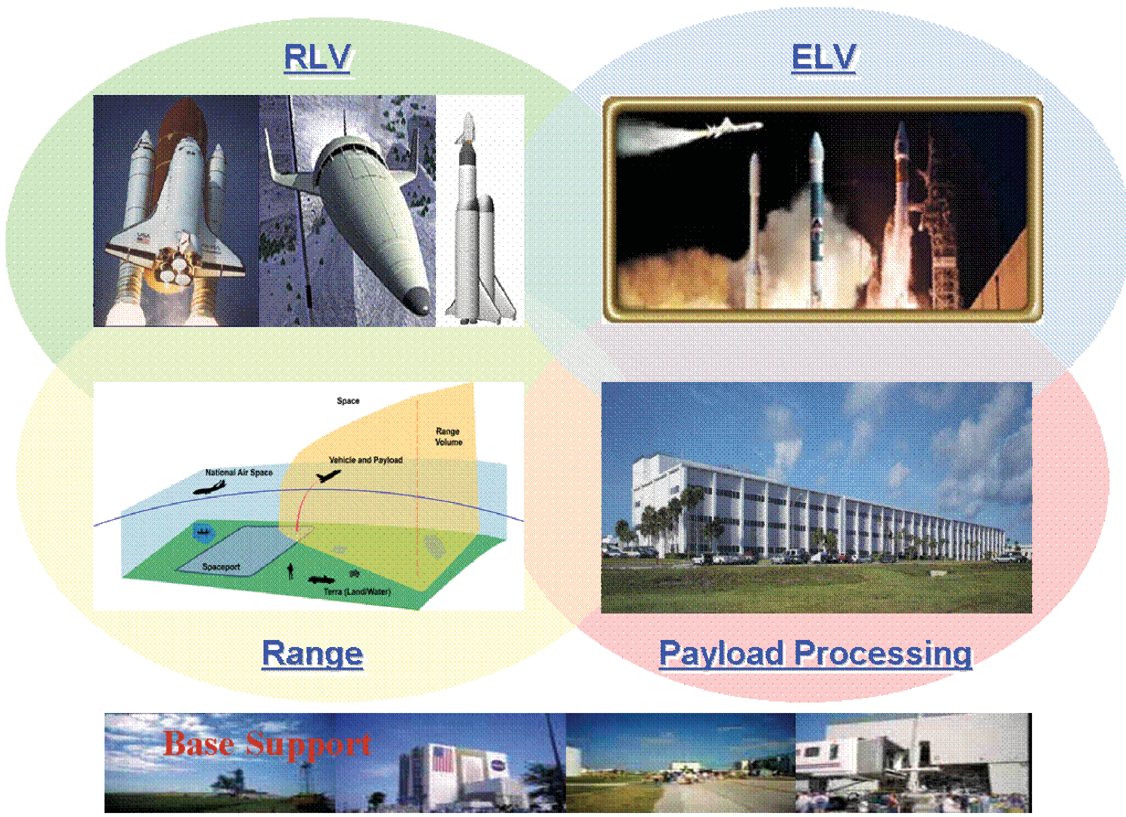

Figure 1. Examples of the different systems in a spaceport [2].

2. Systems Architecting Activities

It is very well known that systems architecting integrates systems theory and systems engineering with architecting theory and practice of architecting [10,11]. Conceptualization is the keyword for architecting. System conceptualization involves creativity and the recognition of potential users and perceived needs. System architectures are driven by the function, instead of the form, of the system. Systems Engineering is the one that provides the form. We utilized in this project QFD (Quality Function Deployment) and in particular a modified house of qualities to guide our architecting activities.

QFD can be used to improve the process of introducing new ideas that translates the user requirements from concept to development and beyond [6,12]. In the application of QFD, the initial phase involves the creation of a matrix called the House-of-Quality matrix due to its roof-like format as shown in Figure 2. The House-of-Quality used here follows modifications of the matrix of change [6] (MOC). This House-of-Quality has a list of the user needs/benefits (organized on the left side of the House). This list of needs/benefits is translated into the features (technical) needed (design requirements of a solution to satisfy the needs and/or provide the benefits).

