Using Simulation in Astronautic and Aerospace Systems

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Summary

This article will introduce ideas of simulation and their agents with their applications in the development of aerospace systems and decision making at NASA. In particular, the following topics will be discussed: simulation of new spacecraft (MPCF / SLS and CubeSats) , continuous simulation in the Martian atmosphere , and the use of agents.

General Concepts of Simulation

A model refers to the construction of an abstract model that represents a real life system. The model describes the relevant aspects of the system as a series of equations, relationships, and / or logic statements embodied in a computer program. This series of equations, relationships, and / or logic statements can then be executed. And this last action is simulation!

Simulation models have been successful and effective in representing various functions and designs of Astronautic and Aerospace Systems. This simulation can be performed several ways:

- Discrete Event Simulation: Traditional processes and object-oriented.
- Continuous Simulation: complex differential equations and math used in many models.
- System Dynamics: Developed at the Massachusetts Institute of Technology with a long history, focused on biofeedback.
- Agent-Based Simulation: Emerge in complexity research.

Simulation systems

Simulation systems provide an environment to run simulators / integrated models developed for specific elements of the area of interest. For example, a simulation system for a new spacecraft includes the operations necessary to carry out the launch, conduct maintenance, and ensure safety. These models would be executed in interactive simulator networks to support a single view of operations. Simulation Systems have to use models of objects and object-oriented methods to practice a hierarchical description of the entities, activities, and interactions represented in integrated models. The Department of Defense (DoD) of the United States and the Institute of Electrical and Electronics Engineers (IEEE) has developed standards for the integration of models [3]. High Level Architecture (HLA) is one of those standards. HLA is used to provide a consistent approach and rules to integrate distributed, heterogeneous, and inherited simulation systems. The HLA has been approved as an IEEE standard (http://standards.ieee.org/) and has been adopted as the method for distributed simulation systems by the Object Management Group (http://simsig.omg.org /) . The software "Run Time Infrastructure" (RTI), which implements the HLA rules and specifications, provides methods that can be called and used by individual federated simulations. RTI interfaces can integrate federal simulations, but the implementation is quite complex.

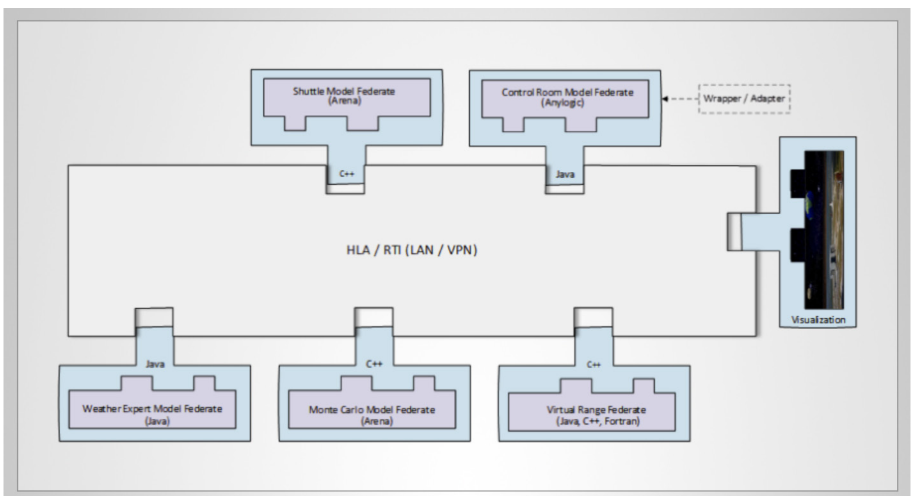


Figure 1. Various continuous simulators and discreet events for simulating the operational life cycle of a spacecraft using HLA.

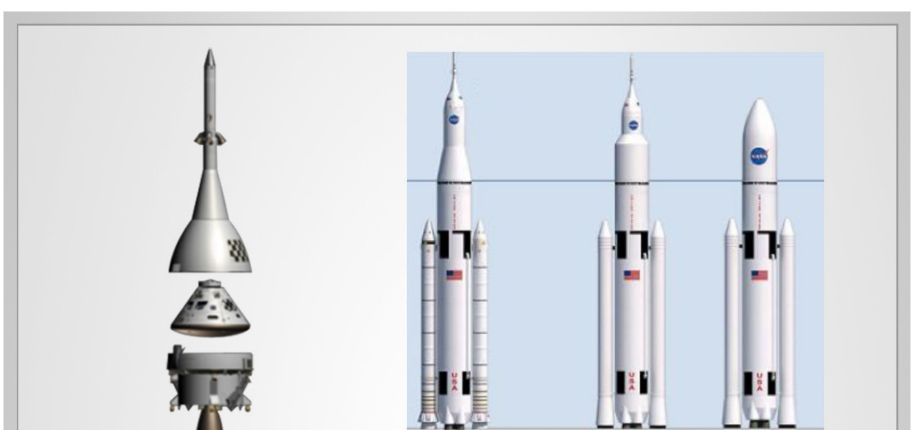
Distributed and Parallel Processing [7]

Computational environments for these advanced systems for decision making use and parallel distributed processing systems. This is due to the need for computer support that (1) is capable of handling multiple models , (2) supports HLA , (3) is Open Source (to allow modifications) , and (4) is a proven system that can be used as the backbone of advanced simulation environments .

