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Model-Based Systems Engineering in Support of TALOS System Integration

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Abstract: The Tactical Assault Light Operator Suit (TALOS) was a project initiated by Admiral McRaven after a Navy Seal lost his life passing through a doorway when clearing a room. United States Special Operations Command (USSOCOM) took charge of the project with the idea of an exoskeleton that protects the first person who enters a room during the team operation. USSOCOM is attempting to deliver an operational prototype of the suit in the summer of 2019. TALOS is in the integration phase of the process and attempting to implement a model-based systems engineering approach to this integration. Our project responsibility was to provide a visual representation of the TALOS operator's tasks and requirements that will make this suit a success. We used functional flow block diagrams (FFBDs), use cases, and a functional hierarchy to represent these tasks to allow both the military and civilian personnel to assess the suit's performance measures.

Keywords: Model-based Systems Engineering, Exoskeletons, Systems Architecting, Engineering-from-the-Middle

1. Introduction

United States Special Operations Command (USSOCOM) created the Tactical Assault Light Operator Suit (TALOS) project after the death of a Navy SEAL during a room clearing operation in Afghanistan. This raised the question of how the military invests so little in dismounted operations compared to vehicles. Consequently, Admiral William McRaven, the then USSOCOM commander, initiated the effort to create an exoskeleton suit in 2013, and since then the Joint Acquisition Task Force (JATF) TALOS has been developing a suit that special operators will use when breaching doors and clearing rooms. The goal of the suit is to increase the operator's survivability, capability, situational awareness, and surgical lethality (U.S. Government, 7). The TALOS program has gone through multiple iterations and revisions; it is currently on its fifth, with the expected delivery of TALOS MK-V due in the summer of 2018 (U.S. Government, 7). Over time, the understanding of the problem has evolved without a corresponding evolution in the base documentation and systems engineering. TALOS MK-V is currently in the "systems integration" phase and must establish test cases to ensure that it is achieving its requirements. Additionally, JATF-TALOS has established a model-based systems engineering (MBSE) team to facilitate this systems integration. A considerable portion of the systems engineering process started from the middle of the TALOS program. This is due to the incompleteness of a system architecture that could take too much time or be unnecessary. Consequently, waiting to develop a system's architecture may prove to be more costly as it may necessitate revaluation and rework which will reverse the progress that the system may appear to have made. Our work will address the gap that USSOCOM has in their behavioral architecture in order to minimize the effect of these consequences.

1.1 Problem Statement

This project's primary stakeholder is JATF-TALOS. Specifically within TALOS, we are supporting its systems engineering team to help develop test instances using model-based systems engineering. The objective of this capstone assignment is to support USSOCOM by providing them with the tools to better assess system performance in future tests and evaluations. USSOCOM has CONOP tasks that have some specificity, and at the end of our research, we should effectively model the functional hierarchy, use cases, and functional flow block diagrams (FFBD) for the TALOS suit's operational tasks.

2. Literature Review

One challenge in systems engineering is creating a set of integrated tools and functions that work in conjunction with one another to get the system into an operable status. The number of tools one could use is nearly endless, but several necessary options are available. This is challenging once a team is already deep in the engineering process. This "engineering from the middle" requires careful selection of tools and are augmentable with MBSE.

While most systems engineering should start at the beginning of a project, it often does not happen. As a result, systems engineers use engineering-from-the-middle in which they utilize a project's previous tools and information (Bahill, 2001). Beginning a project from scratch poses several issues such as a time constraints and cost. Engineering-from-the-middle allows teams to move forward with extensive information, less time constraints, and past information on what may or may not benefit the system.

All systems will have a set of tasks that it must be able to complete which organize into a functional hierarchy. Using these tasks, there are several ways to come up with top-level functions and sub-functions including, but not limited to, brainstorming, interviews with experts, previous work in the field, and morphological analysis. The process of creating a functional hierarchy is fluid and is subject to change at any point during the project (Parnell, 2011). Functional architectural designs allow us to take the functions created within the functional hierarchy, and identify the interactions that each function requires in order to complete system tasks (Parnell, 2011). These interactions may include how the system uses inputs. Separate tables with system inputs and their descriptions are tools that aid in clarity, and allow the further identification of which functions rely on what specific interactions. These designs create cases that test system functionality and accuracy on the system's ability to complete the task.

Functional flow block diagrams (FFBD) are visual representations used to identify and illustrate the relationship between the system functions and sub functions (Parnell, 2011). These diagrams help the concept development and design while identifying the performance measures that the system needs. FFBDs incorporate the elements from the system's functional hierarchy to show how each function and sub function relate to the system dynamic (Parnell, 2011). The diagram takes the top-level functions, and creates a string of events that represent a certain tasks that the system performs. In order to add more detail to the diagrams, sub functions of those top-level functions are below the top-level functions for a more precise order of events.