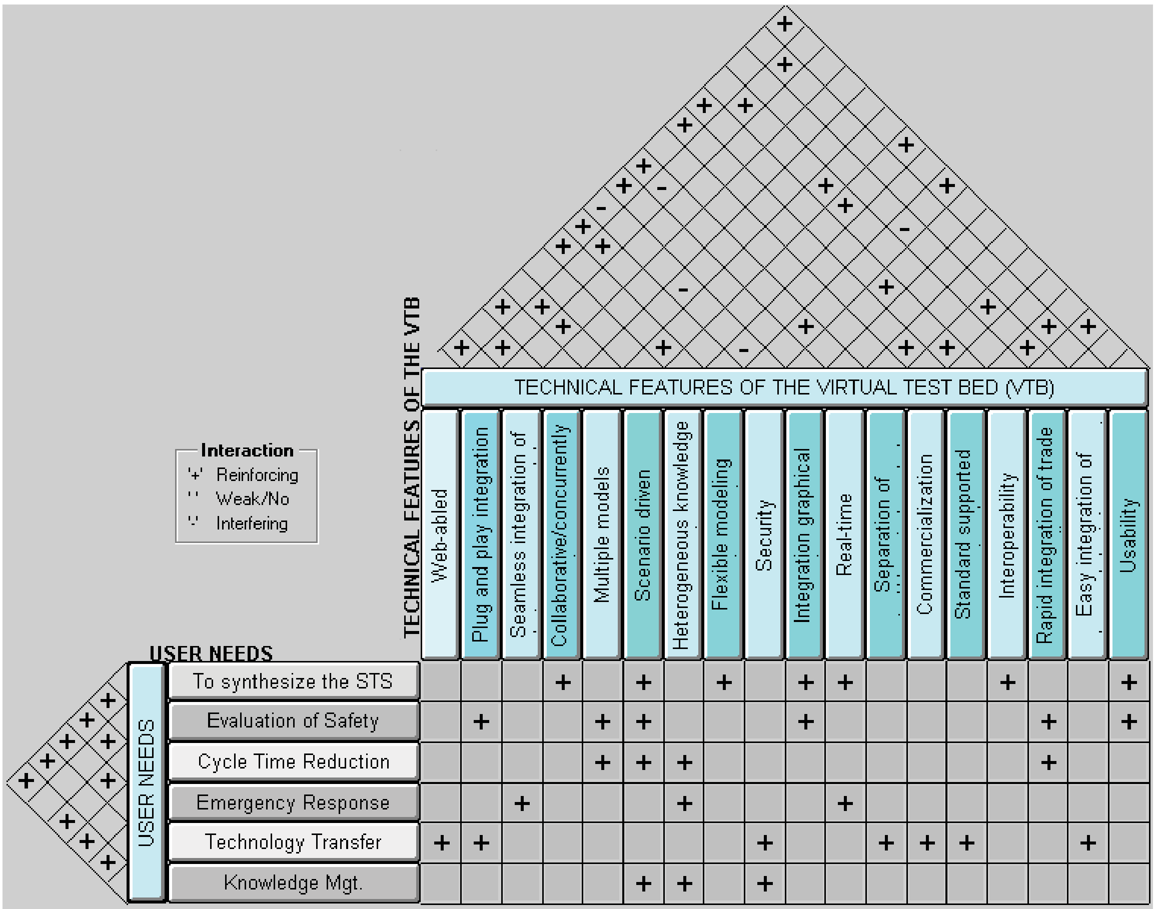

Figure 2. On going modified House-of-Quality for the VTB project. Look and feel adapted from MOC [6]

The potential users "verbalized" their needs and benefits desired. These "verbalized" needs and benefits were clustered in six areas:

1. *To decrease cycle time during the evaluation of vehicles and systems compliance to safety criteria.*
2. *To improve the evaluation of vehicles and systems compliance to safety criteria.*
3. *To synthesize in a single view the different elements of the Space Transportation System.*
4. *To develop precautions/emergency response measures to support range safety & security in a systematic manner.*
5. *To accelerate the introduction of new technologies (technology pipeline), new operational procedures, and help configure the current ones.*
6. *There is a need for a repository of knowledge and Knowledge Management strategies.*

The next step was to translate these needs/benefits to the desired design requirements/technical features of the VTB. The ranking of the technical features is providing a guideline for the selection of a viable computing architecture for the VTB project. We understand that these technical features are very ambitious to obtain and some of them will require trade-offs to be implemented.

