Systems Analysis Using the Vee Model and Concept of Operations in Human Systems Integration

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Abstract. Systems engineering is a holistic approach that typically does not include the human as an integrated part of the system. Having an organization that takes a more HSI (Human System Integration) approach will allow for requirements that integrate people with the technology needed to solve a problem from a user perspective. Using the systems Vee designed for this approach and integrating human information into a concept of operations focusing on the user's perspective we can create user centered requirements. This will be demonstrated using an example of how disabilities can be addressed in an aircraft.

Keywords: Systems Vee, Humans Systems Integration, Concept of Operation, Requirements, Human Centered Design, American Disabilities Association

Introduction

Humans Systems Integration has a focus on TOP (Technology, Organization and People). Systems Integration typically focus on the system with the human as an actor outside of the system. Focusing more on the TOP perspective allows for the human to be better considered. When an organization desires to improve their user experience, system engineering is a vital tool. However, the humans using and making the product need to be fully engaged in the process. When this happens, it allows a company to engage in an organized method for breaking down a project related to human needs.

The Human-centered design (HCD) process is an interactive system design approach that engages the users in problem-solving from the initial stage and considers human perspectives throughout the design process. Although it has been widely used in software design and medical device design industries, it has not been systemically adopted in the aerospace industry. The first step of HCD is to identify users' needs and understand the context of use, which sets the foundation to design for the users. This step often is missed in the traditional system engineering design approach.

This paper intends to share a conceptual model to link HCD process with the traditional system Vee model. Adding a step to the left arm of the Vee will help to ensure users' needs are formally evaluated and documented. The users' needs can then be translated into system objectives and requirements which further decomposed into subsystem and component requirements. A modified Vee model will be introduced in the next section, followed by an example to show how it can be applied to the aircraft cabin design for disabled passengers. The modified Vee model focuses on integrating the human such that it assists as a method of development. Then a discussion on how systems engineering can be used to develop requirements directly for a human user of the system.

Concept of Operations

Using a concept of operation helps to understand the usage, assumptions and intent regarding the system will function. It is one of the first items that should be completed once a new need has been identified. It will describe what the system will do. An important part about the concept of operations is it does not describe how the system will work (It does not design the system). Using human systems integration and human-centered design the user is part of the system, this allows for the integration of the user into the system. Having the user as part of the system, this allows for the operational analysis to include the human interfaces. The integration of human and systems allows for a more detailed concept of operations.

Systems Vee model and Humans systems Integration

Using the INCOSE systems Vee as a starting point (Figure 1). It can be seen that the Vee is fairly generic and allows room for the general description of what is used to accomplish each phase in the development of a project. The system Vee typically moves between the functional and physical design of the system. The core activities are usually synthesis, description, analysis, simulation and decision-making. The involvement of the system user is normally considered an actor outside of the system. This typically does not address the social-technical aspects of the system from an HSI (Human Systems Integration) perspectives. The people and organizations, such as the skills, culture, and attitudes that they provide, need to be a part of the system. The technology of the system such as software, hardware, tools need to relate to the user of the system.

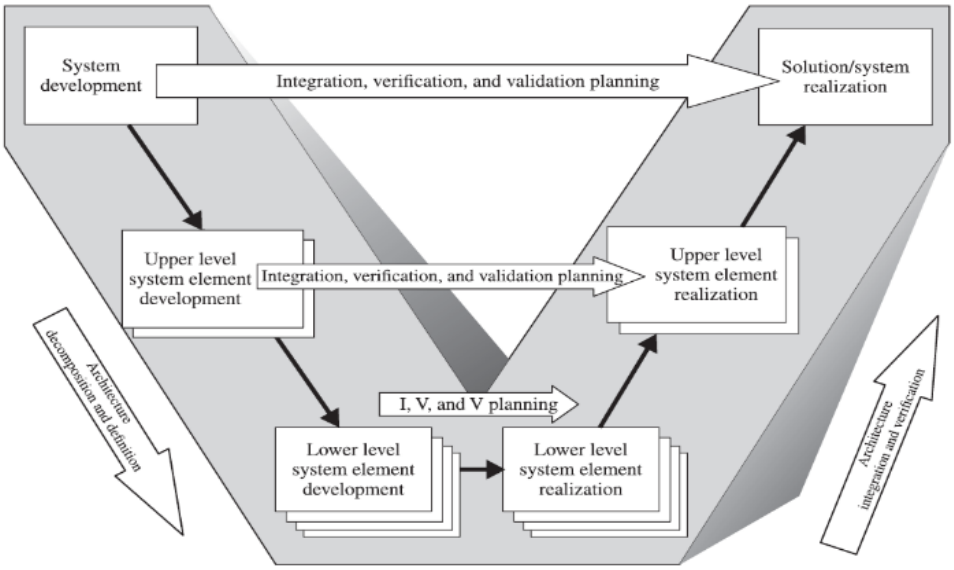

FIGURE 2.6 The SE Vee model. From Forsberg, et al. (2005) with permission from John Wiley & Sons. All other rights reserved.