A use case describes a system's behavior under certain conditions as it responds to requests from the stakeholders. The primary actor initiates an interaction within the system, and the system responds to protect the interests of all the stakeholders (Cockburn, 2012). Although there are different behaviors or scenarios that can unfold, the use case compiles those different scenarios together (Cockburn, 2012). A typical use case contains the scope, primary actor, level, actor, stakeholder, primary actor, use case, scope, preconditions and guarantees, main success scenario, extensions, and technology and data variations (Cockburn, 2012).

"Model Based Systems Engineering (MBSE) techniques facilitate complex system design and documentation processes" (Topper, 2013). It includes a conceptual development process consisting of domain modeling, use case development, and behavioral and structural modeling. A model-based approach allows us to break down the system into component parts, and create test cases that reveal the functionality of the system. In the development of complex systems, models assist in decreasing the cost, test errors, and risk of design, improve communication, and product quality much better than the traditional alternative of document-based systems engineering (INCOSE, 2015). In this method, most of the systems design is in documents and reports and contributes to the complications that MBSE assists in resolving. Traceability becomes a massive problem within this method because many systems have single functions that could take dozens of pages to explain or properly describe.

A combination of all these tools allows systems engineers, whether they start from the beginning or the middle of a project, to take a problem definition, realize its scope, and come up with, in many cases, multiple models and scenarios that solve the issues. The model design of the TALOS project did not start at the beginning with the current capstone group. Although there are other functional modeling techniques that could provide usefulness to TALOS, our group created FFBDs, use cases, and a functional hierarchy as per guidance from COL MacCalman. In order to meet the system requirements, we must take the guidance given to us, integrate functional architectures, and create models to better define the capability and probability of the TALOS system.

3. TALOS Operational Modeling

The TALOS project has evolved since 2013. TALOS is currently attempting to integrate subsystems and testing evaluations. To support this effort, there needs to be a means to check the functionality of the suit and evaluate how USSOCOM intends to continue the project.

3.1 TALOS Functional Hierarchy

The TALOS functional hierarchy includes six level 0 functions: Engage enemy, Move, Communicate, Use Equipment, Make sound decisions, Sense environment. In the creation of our functional hierarchy for the TALOS system, we came up with discussed the different sub-functions we should place under each level 0 function with an expert in the field, MSG Joaquin Marquez. Moving forward, we simultaneously continued to create new functions while corresponding with MSG Marquez to test the validity of our functions ability to accomplish the task. As we continued to use the MK-5 Storyboard given to us by COL MacCalman to accomplish each task, we continued to adjust and add additional functions to the hierarchy we created. Continued adjustment to the hierarchy is not only crucial but also necessary to ensure the TALOS has the required functions resulting in the ability to accomplish each task and mission.

TALOS is a rather complicated system that both military and civilian personnel are working on. In order to help fill the gaps between both the two groups, our task was to create a visual representation of the tasks that the TALOS operator must complete. By creating these visual representations, it allows both parties to see where they are able to measure the suit's performance and decide what they need to focus on moving forward. We used functional flow block diagrams and use cases as the visual mechanisms because they both are simplistic in nature while being conceptually sound.

