Design and Development of a Pediatric Therapeutic Device Using NASA's Systems Engineering Processes

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Abstract

The Rural Infant Stimulation Environment (RISE) School of Huntsville requested a senior-class Capstone Design Team (CDT) from the University of Alabama (UAH) Mechanical and Aerospace Engineering (MAE) Department design and manufacture a device that will assist a RISE student who possesses severe muscular weakness gain more independent mobility. The CDT is utilizing the National Aeronautics and Space Administration (NASA) Systems Engineering (SE) Handbook to ensure a methodical approach to the design and development of a quality product. The NASA SE Handbook will enable the CDT to learn and apply important concepts for product design and development that are practiced in industry. The CDT's design solution, a rechargeable electric mobility platform that will incorporate the RISE student's favored Tumble Form® seat and deploy his existing, rudimentary abilities, is ready for development. This paper will detail the design efforts and assess the educational impact of the NASA SE Handbook upon the CDT.

Keywords

Engineering Design; Systems Engineering; Capstone Design; Design Processes; Trade Studies.

Introduction

The UAH MAE senior Capstone Design Course (CDC) is a two-semester sequence: *Introduction to Engineering Design* (MAE 490) and *Product Realization* (MAE 491). At the onset of the Fall 2016 MAE 490 class, the CDT was introduced to various industry customers with real product needs. One of the customers, the director of the RISE School of Huntsville, requested a product that will assist a RISE student gain more independent mobility to improve his classroom experiences. The CDT employed the NASA SE Handbook[1] to guide the design and development process. At the end of the CDC sequence, the CDT members will be surveyed to assess the impact of the NASA SE Handbook on the design and development of the capstone projects.

Systems Engineering Engine

One of the fundamentals of the NASA SE Handbook is the Systems Engineering Engine, which organizes the overall design and development processes into three major categories: System Design Processes, Technical Management Processes, and Product Realization Processes. The System Design Processes are utilized in MAE 490 to define the project requirements and create a design solution. The Product Realization Processes are utilized in MAE 491 to drive the development and implementation of the final product. The Technical Management Processes provide structure for managing the assessments and analyses that are considered when designing and developing the product throughout the CDC sequence.

Conceptual Design Phase

Adhering to a team schedule of delegated tasks, the CDT conducted patent searches and benchmarking, created a customer questionnaire, distributed market surveys, and visited RISE School of Huntsville to gather vital information regarding the end use of the desired product, generate ideas for its systems, and develop product requirements that would dictate the design process. These requirements were documented based on whether they were customer requested or derived by the CDT as well as the verification method (VM) by which they will be satisfied: analysis (A), demonstration (D), inspection (I), or testing (T). Some requirements include:

- The system shall incorporate a Tumble Form® seat. *[Customer, VM: I]*
- The system shall be electrically powered. *[Derived, VM: D]*
- The system shall operate at a speed of 3 miles per hour or less. *[Derived, VM: T]*
- The system will be used at the RISE School of Huntsville. *[Customer, VM: I]*

The CDT named the project the *RISE Assistance Device*, or RAD. The CDT utilized a weighted decision matrix to determine the best type of control subsystem for the RAD (Figure 1). The weights of the criteria were based on product requirements, and the scores were assessed via deliberation based on trade studies and research. Once it was established that a foot-controlled subsystem was the best option for the design, the CDT generated many different top-level concepts that were similarly evaluated until a single design solution emerged: a rechargeable electric mobility platform with a foot-controlled differential drive system.

RAD Control Subsystem Matrix				Foot Switch	Sip 'n' Puff	Joystick
CRITERIA	MANDATORY	WEIGHT	SCALE (1-3)			
Cost	0	10	3 = Least Expensive 1 = Most Expensive	3	1	2
Maintenance	0	10	3 = Least Required 1 = Most Required	2	1	2
Usability	0	20	3 = Most Usable 1 = Least Usable	2	1	1
Safety	1	40	3 = Most Safe 1 = Least Safe	2	1	2
Durability	0	20	3 = Most Durable 1 = Least Durable	3	2	1
TOTALS		100%		65%	10%	30%

Figure 1: Decision Matrix

A Computer-Aided Design (CAD) of the product was rendered with influence from an established Product Breakdown Structure- a hierarchical chart relating each system with its corresponding subsystems. To show that the initial concept design was feasible, the CDT generated a preliminary manufacturing strategy and estimated the costs of parts and services that will be essential to the future development of the RAD.

Preliminary Design Phase

Having established a top-level concept design, the CDT identified potential issues by considering human factors and ergonomics, analyzing subsystem interfaces, performing a military standard (MIL-STD 882B) risk and hazard assessment, and conducting technical analyses such as a Finite Element Analysis on the frame, power usage calculations, and tip-over analyses. A Concept of Operations was produced to visually describe the RAD's characteristics and how it will operate to meet customer expectations during its life-cycle (Figure 2).

