SAND2020-12024R

SANDIA REPORT
SAND2020-1230993
Printed October 2020

Sandia National Laboratories

A Systems Engineering Approach To Accident Response Planning

Master's of Engineering in Systems Engineering Mid-Term Project Report

Barrera, Dulce Tanya

Issued by Sandia National Laboratories, operated for the United States Department of Energy by National Technology & Engineering Solutions of Sandia, LLC.

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico
87185 and Livermore,
California 94550

ABSTRACT

This paper explores the Systems Engineering structure, strategies and tools for real world scenarios involving work with accident response groups. A systems engineering approach must be taken by the technical teams to prepare for a successful response and design the technical systems in support of the operations. The scope of this project is focused on laying out the foundation of the systems engineering approach taken to help the teams develop an accident response strategy and identify new engineering designs in support of these operations for the black box systems.
This Master's project involves several interdisciplinary teams & stakeholders across different areas. Identifying the proper tools to use is key to addressing the big picture needs of the multiple stakeholders. This project explores some of the key tools used by the integrated team. The integrated project work will primarily take place over the course of 8 weeks via integrated team meetings. Other work in support of this project will take place off-line as needed by the project lead. Details on the prospective timeline, milestones, key dates and work scope can be referenced in other sections of this paper. Key systems engineering methodologies and tools used thus far in support of this project includes:

- Market Surveys and Interviews
- Project Charter
- Feasibility Study
- Swim Lane Diagram
- Knowledge Management Plan

ACKNOWLEDGEMENTS

Master's Project Advisor: Professor William 'Bill' Robinson, Stevens Institute of Technology, SYS800 Special Problems in Systems Engineering, https://web.stevens.edu/facultyprofile/?id=1242

CONTENTS

LIST OF FIGURES

LIST OF TABLES

This page left blank

ACRONYMS AND DEFINITIONS

Abbreviation	Term
SME	Subject Matter Expert

Term	Definition
Feasibility Study	
Swim Lane Diagram	
Critical Knowledge	

1. INTRODUCTION AND SCOPE

Accident response planning is a set of preparatory approaches and policies to mitigate risks. It helps teams prepare for challenges and address the needs of the situation. Generating an emergency response strategy includes a wholistic understanding of the systems and operations. This paper explores the systems engineering approach taken by the technical teams to prepare for a successful response and design the technical systems in support of the operations. The integrated teams will develop an accident response strategy and identify new engineering designs in support of these operations for the black box systems. This will involve several interdisciplinary teams & stakeholders across different areas.

This mid-term Master's project report details the work that has taken place thus far and the systems engineering methodologies and tool used. This includes tools and concepts derived from systems engineering sub-disciplines, such as project management. The identification & use of systems engineering tools will continue as this Master's project progresses. The results and optimal solutions identified by the Master's project team will be presented to the project executives/leads. Approval to implement the optimal solutions will be requested. A tentative project plan will be developed based on the optimal solutions identified that will help guide the technical teams in establishing a response strategy & creating new engineering designs for the black box system if approved.

2. MARKET SURVEY & INTERVIEWS

Design Agencies study, research and develop ideas for new systems and products. They work to create something completely new or to modify and innovate existing products and process to improve their performance and increase their efficiency. The black box system evaluated is a large-scale design product with several years of ongoing development. It is approximately half-way through the design development process.

Additionally, peer reviews and design reviews are a common part of design development. During one of the design reviews, the need to start evaluating emergency response operations with the existing design was identified. This took place about a year and half prior to the start of this Master's project. Due to the time lapse, this Master's project began with a market study and interviews to confirm the need of the project with key stakeholders.

2.1. Market Survey & Interviews Methodology

The first steps for the Market Survey included the development of a project charter. Stakeholders from the emergency response team & design team were identified. Prior to meeting with the team members, a project charter was drafted to help the team pinpoint the scope, project drivers & team needs. During the interview the primary subject included the topics covered in the project charter and confirming the accuracy of the content detailed within the charter. The project charter captures a consensus of the proposed work acted as an agreement among all stakeholders. Several updates were made to the charter based on the feedback from team members interviewed. Key topics covered by the project charter and a description of each topic is included in Table 1.