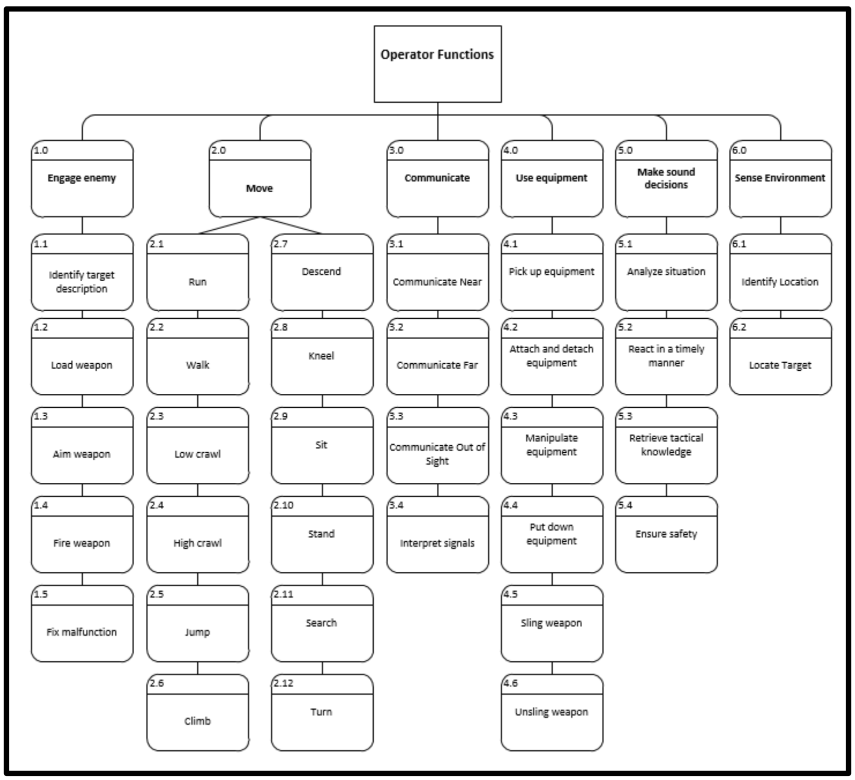

Figure 1. Functional Hierarchy for the TALOS operator

3.2 Operator Tasks

The MK-5 Storyboard is a PowerPoint presentation our group received from TALOS. The storyboard contains a list of twenty-three TALOS operational tasks that the operator is required to perform while wearing the TALOS suit. Each task contains information specific to how the task will start, specific actions and parameters for the task, when the task is complete, and information that is still to be determined. We used this information to help construct our functional hierarchy, functional flow block diagrams, and use cases. Our group used all of the operational tasks to construct our functional hierarchy. However,

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our group only constructed use case diagrams and FFBDs on twelve of the twenty-three operational tasks. We decided to exclude certain operational tasks whose simplicity did not warrant FFBDs or use cases.

In regards to TALOS, each task uses the six top-level functions, engage enemy, move, communicate, use equipment, and sense environment, to create functional flow block diagrams for each operator task. These tasks are identified in the systems requirements, mentioned in the previous section. We broke down each task in terms of the top-level functions are identified which of them were necessary in completing the said task. After identifying the top-level functions involved, we created the scheme of maneuver, in the form of FFBDs that the operator would have to perform in order to complete the task. Once top-level functions are in ordered sequence, we added more depth in the analysis by breaking down the top level functions into sub functions that better described the actions.

3.3 FFBD Example

To explain how we created our FFBD we will review one of the key tasks, walk upstairs while engaging target, as shown in Figure 2. The CONOP provided the steps of the stairs would have an 8” rise with a 12” run, and the house would only have a single hallway at the top of the stairs. We have acknowledged the other system inputs of the stairwell characteristics along with team members that will affect the performance of the operator. Through our personal knowledge and the guidance of tactical expert MSG Marquez, we were able to create the plan of action for this task. Additionally, MSG Marquez revised the FFBDs for accuracy. We started with the top-level function of engage enemy, as you do not know when you will encounter the target. We broke down engage enemy into its sub functions in the following order: load weapon, locate target, aim weapon, fire weapon or fix malfunction, and identify target description. These are the simple tasks needed to prepare to react to enemy shooting. After engaging the target, the operator will continue to ascend the stairs. While moving up the stairs, the operator will be communicating with his/her team members to get a better handle on the situation. Through communication, the operator will communicate nearby to team members to gather information or give them an update on the enemy. Once the team is on the same page, the operator will make a sound decision by analyzing the situation in the stairwell and deciding whether they should continue to move forward. From there the last decision would be to engage the enemy if another one was there, at which point the operator would go back through the process of this task from the beginning.