Computer systems that assign events on multiple processors to speed up the simulations improves execution time , especially when operating the large number of high speed processors and internal communications that are found in high-performance computing platforms . The object-oriented architecture has a significant impact on the development of these systems. The entities in a system can be represented by individual classes. These representations, in turn, facilitate the distribution of the models on different processors and the design of parallel experiments. Additionally, the distributed environments are run through the World Wide Web.

Discrete Event Simulator for the Operational Cycle of Spacecraft

NASA [8, 9] has announced that the next manned spacecraft will be the MPCV which is based on the design of the capsule of the Apollo Program (Figure 2a). The MPCV and SLS (Figure 2b). Figure 3 is a model of a discrete event simulation to model the assembly of the SLS and MPCV in the VAB building which is also shown in Figure 4. This discrete simulation model was built by consulting experts from NASA and used time / characteristics of the NASA Space Shuttle as a baseline. SLS consists of different modules. These modules should be assembled in the VAB. The following sequences are required for this assembly:



(a) The MPCV is for astronauts [2]

(b) The SLS will be the most powerful rocket in history [1]

Figure 2. The MPCV and SLS.

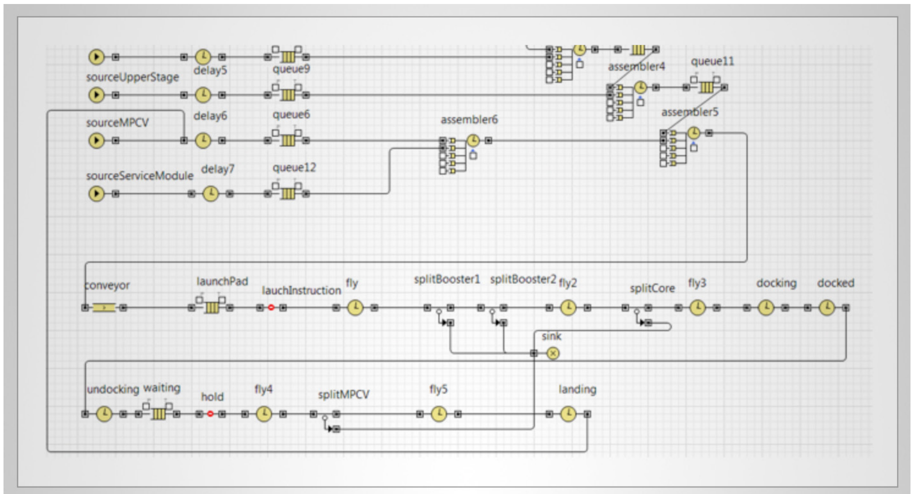


Figure 3. Partial representation of the model for the discrete event simulation for assembly of the SLS and MPCV inside the VAB .

1. Phases 1 and 2 of the SLS are transferred to the VAB: the first phase and the second phase of the SLS arrive at Kennedy Space Center (KSC). They are inspected, then off-loaded and towed to the VAB transfer "island", where they are stored until they are integrated with the solid rocket boosters (SRBs).

2. Solid fuel rockets (SRBs) are assembled in the VAB: The SRBs are assembled in the hangars of the VAB . Also, parachutes and avionics systems are added to the SRBs.

3. Phases 1 and 2 of the SLS are assembled and coupled to the SRBs in the VAB: This is achieved through cranes which bring the phases into a vertical position at the transfer island, are raised, and are assembled.

4. MPCV is integrated in the VAB: The MPCV is towed to the VAB and placed in the VAB transfer island. A crane is attached to the MPCV and the vehicle is lifted and attached (coupled to Phase 2) to Phase 2 of the SLS and thus completes the spacecraft.

Not only you can make simulation models for CubeSats. A CubeSat is a miniaturized satellite for space research that has a volume of exactly one liter, a mass of 1.33 kilograms, and typically uses industrial electronic components. "Beginning in 1999, the California Polytechnical State University (Cal Poly) and Stanford University developed the CubeSat specifications to help universities worldwide to perform space science and exploration." The majority of the development comes from the academia, but several companies have also built CubeSats .