Table 1: Project Charter Topics

Topic	Description
The Problem/Opportunity Statement	This details the issues that the organization is trying to address and the benefit that will be created by the product
Design Objectives	This explicitly defines the target improvements and implementations steps and strategies in a way that is measurable and specific of the ***technical product*** (what does the design or technical product have to accomplish?)
Project Objectives	This explicitly defines the target improvements and implementations steps and strategies in a way that is measurable and specific for the ***team members*** (what does the team have to accomplish?)
Scope information	This details what work is to be performed to deliver the product. It also determined work scope boundaries (what is included or excluded)
Project Constraints	This identifies obstacles or limitations that might impact the work scope
Deliverables & Schedule Summary	This defines what the end tangible products will be and high-level milestones for the deliverables
Dates	This provides detailed dates in support of the high level milestones
Champion	The champion is the person or group that ensures everyone involved is on board and behind the ultimate success of the project. The

	champion is typically a manager and funds the project and commits resources.
Sponsor	The sponsor is the person or group who owns the project or the program area that the project resides under
Team Lead	The team lead manages day-to-day operations and coordinates with the project champion, sponsor and team members
Team Members	Team members are representatives or subject matter experts of key project areas.
Strategic/Business Objective Tie:	Defines how the project aligns and supports the overall mission of the organization(s)

The project charter is one of the first system engineering tools used for this Master's project and sources from the project management & lean six sigma disciplines. It also important to note that the format for project charters varies from project to project. The project template should be selected and tailored to the project at hand. Some project will benefit from using an extensively detailed word document that extends to multiple pages. Others will benefit from a one pager that consolidates all the information in one place. Because this project charter was used as an interview tool, the one page methodology was preferred. It allowed team members to easily process the information and converse on the topics. A copy of the one page template has been included as Figure 1. Ultimately, a good project charter should contain and provide a comprehensive summary of the essence of the project. It is meant to be a document of agreement between the major stakeholders, the sponsors of the project, and the whole team. ***[REF 1]***

Project Charter Template

Problem/Opportunity Statement:

Currently the black box system is in the design and development phase. As the system design undergoes qualification & transitions to the production phase it will be key to evaluate, determine and integrate accident based requirements and capabilities into the design

Design Objectives:
- The system will include….
- The system shall be able to….
- If project parameters allow, the system should be incorporated into parts of design

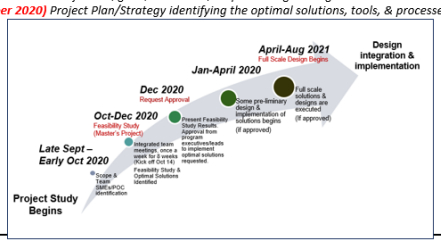
Project Objectives:
- Identify system(s) that will be used to develop the design & will contain the design details
- Link communication channels and increase knowledge sharing between designers and accident response team
- Conduct work per the existing processes, designs, & procedures. Develop and implement additional tools as needed (Optimal solution & continuous improvement focus)

Scope Information:
- Scope includes the design capabilities, procedures, and processes that meet the needs of our customers
- This Project facilitates design and requirements to meet both short-term and long-term customer business objectives & requirements

Project Constraints:
- Resources (people), project schedule, limited funding
- Security constraints: Broad spectrum of portioning of information in various classification categories

Deliverables:
- Documents: Feasibility Study & Project Plan
- Identification of integrated mission, organizational objectives, goals, milestones, & systems engineering elements

Schedule Summary: ***(Sept 2020-November 2020)*** *Project Plan/Strategy identifying the optimal solutions, tools, & processes* ***(April 2021-Aug 2021)*** *Definition of Design, design development and integration*



Dates:
Sept 2020-November 2020 (Master's Project)
- 9/22/2020: Identify Stakeholders & pinpoint scope & needs
- 9/28/2020: Prework for feasibility study begins
- 10/14/2020: Official project & feasibility study 'kick off'
- 10/31/2020: First Draft of Master's paper submitted
- 11/30/2020: Final Master's Project Report submitted
- 4/1/2021: Design Begins