Figure 1:

INCOSE Systems Engineering Handbook Vee diagram (2023)

The systems Vee used in this example is a hybrid derived from traditional systems Vees used by several industries, such as the computer industry. The Vee is shown in Figure 2. This Vee has more of a focus on developing the system for the human using the system. The main difference is the addition of a concept of operations before creating any design requirements. This keeps the focus on the users' needs and works to provide a design that addresses these needs. In the early stages of systems engineering customer needs and desires are typically identified and considered. This addresses how to look deeper at achieving the users' needs and find the requirements that will fulfill those needs. With this approach, it is possible to find needs that are critical and unknown to the user.

The top row of the diagram in Figure 2 is a summary list of the typical items needed in the development process. It starts with the high-level identification of requirements. These are requirements needed to understand and scope the project. If the project has multiple systems, requirements need to be developed for each system and their interfaces. Once this is completed, the item can be designed and verification activities will begin. Then, the system verification can occur. The integrated system then needs verification. The verification activities can be completed through several methods, such as modeling and prototyping. This allows for the development in a systematic manner.

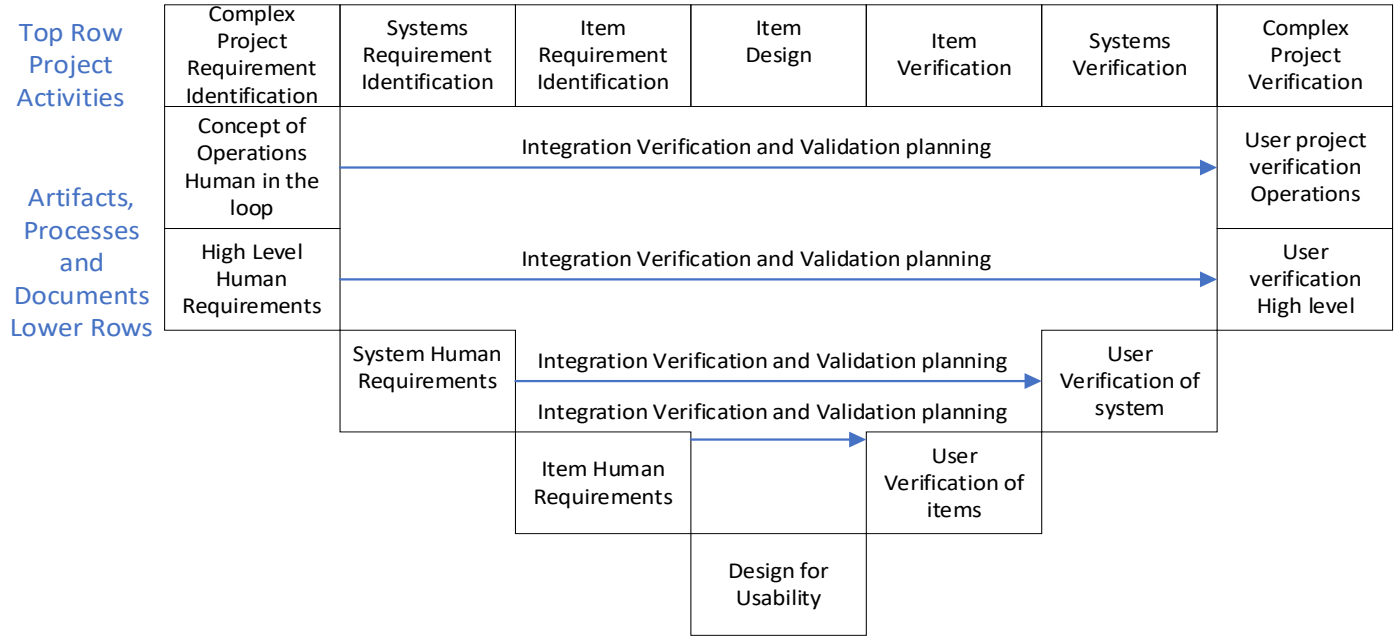

Figure 2: Systems Vee using a human systems integrated approach

The Vee portion of figure 2 has the addition of a concept of operations. The use of the concept of operations in this case will be a function to help determine how the human will use the system. The concept of operations will be key in understanding the user and link many of the methods used in this task. In order to get a complete concept of operations, user needs must be understood. Some methods that can be used to define user needs are defining the end-user population, case studies, user-based evaluation, journey mapping, expert-based evaluations, and day-in-the-life analysis. Once user needs are collected, a concept of operations can be created and used to develop the operational architecture and user requirements. Model-based systems can and should be used for this approach, they can provide a visualization and integration of data.

The rest of the Vee follows a decomposition of requirements from the system level to the item level. From this point the design is started. The verification process starts at the item level than system level and lastly the high-level varication of the user of the system.

Case Study: Accessible Airplane Cabin design

This case demonstrates taking user centered design and integrating HSI when designing an accessible airplane cabin for disabled passengers, considering the technology, organization and people. A concept of operations would be created. The would outline what operations are intended to be accomplished. In this example, the concept of operations is set up to bring a disabled person into the airplane, go through a flight and leave the aircraft safely and comfortably. It is important to understand that the concept of operations will include the human to machine interface. A simplified concept of operations example is in figure 3.