Figure 4. The Vehicle Assembly Building (VAB) was built for the Apollo program (1964). The VAB was designed to store and assemble the 110 meter tall Saturn V rocket. One of the most notable characteristics of the VAB is its 139 meter tall doors (they are the tallest doors in the world). The VAB is also used to mount the NASA Space Shuttle. The VAB is used for the mounting and assembly of the SLS and the MPCV. Photo courtesy of NASA.

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*Figure 5: CubeSats are small satellites used to study space weather and atmospheric changes (Adapted from http://www.nsf.gov/news/news_summ.jsp?cntn_*

Continuous simulator to investigate whether microorganisms can survive on Mars

Mars is considered a likely place to find extraterrestrial life for the following reasons:

- Proximity to Earth:
- The presence of Carbon and other essential elements,
- The presence of water.

There are possible sources of energy on Mars that could support microbial proliferation, such as:

- Sunlight,
- Iron ,
- Sulfur ,
- H2/CO2.

The current debate is whether terrestrial microorganisms can survive and live on Mars despite the Martian environment where they would be exposed to intense radiation, oxidation and extreme dehydration. This can be verified by creating continuous simulators that simulate the microorganisms and their DNA and their exposure to the Martian environment. The Martian atmosphere can be described in mathematical way and the chemical reactions can be described.

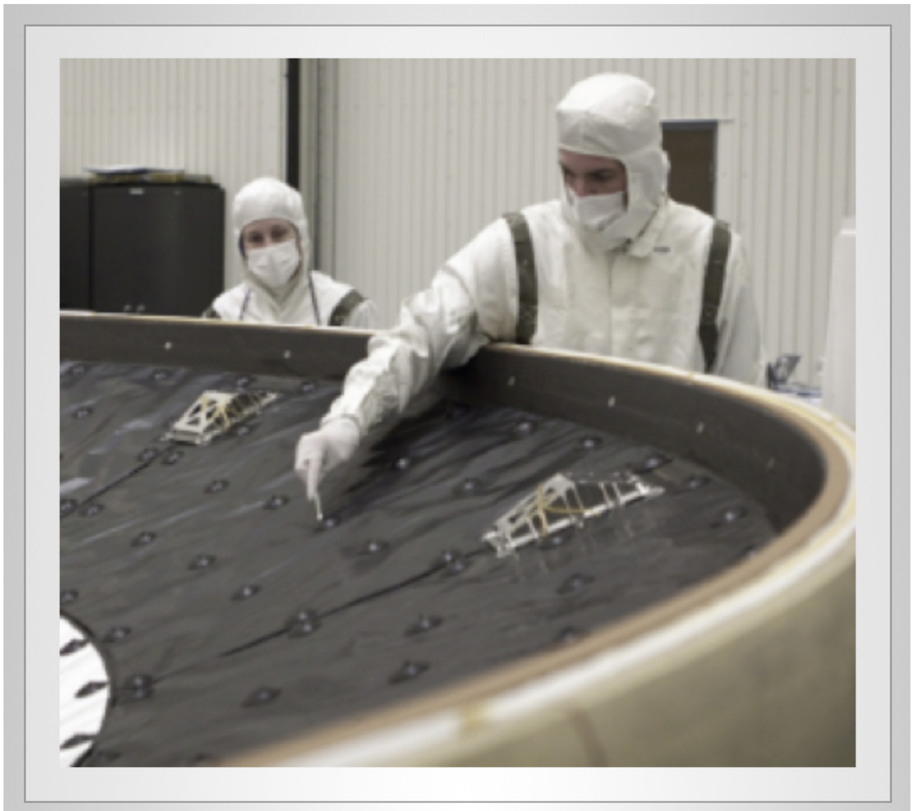

Figure 6: NASA engineers examine the heat shield of the "Curiosity Rover" and check its cleaning. Photo courtesy of NASA [6].

Simulation with Agents to study human resources for the Space Program

Agent-based models are able to capture certain features that are not possible with discrete and continuous event models. In this simulation there are two types of agents. One type of agent is the employer (e.g., NASA KSC) and other agent is the employee (for example, a NASA engineer) [4]. The agents are implemented using AnyLogic (http://www.anylogic.com/). AnyLogic provides a "Class" called an "Active Object ". Active objects can be used to model employees and employers. Employees are modeled by a discrete event system with the support of state diagrams. Employees move from one state to another based on the decisions made by the agents (e.g., training) and / or interactions with the environment. These agents can share states and resources with other employees. Furthermore, an active object is derivative of a class of active objects. Active objects such as an “Employer” may encapsulate other active objects to any desired depth.