Champion: Manager
Sponsors: Lead
Team Lead: Dulce Barrera

Team Members:
- Design Subsystem Lead 1
- Design Team member 1 (SME)
- Design Subsystem Lead 2
- Accident Response Team Lead 1
- Accident Response Team Member 2
- Accident Response Team Member 3
- Design Team Emergency Response Lead & Point of Contact (POC)
- Systems Engineering Lead
- Systems Engineering Team member
- Quality engineer

Strategic/Business Objective Tie:
- Align accident response and design team mission, organizational objectives, goals, milestones, performance
- *Drivers:*
- *Key Terms:*

Figure 1: Project Charter Template

2.2. Interview Chain & Team Member Identification

At the end of each interview team members were asked if there were any other team members that they would recommend be consulted and what particular topics they should be consulted on. Team members made recommendations and a chain of interviews took place as detailed in Figure 2.

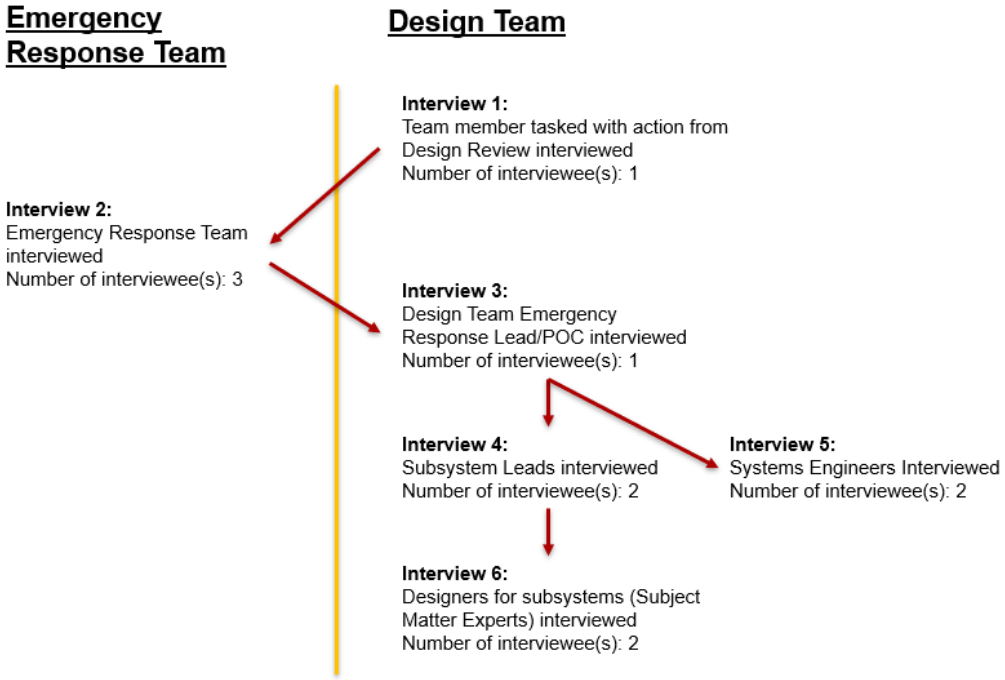


Figure 2: Market Study Interviews

2.3. Team Commitments and Schedule

During the interviews the key milestones and prospective schedule was also discussed with the team members. The milestones summary referenced during the interviews can be referenced in Figure 3. Team members were informed that the feasibility study would take place over the course of 8 weeks and that a meeting would take place once a week with the integrated team. Team members were explicitly asked if they would be willing to be a core team member, which entailed a commitment of an hour a week for the next 8 weeks (8 hours total time commitment). Those who agreed were designated as core team members. Those who were not able to support the time commitment became team consultants who the team will reach out to when needed.

An Outlook meeting invite was then created with the following description "Key deliverables will include a feasibility study & project plan. The intent is to meet once a week for the next 8 weeks to have the critical discussions/brainstorming sessions as an integrated team with representatives from both the design team and accident response team. I will conduct the majority of pre-work/post-work outside of these meetings to make the most of our integrated meeting time. Other Subject Matter Experts (SMEs) will be included at some sessions as needed". The final version of the project charter was reviewed by team members during the first integrated team meeting and a team consensus was established.