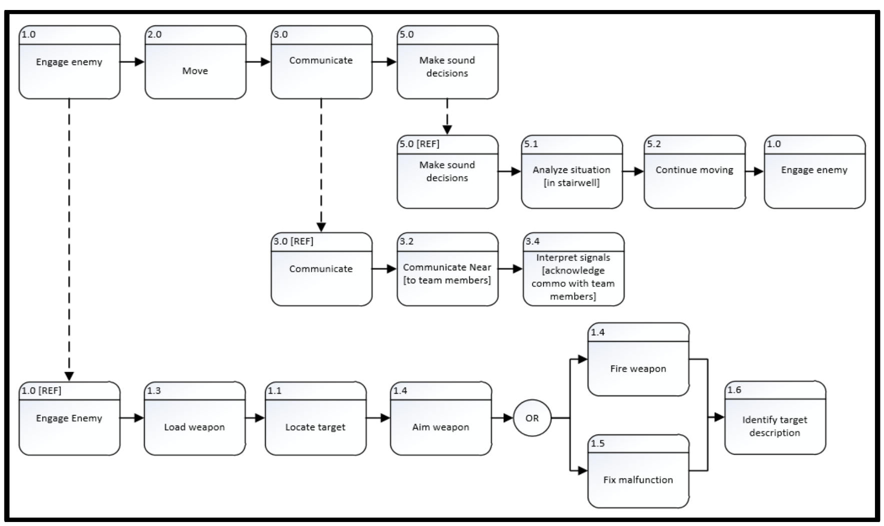

Figure 2. FFBD for Task #14 Climb Stairs While Engaging Enemy

3.4 Use Case Example

We used the information from the TALOS Task Concept of the Operations, and created a one-column table for each of the twelve tasks in order to communicate the relationship between the stakeholders, primary actor, and different tasks the TALOS operator needs to be able to perform. The use case provides a more transparent understanding of the task the operator will perform. Our methodology for constructing use cases includes taking information from each of the TALOS Task Concept of the Operations, and organizing the information into a one-column table use case. Figure 3 in the appendix references use case number fourteen which involves the TALOS task climb stairs while engaging an enemy. The scenario involves a situation where an operator is searching a house, and would need to engage an enemy while walking upstairs. The operator will have his

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weapon at the high ready, and there will be a possible enemy threat at the top of the stairs. The operator will aim his weapon upwards, and continue to ascend the stairs. The task is considered a success if the operator can successfully ascend stairs and engage any potential enemies. Figure 3 represents how our group organized TALOS Tasks Concept of the Operations into an effective use case.

USE CASE # 14	Climb Stairs While Engaging Enemy
Context of Use	Operator will ascend flights of stairs while engaging an enemy
Scope	TALOS Suit
Primary Actor	Operator
Stakeholder and Interests	Operator successfully climb stairs while engaging any enemies
Preconditions	Stairs that operator must ascend
	Weapon at high ready
	Possible Enemy threat above
	Local security already established
	Dark, light, or limited visibility
Minimal Guarantees	Operator is capable of moving up stairs
	Operator is capable of aiming weapon upwards
Success Guarantees	Operator successfully ascended stairs
	Operator engaged any enemies
Trigger	Operator begins moving up stairs
Description	**Task Steps**
	1. Operator identifies stairs that must
	2. Operator aims weapon upward
	3. Operator begins ascending stairs
	4. Operator engages any threats
	5. Stairs have been ascended
Extensions	**Steps**
	4a. Shoots any enemies readily visible
Technology and Data Variations	TALOS Suit
	Weapon

Figure 3. Use Case for Task #14 Climb Stairs While Engaging Enemy

4. Future Work

This project is ongoing as JATF-TALOS is ongoing. The JATF is currently developing test cases for integration events in the spring and summer of 2018 and beyond. This work provides important context for these test cases. More importantly, it will incorporate into the JATF's SysML model using MagicDraw. With this, we can allocate these tasks or functions and external actors to TALOS system assemblies or test assemblies for these events. For future work, MagicDraw could facilitate the production of activity diagrams based on the FFBDs of the operator tasks. USSOCOM will also be able to use the FFBDs we have created for testing purposes as they continue development of the exoskeleton because this model based systems engineering for TALOS defines the relationships between system requirements and functionality. This enables USSOCOM to evaluate answers to questions such as the time required to complete a series of test events, concerns and risks they may have in the system plan, required resources to complete the test events, how to complete testing, and current progress on the completion of system testing. The FFBDs also improve USSOCOM's traceability for the TALOS system and its requirements as well as their ability to evaluate TALOS in an integrated assessment. Furthermore, as TALOS becomes more widely looked at as an option for different military purposes, the operator tasks may increase, which will create a need for more FFBDS and use cases. In addition, technological advancements are a continuous process that will occur apace with the TALOS project. These improvements in capabilities may necessitate the change of some FFBDs created for the TALOS operator tasks. For example, the unknown capabilities of the VAS assemblies and HUD components, referenced in the TALOS tasks, still need determining. These discoveries will make the tasks easier to perform and may consequently require a change in the structure of several related FFBDs. Constant adjustments will remain a part of this project until completion.

5. Conclusion

After the death of a navy seal when clearing rooms in Afghanistan, military leaders pushed for more dismounted protection for operators via an exoskeleton. JATF-TALOS began development of TALOS, and now they are currently in the system integration phase. They must run test cases to evaluate any missing requirements. However, they are unable to run these test cases with the gap in their behavioral architecture for TALOS. Consequently, our objective was to fill in the gap by modeling the TALOS operator tasks using various systems modeling tools. The completed FFBDs for the CONOP tasks depicts the process which the TALOS Operators will be required to complete in order to obtain operational success throughout their various missions. The functional hierarchy shows the breakdown of the functions located in the FFBDs, and the function definitions provide the specific details of each function. The Use Cases of each operator task outline the requirements to complete the task, as well as specific conditions and parameters for the completion of the task. This work will allow USSOCOM to assess and validate the progress on TALOS thus far and take into account any necessary changes or considerations.

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