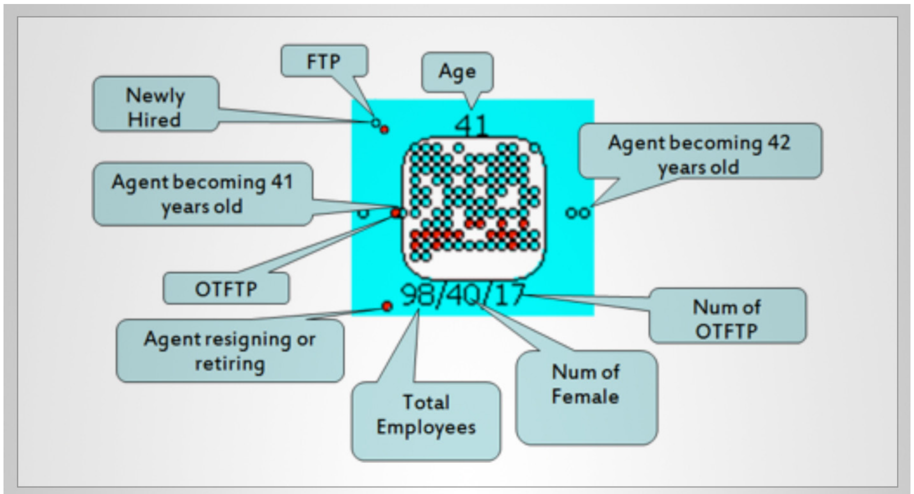

Figure 7: Animation of the engineers who are 41 years old.

According to Figure 7, there are 98 engineers with 41 years of age , 40 of the 98 are women , and 17 of the 98 are on temporary contracts . In another dimension, one can visualize the area of specialization and the corresponding level of experience.

Therefore, the modeling of the individual productivity of engineers and their teams to achieve different objectives of the program / project can be achieved using agents. The different areas are based on the engineering needed to carry out the transformation of the Space Center of the Space Shuttle to a Launch Center for the MPCV / SLS .

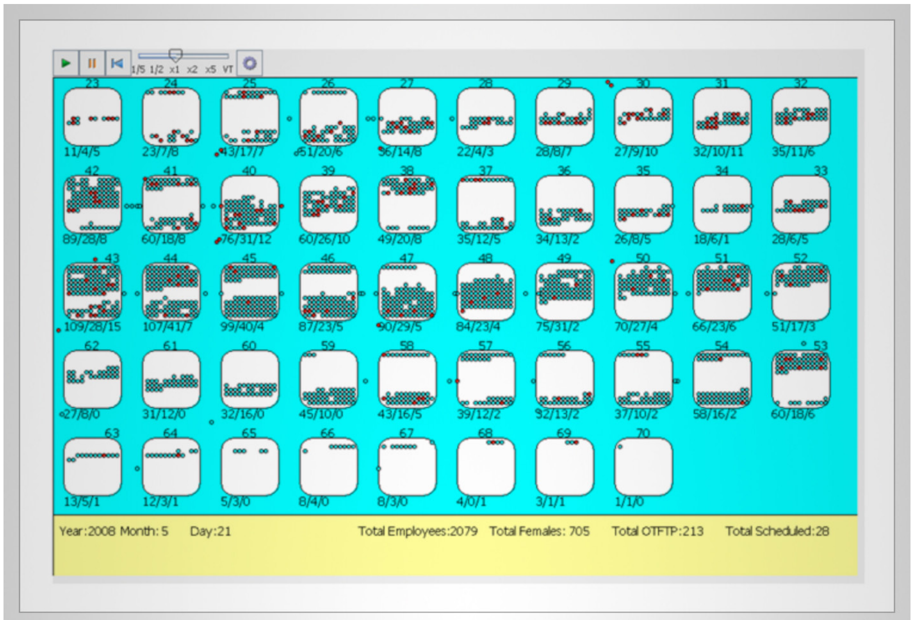

Figure 8: Representation of all simulated labor of the NASA Kennedy Space Center at a determined moment (May 21, 2008). There are different blocks of employees, aged 23 to 70 years old (2079 employees).

Conclusions

Simulation is one of the most important areas for space exploration. The Office of the Chief Technology Officer (OCT) of NASA [5] has stated that "simulation focuses on the design, planning and operational challenges of the distributed and long term NASA mission systems." We agree in that the model represents the characteristics of a system from a one dimensional or multidimensional viewpoint. On the other hand, the simulation is the execution of a model that has the potential (if the model is able to adequately capture the characteristics to a certain level of fidelity) to represent behavior. In addition, the OCT Office tells us that "Through the combination of the two, we can make better decisions and communicate decisions early in the design and development process when changes are easy and quick , rather than during production when they are very expensive and almost impossible " . For this reason simulation is very important for Astronautical and Aerospace systems.

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