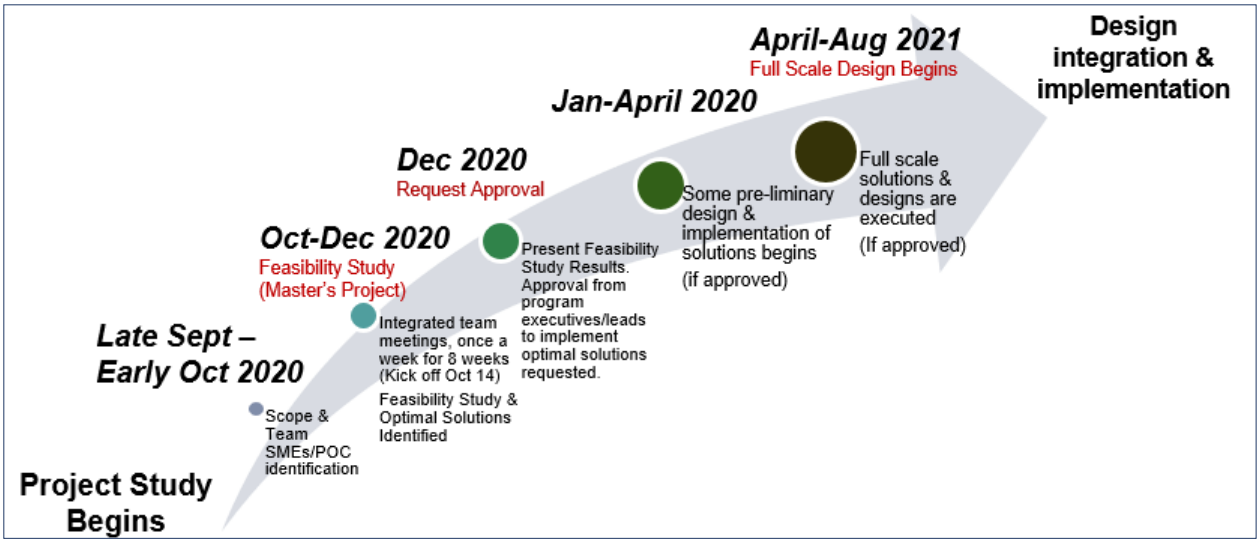


Figure 3: Milestone Summary

2.4. Interview Summary and Findings

Before the interviews began the project seemed to be in a preliminary system design phase where initial technical design could begin development. However, after the interviews concluded it became evident that the project was in the conceptual design phase. This highlighted that there is a large gap remaining to be bridged by integrated teams before reaching the preliminary design phase in the design lifecycle. Figure 4 explains the difference between conceptual, preliminary, and detailed designs and how each evolution leads to a greater design maturity.

Differences between conceptual design, preliminary system design, detailed design and development:

Conceptual design	Preliminary system design	Detailed design and development
The conceptual design phase starts when a system requirement arises and the phase searches for a potential solution. The definition for the need and solutions is laid down for further evaluation.	In the preliminary System Design phase, the life-cycle of the system is designed and its related sub-systems are formulated along with the functional layouts.	The detailed design and development phase for any system development brings in the detailed specifications for each phase, and functions.
After the evaluation, the specifications act as the technical guidelines for various phases of development and the requirements.	The evaluation requirements are considered after the test phase of sub-systems.	During the evaluation, the interactive interfaces between the environment and the system are specified. The maintenance and support phase details are formulated.
At the end of this phase, the solution and the specifications are put in one review which is the conceptual design review.	At the end of this phase, the platform is ready for taking design to another level.	After analysing for all the sub-phases in the system, then the product specifications are initiated.

Figure 4: Design Development Phases

Additionally, upon conclusion of the interviews it was clear that key stakeholders had not communicated or worked on the task at hand since a year and half ago when the need for the work

was initially identified. The stakeholders interviewed are very mission driven and dedicated with a full work load. The start of this task was not delayed due to lack of interest but rather resource constraints. Currently, team members supporting this project are balancing several priorities and have a full work load, which is why the request of an 8 hour commitment from core team members was requested. It must also be noted that all team members recognized that there was a strong need for the project to take place and expressed high interest in participating in this integrated effort. As lead of the project, key responsibilities will involve being a strong facilitator or integrator for the stakeholders. Helping key stakeholders maximize their integrated meeting time will be key to the success of this project.