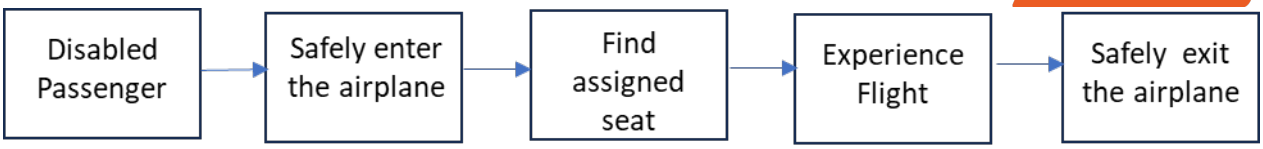

Figure 3: Simplified concept of operations

The first step is to understand what the concept of operations intends to accomplish. In this case understanding how to safely bring a person in the aircraft, through the flight and exiting the aircraft is the primary goal. This outlines the concept of operations.

The second step is to understand the user group. The user population include a wide range of capability in mobility (strength, balance, coordination, endurance, body parts involved, functional level and more), hearing, sensory, visual, speech, and cognitive functions. They could have a single or multiple disabilities and in all age groups. The system components include controls and features such as attendant call buttons, toilet flush control, faucet, soap dispenser, toilet seat cover, door lock, light, air vent, and in-flight entertainment. It helps to scope how the variations of the humans operate the system and controls.

As outlined in the Suggested Guidelines for Accessible Lavatories in Twin Aisle Aircraft (Air Transport Association of America, ATA Document 91-XX, 1992), passengers with mobility impairments can be categorized into several groups by mobility function, use of mobility aids and toileting function.

The first group is limited ambulation and they can move unaided. These people have a wide range of strength, coordination and balance. They could have difficulty sitting or standing. The representative medical conditions in this group include elderly, cerebral palsy, epilepsy, chronic pain, arthritis, Parkinson disease and more.

The second group is limited ambulation with aids. They use a cane or walker during boarding and are able to walking down the aisle to use lavatory. The walking aids require extra space inside an aircraft. This group can be further subdivided according to their ability to transfer and their ability for toileting functions.

The third group is wheelchair dependent. They can be further divided up into 5 sub-groups as defined in table one.

Table 1: Division of Wheelchair Groups

Group Number	Description
1	Independent Transfers with Normal Toileting: may choose to use the airport terminal lavatory to avoid transfer
2	Partially Independent in Transfers with Altered Toileting
3	Dependent in Transfers with Normal Toileting

4	Dependent in Transfers with Altered Toileting
5	Spinal Cord Injured with Altered Toileting

There are various transfer techniques used by the wheelchair users, one is they can do the transfer independently another is the use of assassinates from others. Depending on the type of the transfer, the space requirements will vary.

After understand the characteristics of the disabled passengers and define the sub-groups according to the functional variations as discussed above, the next step is to use journey mapping to identify users' needs during flight when performing various activities.

Additional research such as observing users during flights can be done to capture users' pain points and needs during the flight that may not have been documented.

When all this information is placed together with a concept of operations the requirements are created. These requirements are focused on the user of the system. In order to make sure they are good requirements; the following are key to understand. Do the requirements trace back to the concept of operation and work with the intended function? The traceability is important to understand, this provides information on how the system requirements relate to the human requirements. Lastly, validate requirements are developed for all system stakeholders and verify all the user needs are covered.

Once the user requirements are understood the system requirements can be started. This then leads to the typical systems engineering processes and it can design the items to meet the user requirements.

Conclusion, Benefits, Challenges and Opportunities

Following the outlined methodology has some very useful benefits. Using HCD, HSI and forming a concept of operation allows for requirements to be focused on the needs of the user. The disabled passenger population constitutes a diverse composition. Therefore, capturing the user's need is extremely important to create requirements that will ensure systems or products that are inclusive for all users. Without this approach, the design requirements may not properly reflect the user's needs and may not solve the problems or fulfill the design intent.

This approach can allow for Model Based System Engineering (MBSE) to allow for a digital environment that would provide traceability throughout the process. The models can be focused on the user with an architecture based on how the user operates the system.

Some of the implementation challenges are the integration between systems engineering, human factors engineering, design engineering and all stakeholders. This creates a need for a broad cross-functional team with the appropriate technical knowledge to develop the models properly. Gathering suitable data and information to complete the studies and the concept of operations can be very complex but can save cost of re-work in the long run.

This does provide us with several opportunities. It is key to understand that updated methodology can take time to adapt to a company's culture. As a result, before implementation it is important to get support from all levels of the organization. This paper detailed information for the ability to create a concept of operations and requirements with a user focus. It did not go through the other portion of the Vee, where the design and verification occur, this creates the opportunity for future topics.

To summarize, when the systems Vee is considered and viewed in a manner to be used for HCD and HSI principles, it can be used to focus on the user needs. This allows for the creation of requirements that can fulfill the users needs and be used to create a design that will meet those needs. Having the user integrated as part of the system that using system engineering principles provides more opportunity to fulfill their needs.

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