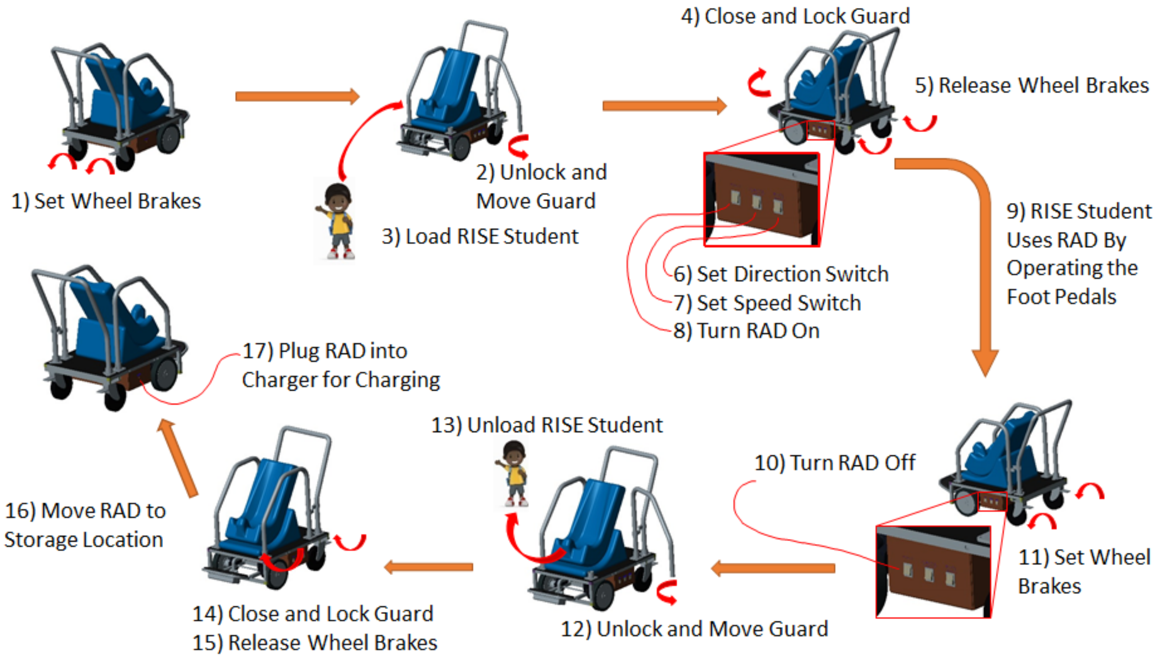

Figure 2: Concept of Operations

Detail Design Phase

The Detail Design Phase was a continuation of the Preliminary Design Phase with the objective of finalizing all intricate details of the RAD and its subsystems and verifying that they will meet all the design requirements. The CDT resolved or mitigated all issues recognized during the previous design phases. The CAD renderings were modified to showcase the overall design solution (Figure 3). Lists for all parts, manufacturing processes, and total costs as well as CAD drawings of every part and interface were completed so that the RAD is ready for development.

Conclusion

The CDT is ensuring a methodical approach to the design and development of a quality product by learning to apply important concepts that are practiced in industry. Additionally, exposure to team dynamics and official design reviews are facilitating the professional development of soft skills essential to engineering. Nearing the completion of MAE 490, the use of the NASA SE Handbook has proven a successful tool in the design of the RAD, and the CDT is adequately prepared to begin the Product Realization Processes during the Spring 2017 MAE 491 class. Once delivered, the RAD will facilitate an increase in the RISE student's educational and social involvement with his teachers and typical peers and will be shared by many RISE students possessing similar capabilities.

Figure 3: Keyshot® Rendering of the RAD

References

1 National Aeronautics and Space Administration, Systems Engineering Handbook, NASA/SP-2007-6105 Rev 1, December 2007

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An undergraduate studying Mechanical Engineering at UAH, Greg is also a *Student Specialist* working for the UAH College of Nursing to develop a novel bioreactor for the International Space Station. Greg is the President of the Tau Beta Pi Engineering Honor Society and is a member of the American Society of Mechanical Engineers, the National Society of Leadership and Success, Phi Kappa Phi Honor Society, and Pi Tau Sigma Mechanical Engineering Honor Society. Greg has worked as a *Research Assistant* for the UAH Rotorcraft Center where his services were supplied to The Boeing Company for five months in 2016, received two Dean's List awards for 2014 - 2016, and won the Siemens Student Design Contest in January of 2015.

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