3. FEASIBILITY STUDY

Upon identifying that the project was in the conceptual design phase, the need for a feasibility study was determined. The feasibility study will help the team evaluate different operational concepts, design options, schedule constraints & funding availability. The team will determine optimum solutions involving both the design and operations per the project parameters through this feasibility study. This feasibility study will be another system engineering tool used in support of this Master's project.

3.1. What is a Feasibility Study and how will it be conducted?

Conceptual designs help to create a clear user interface which is easy to understand and interpret. It helps to describe the roles of different users and their requirements in detail so that the project is better understood from the offset. [REF 2] It common to conduct feasibility studies during the conceptual design phase of a project, as it allows for better definition and planning for the other phases of the design lifecycle.

The word 'feasibility' means the degree or state of being easily, conveniently, or reasonably done. If something is 'feasible,' it means that we can do it, make it, or achieve it. In other words, it is 'doable' and also 'viable.' A feasibility study is an evaluation and analysis of a project or system that somebody has proposed. [REF 3] Through this study several aspects of the project can be evaluated for feasibility such as cost, technical, operational, and schedule feasibility. Figure 5 details the feasibility study process and steps that the integrated team is following.

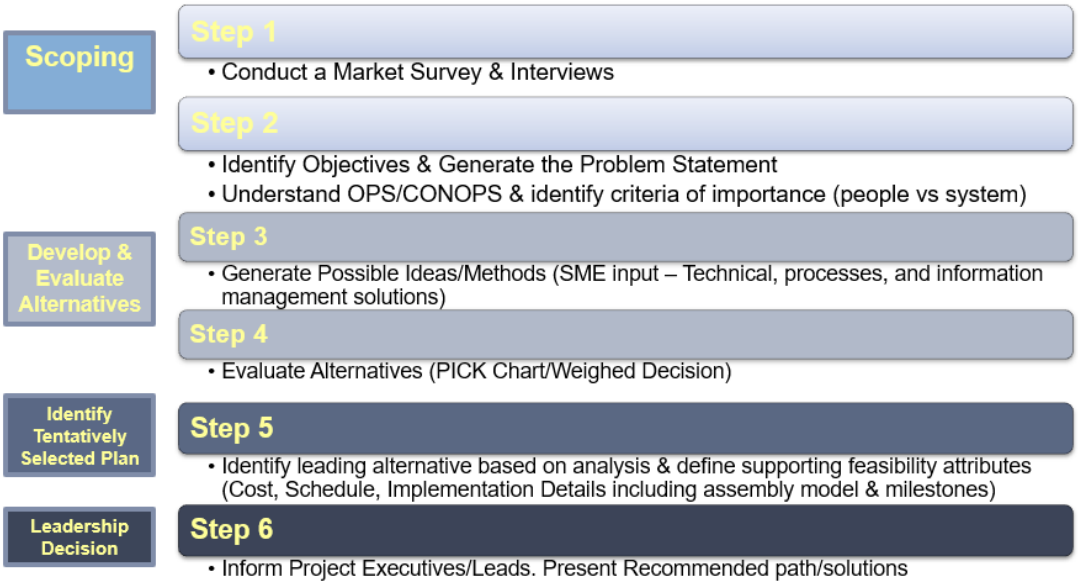


Figure 5: Feasibility Study Process

The initial portion of this study will focus on technical and operational feasibility. This will take place by mapping the current operational model for accident response operations and by mapping the existing technologies and designs that support this operational model. This feasibility study is planned to take place during the course of 8 weeks (the duration of this Masters project). An integrated working meeting will take place each week where the team members can brainstorm and work on different elements together. We are currently on week 4 of 8. Other tools will be developed as needed in support of this feasibility study and will be detailed in the final report of this Master's project.