3. Issues About Architecture

A VTB-SM is created by one or more simulations and is a selective recreation of the real world. The simulated "world" consists of a representation of the environment, a well-defined set of objects that populate and evolve in that environment, and a communication mechanism to make sure that all interactions between the different elements occur in a managed and time consistent fashion [9].

Important aspects are:

- *Visualization - Visualization allows (potentially widely distributed) users to collaborate using VTB-SM. The utilization of standards and Web technologies will be very important to achieve this.*

- *Knowledge and Information Repository - A repository for storing data, software, object models and lessons learned, so that new exercises or scenarios or tests can be readily constructed.*

- *Integration Environment - A suite of tools and a human-machine environment for integrating models, visualizing, planning, executing, collecting data from, analyzing and reviewing scenarios.*

- *Flexible and Evolving Architecture - The VTB-SM will have the ability to flexibly reconfigure resources to meet new and changing needs.*

Technological developments will be very important to bring this concept to reality. For example, the development of Ontologies will be essential for this project. Ontologies can support a modeling language for spaceports. This language will be for the use of the "VTB Model Integrator Expert" (the person with expertise in the steps required to integrate a model to achieve temporal integration, functional integration, and geo-spatial integration) and can be based on a shared and consensual terminology [5]. A shared and consensual terminology (i.e., ontology – formal, explicit specification of a shared conceptualization) for spaceports can prove useful for information sharing and integration of models. The Human Centered Computing (HCC) program at NASA Ames Research Center (ARC) has important developments in this area of Ontologies, Concept Maps, and advanced user interfaces for space operations that can support the development of the modeling language [8]. This modeling language for spaceports will have to be Extensible Markup Language (XML)-compliant. Simulation and modeling of systems are gradually changing from single systems approach to a more sophisticated network of information exchange and transactions. Therefore support in the exchange of data, information, and knowledge is becoming one of the key issues in current simulation technology. Ontologies provide the capability to share the required information among various simulations, whether the information needed is quantitative, qualitative, or logical reasoning. Therefore, Ontologies are a critical methodology in information exchange within simulation environment such as VTB-SM.

Another important development will be the simulation engine. The "Simulation System" will have to provide an environment to execute integrated simulators/models developed for specific elements of space operations into interactive simulator networks to support a single view of operations. For instance, NASA KSC has existing models that have been developed over time by different sources [4]. These existing models have been developed from different points of view and for different aspects of the operation cycle. Consequently, existing models represent different levels of resolution and have selected different representation methods for internal entities, activities and interactions. The Simulation System will employ object models and object-oriented methods to exercise a hierarchical description of entities, activities, and interactions represented in the integrated models. In addition, the Simulation System shall follow the standards of DOD and the Institute of Electrical and Electronic Engineers (IEEE) for the integration of models. The High Level Architecture (HLA) is one of those standards [1]. The Simulation System will follow HLA as the principal framework.

4. Conclusions

The Virtual Test Bed (VTB) for Spaceport Models (VTB-SM) will provide a collaborative computing environment that will enable engineers and managers to develop, exercise, and modify their concept of operations in their respective areas of responsibility. VTB-SM will be a collaborative engineering space to support simulation scenarios, reuse, and integration of multidisciplinary models, which represent elements of the launch range and operations at spaceports. VTB-SM will provide several benefits such as the risk management evaluation of Second and Third Generation Vehicle processing, a technology pipeline, and knowledge management. This is an on-going project. We will report in future papers the status of the project.

Acknowledgements

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