

An Evolving Functional Digital Twin Tool Suite for Human Space Systems

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From its inception, the National Aeronautics and Space Administration (NASA) has relied heavily on Modeling and Simulation (M&S); that continues to this day. Even as early as the Apollo 13 mission, NASA used what was then called 'living models' to help save the crew. Those 'living models' of the Apollo 13 spacecraft would now be called a digital twin. NASA's Johnson Space Center (JSC) is the center for human space flight and the home of NASA's astronauts. It is also the home of the Software, Robotics, and Simulation Division (ER) and its Simulation and Graphics Branch (ER7). For over 30 years, ER7 has been responsible for assessing M&S technologies, developing methods of applying those technologies, and deploying solutions to address the challenges of human space flight. Initial ER M&S technologies were specific to the needs of single spacecraft simulations operating in low Earth orbit (LEO) (e.g., Space Shuttle and the International Space Station (ISS)). However, the ISS introduced the need to model a variety of visiting vehicles. With the advent of the Constellation program, it became clear that our simulation tool sets needed to be more capable in both modeled destinations and space systems architecture. The Constellation destinations were the Moon and Mars, beyond LEO. The mission architectures were more complex than either Shuttle or ISS and even more complex than Apollo. To address these challenges, ER7 began to modify, enhance, and rearchitect its core M&S tools, many that were validated against flight systems. As NASA moved forward in establishing the Artemis program, ER7 was well positioned to adapt these tools into a better integrated and primarily open-source M&S infrastructure. These tools now form a foundational product line that are used to create large scale distributed integrated simulations of many of the complex system of systems that constitute current and proposed Artemis missions. These tools are a functional foundation for building a digital engineering environment for NASA's human space flight systems and will enable the creation of digital twins for elements in the Artemis program. Many of these tools have been discussed in previous referenced publications. This paper will focus on the overall tool suite and the general framework relating to a functional digital engineering environment. In addition to a high level outline of the tools, it will also focus on the associated workflow between tools, discuss technology gaps and choke points in the current workflow, and identify interoperability and data standards in current use. We will also provide some examples of specific Artemis applications along with descriptions of the hosting facilities. The paper ends with a discussion of plans to better support both digital engineering and digital twins.