The following work in support of this feasibility study that has been completed is as follows:

- *Week 1 (Oct 5, 2020):* Scoping, Step 1 – Draft Project Charter. Conduct Market Survey and Interviews.
- *Week 2 (Oct 12, 2020):* Scoping, Step 2 – Confirm Objectives, Problem Statement, Project Deliverables. Begin knowledge sharing.
- *Week 3 (Oct 19, 2020):* Scoping, Step 2 – Understand and map accident response operations and CONOPS for the processes. Identify criteria of importance to people supporting the operations and executing the processes. Understand technical systems that support operations and that accident response personnel need to access. Draft of an integrated process map that links processes, technology and people is created.
- *Week 4 (Oct 26, 2020):* Scoping, Step 2 - Develop a knowledge management plan to identify subject matter experts to consult with to further refine the mapping of applicable technical systems.

The following work is still pending and the tentative timeline for completion of the work is as follows:

- *Week 5 (Nov 2, 2020):* Scoping, Step 2 – Conduct brainstorming session with SMEs identified in the knowledge management plan. Update draft integrated process map that links processes, technology and people with the new information.
- *Week 6 (Nov 9, 2020):* Develop and Evaluate Alternatives, Step 3 & 4
- *Week 7 (Nov 16, 2020):* Identify tentatively selected plan based on optimal solutions, Step 5
- Thanksgiving (Nov 23, 2020): Team lead will draft project plan/proposal
- *Week 8 Final Team Review (Nov 30, 2020):* Integrated team will conduct final review of project plan/proposal
- *December 2020:* Leadership Decision, Step 6 -Present feasibility study results and optimal solutions to project executives/leads

3.2. Operations Swim Lane Flow Chart & Operations Feasibility

Mapping operations is the first steps towards being able to assess operational and technical feasibility. Accident Response Operations and technologies can be modeled with abstract and visual representation of how the organization and system operates. A diagram is a representation of the model and provides a snapshot of the operations and technologies supporting this feasibility study. The framework selected to represent the accident response operations was a swim lane diagram. A swim lane diagram, also called a cross functional flow chart, or swim lane process map, is an element used in mapping process workflows. It groups components or teams into a distinct sequence, or lane, in the visual presentation of workflow and process charts. [Ref 4] The process is then mapped in sequential order with each process step in its designated swim lane.
The steps to creating a Swim Lane Flowchart are as follows:

- Identify the lanes. Decide what divisions you need represented by swim lanes and label them.
- Start your chart. Define the starting point of the process.
- Add steps. Next add more steps to your chart.
- Organize the steps per their designated swim lane. Define the end point of the process.

This meeting was facilitated as a brainstorming session for the team. The primary tools used to facilitate the meeting was a white board and sticky notes. The effectiveness of the brainstorming session is driven by the methodology chosen to collect and organize the information from all team members. The facilitator must determine what is the relevant information of importance and the best way to collect the relevant information from the team. The facilitator makes these determinations prior to the meeting and defines a methodology. The methodology used for this project is as follows:

1) Each team member was given a set of sticky notes and were first asked to individually brainstorm all and any process steps that they could think of. The team was given 5 minutes to do this and each team member captured one process step per sticky note. The sticky notes were then collected by the facilitator.
2) Lanes were then drawn on the board and team members were asked to brainstorm on the applicable systems, technologies, and stakeholders. Groupings were then created and grouping names were assigned to a swim lane and labeled.
3) All the sticky notes were then laid out on the board. Team members were then asked to determine the first process step and sequential steps to follow until the end of the process was reached. As the sequential ordering took place, duplicate steps were eliminated and additional steps were added were gaps remained. Each process step was assigned a number. A process step with a number and letter means that the step is taking place in parallel with another step.
4) Pictures of the white board were taken at the end of the brainstorming session and the diagram in Figure 6 was created detailing the process for emergency response operations.

