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Human systems integration: process to help minimize human errors, a systems engineering perspective for human space exploration missions

Jackelynne Silva-Martinez *

Georgia Institute of Technology, NASA Johnson Space Center, 1315 Nasa Parkway Apt 301, Houston, TX 77058, United States
Georgia Institute of Technology, NASA Johnson Space Center, 2101 E NASA Parkway, Houston, TX 77058, United States

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ABSTRACT

This review article highlights the importance of human systems integration (HSI) in human space exploration. One may think of these terms as common sense, some companies even have some regulations in place for something that sounds similar. However, there is still some work to do in order to fully incorporate the human aspect into our aerospace systems, especially today when we are working with complex and multidisciplinary system of systems. For that reason, this article brings the concepts that different programs are using and integrates them, to put into perspective how different disciplines have similar concepts and goals, bringing opportunities for collaboration. Definition of system, system of systems, systems engineering, human systems integration, human error are provided, and how all these come together. Then an assessment is made of various human reliability analysis techniques used in non-aerospace industries, and how they can be applicable to space systems. The use of error prevention HSI tools is discussed, including human in the loop evaluations, usability tests, and workload evaluations. The article dives into the human systems integration domains at the Department of Defense (DoD) and at the National Aeronautics and Space Administration (NASA). A comparison graph was created showing HSI activity across mission lifecycle phases and reviews for a commercial product, the DoD, and NASA, using the SEBoK System Life Cycle Process Model, ISO/IEC/IEEE 15288 Systems and Software Engineering International Standard for System Life Cycle Processes, NRC Human-System Integration in the System Development Process, and the Human Systems Integration Practitioner's Guide NASA/SP-2015-3709. Learning about these tools and processes will aid the architecting and engineering of habitats, vehicles, and simply put systems for deep space missions, for which human limitations and capabilities must be accounted during the design phase and continue throughout the product lifecycle to help minimize human error, hence increasing human and product safety.

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* Address: Georgia Institute of Technology, 1315 Nasa Parkway Apt 301, Houston, TX 77058, United States.
E-mail address: jackelynnesm@yahoo.com

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1. Introduction

Human spaceflight has a long history of success and also failures that have been used to make space missions stronger. Starting from a space race and science fiction the ultimate goal now is to satisfy that exploration part of our human system. Human evolution is driven by that exploratory spirit that took by hand technology to aid on our search to go above and beyond. This review article salutes those endless efforts to make discoveries, take risks, learn from mistakes, and use innovative ideas and technology to help us better understand our universe and ultimately help our society in daily activities. An important consideration for success is the learning curve that we have with the unknown characteristics of space. In earlier phases of preparation for our exploratory trip to space there was a lot of pressure that made our space missions vulnerable to failures. As we learned the systems and applied new knowledge these missions became more robust and we are now guided by governing documents and processes that help minimizing that risk upfront.

This paper puts into perspective Human Systems Integration (HSI), starting from concepts that different programs at various organizations are using and integrating them to provide a robust guide for enabling better error management in human space missions, as well as other aerospace programs. This can only be achieved by being open to learning from and understanding other disciplines. The first section of this article focuses on the definition of terms that we may commonly use in our daily work activities but sometimes may mix them up. We define a system, system of systems, systems engineering, human systems integration, human error, and how all these come together. The second section makes an assessment of various human reliability analysis techniques used in other disciplines and how they can be applicable to space systems. The third section dives into HSI domains at the Department of Defense and at NASA, and how they compare. We conclude with future work and conclusions.

1.1. System of systems

System of systems (SoS) sounds like a trend term in industry nowadays. In reality, this idea has been out there for quite a long time [1]. Before we dive into SoS, we need to understand settle differences in the definition of some terms:

1.1.1. System

The Systems Engineering Guide for Systems of Systems defines system as "a functionally, physically, and/or behaviorally related group of regularly interacting or interdependent elements; that group of elements forming a unified whole" [2]. In other words, a system is an integrated composite of people, products, and processes that provide a capability to satisfy a stated need or objective.

1.1.2. Systems engineering

Systems engineering consists of two significant disciplines: the technical knowledge domain in which the systems engineer operates, and systems engineering management [3]. INCOSE defines systems engineering as an interdisciplinary approach and means to enable the realization of successful systems [4].

1.1.3. System of systems

SoS is defined as a set or arrangement of systems that results when independent and useful systems are integrated into a larger system that delivers unique capabilities. For this we need to define capability, which is the ability to achieve a desired effect under specified standards and conditions through combinations of ways and means to perform a set of tasks [2].