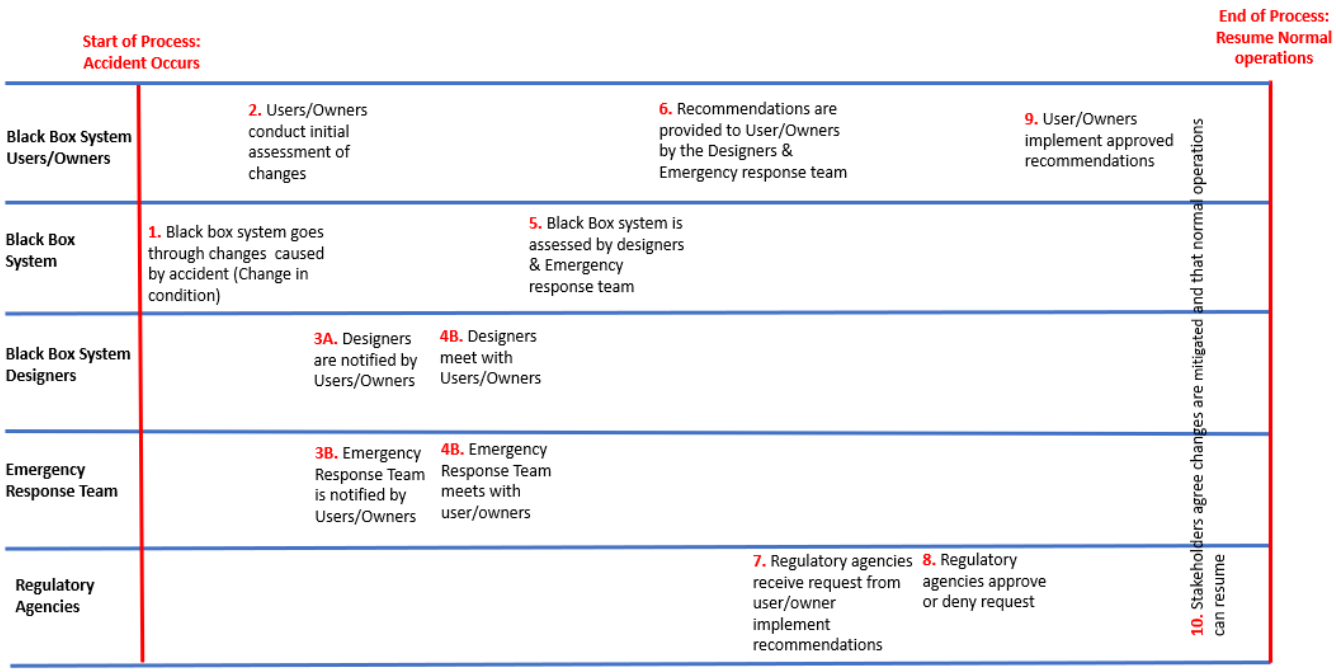


Figure 6: Emergency Response Process Swimlane Diagram

3.3. Use Cases and CONOPS

The swim lane diagram helps the team pinpoint key information that supports the development of Use Cases and a Concept of operations (CONOPS). Two Use Cases are in the process of being created. One use case is for normal operations and in contrast the second is for accident response operations. The use cases provide a high level view of the system and interactions of the system with the stakeholders. **[Will Insert USE CASE DIAGRAMS for final report]**

3.4. Knowledge Management Plan

To further define the emergency response operations, additional subject matters experts (SMEs) need to be consulted. A knowledge management plan was developed to identify SMEs and areas of interest. These team members will be invited to future brainstorming sessions and will be asked to present to the team on their area of expertise as it relates to the black system & the emergency response operations. The core team will then use this information to refine the swim lanes and use cases.

Developing a knowledge management plan includes the identification of critical knowledge and personnel who hold that critical knowledge within the organization. Knowledge-intensive teams rely on the task-relevant knowledge held by members to perform effectively. Critical knowledge is defined as the most influential information, know-how, or feedback that contributes directly to an organization's task outcomes. The critical knowledge structure in a team can be defined by identifying who needs to share critical knowledge with whom. [REF 5] The knowledge structure for this feasibility study includes critical knowledge of Core Team members and the consulting team members. Table 2 and Table 3 are templates that show the methodology used to identify critical knowledge and SMEs for this project (Note: Random numbers were selected for areas of expertise).

Table 2: Core Team Members Critical Knowledge Identification

Team Member (SME)	Area of Expertise	Relevance/Impact to Study
Team Member 1	Knowledgeable in emergency response operations	This allows team members to create a mapping of the operations
Team Member 2	Knowledgeable in subsystem 1 design	This allows team members to identify technologies of importance during operations

Table 3: Consulting Team Members Critical Knowledge Identification

Team Member (SME)	Area of Expertise	Relevance/Impact to Study
Consultant 1	Knowledgeable in subsystem 1 Assembly 1 design	This allows team members to identify technologies of importance during operations
Consultant 2	Knowledgeable in subsystem 2 Assembly 3 design	This allows team members to identify technologies of importance during operations
Consultant 3	Knowledgeable in subsystem 4 Component 5 design	This allows team members to identify technologies of importance during operations

4. FEASIBILITY STUDY FINDINGS AND RESULTS

As the feasibility study progressed key findings included.... Further research and work is still to be conducted and will be elaborated upon in the Final project.
[Will be included in the Final Project Report]

5. FEASIBILITY STUDY CONCLUSIONS

Further research and work is still to be conducted and will be elaborated upon in the Final project.
[Will be included in the Final Project Report]

6. RECOMMENDATIONS FOR FUTURE WORK

Further research and work is still to be conducted and will be elaborated upon in the Final project.
[Will be included in the Final Project Report]

7. ASSUMPTIONS AND CONSTRAINTS

Constraints for this Master's Project includes:

I. Limited time availability of Resources (people) due to commitments on other projects/tasks.

II. Security constraints: Broad spectrum of portioning of information in various classification categories (Some Classified document & some UUR content/documents). This project is be solemnly focused on the system engineering strategies needed to define the emergency response operations & engineering designs. All content within this document will be Unclassified Unlimited Release (UUR) Information, which means details of the engineering designs and technical systems will be excluded from this paper.

III. Schedule alignment between the Master's Project schedule and the company's schedule. Holidays such as Thanksgiving will impact team member availability. Team member availability is also limited to an 8am-5pm workday. Team members are also supporting other commitment so finding meeting times that work for everyone can be challenging. Scheduling the meeting a week or two in advance is key to ensuring all team members will be available.

IV. The COVID19 pandemic currently impacts the ability of team members to work onsite. Additionally, if a project team member is COVID positive quarantine will be required until full recovery. Depending on the interactions with the COVID positive individual, other team members may also be quarantined.

Assumption for this Master's Project Includes:

I. None for Mid-Term Report. **[Will be updated in the Final Project Report]**

8. LESSONS LEARNED

I. In design projects there are sensitivities revolving around the word 'requirements'. Requirements changes heavily impacts a designer's work scope. Defining what is meant by requirements and what type of requirements helps eliminate miscommunications. Requirement types could include systems engineering requirements, regulatory requirements, operational requirements, etc.

II. Conceptual Design Phase - An initial assumption was that the project was in the preliminary design phase and the intent was to develop a project plan as part of this Master's project. A few weeks into the project it was evident that the project was in the conceptual phase which impacted the project scope and lead to a the execution of feasibility study instead of the development of a project plan. A tentative project plan will be drafted as part of this project based on the optimal solutions identified but execution of the project plan will be dependent on approval from the project executives/leads.

REFERENCES

[1] **REF 1** – [insert reference info]

[2] **REF 2** – Systems Engineering and Analysis Book, Benjamin S Blachard)

[3] **REF 3** – [Insert Reference Info] https://marketbusinessnews.com/financial-glossary/feasibility-study/

[4] **Ref 4** – [Insert Reference Info]

[5] **Ref 5** – Huang, Siyuan, and Jonathon N Cummings. "When Critical Knowledge Is Most Critical Centralization in Knowledge-Intensive Teams." Researchgate.net, Small Group Reasearch, Dec. 2011, www.researchgate.net/publication/258187588_When_Critical_Knowledge_Is_Most_Critical_Centralization_in_Knowledge-Intensive_Teams

DISTRIBUTION

Email—External (encrypt for OUO)

Name	Company Email Address	Company Name
Professor Bill Robinson	william.robinson@stevens.edu	Stevens Institute of Technology

This page left blank

Sandia National Laboratories

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.