JOHNS HOPKINS
WHITING SCHOOL
of ENGINEERING

SYSTEMS ENGINEERING PROJECT

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This document provides the guidelines and requirements for the Johns Hopkins University Whiting School of Engineering Systems Engineering Project

Guidelines and Requirements

TABLE OF CONTENTS

MEMORANDUM TO SE PROJECT STUDENTS....3

SYSTEMS ENGINEERING PROJECT - Guidelines and Requirements....7

1.0 SCOPE AND REQUIREMENTS....7
2.0 ORGANIZATION....8
2.1 Selection and Approval of Project....8
2.2 Application of Systems Engineering....8
2.3 Final Report and Oral Presentation....8
3.0 FACULTY GUIDANCE....9
3.1 Project Mentor....9
4.0 SELECTION AND APPROVAL OF PROJECT....10
4.1 Selection of the Project System....10
4.2 Criteria for Successful System Projects....10
4.3 Project Proposal....14
5.0 APPLICATION OF SYSTEMS ENGINEERING....17
5.1 Requirements Analysis and Concept of Operations Reports....17
5.2 Functional Analysis Report....18
5.3 Trade Study....18
5.4 Conceptual Design....19
5.5 Test Plan....20
5.6 System Specification (A-Spec)....20
6.0 FINAL REPORT AND PRESENTATION....21

6.1 Final Project Report....21
6.2 Oral Presentation and Critique....23
7.0 SCHEDULE....25
8.0 REQUIREMENTS FOR ONLINE STUDENTS....26
9.0 GRADING RUBRIC....26
APPENDIX A - Selection of Project System Topics....29

General Attributes....29
Work Related Projects....29
Community Related Projects....30
New Device Projects....30
Personal Projects....31
Reality and Originality....31
APPENDIX B - Frequent Project System Deficiencies....32

Revision History....34

MEMORANDUM TO SE PROJECT STUDENTS

June 2017

To: JHU Systems Engineering Project Students

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Subject: Systems Engineering Project (645.800 Series) Guidelines and Requirements

NOTE: This revision to the guidelines is effective immediately.

Changes from the previous version:

1. Removed 800-series specific requirements (concentration specific mentors)
2. Updated the grading rubric to address late submissions.
3. Modified timeline to include pre-course work.
4. Modified proposal format.
5. Addressed changes to the proposal conceptual block diagram.
6. Included EVM as a component of project scheduling and execution.
7. Added a reference to the Thesis option.
8. Included Revision History table.

If you are reading this document, you have selected the SE Project as your Capstone course in the Master of Science in Systems Engineering Program. If you are planning to produce a thesis for your Capstone, please contact Larry Strawser (lstraws1@jhu.edu) or Jacqueline Rowe (Jacqueline.Rowe@jhuapl.edu) for more information about that course.

The Systems Engineering Project represents the Capstone course in the Master of Science in Systems Engineering. It is designed for you to (a) demonstrate that you can apply the

"Systems Engineering Viewpoint" and (b) exercise the skills and tools you have learned throughout the program. It requires you to select and complete a complex and unique systems engineering project as an individual student. Faculty mentors are available to assist students in selecting and defining an appropriate project. An approved JHU faculty member will serve as a mentor to guide you through the remainder of the project. The class structure is similar to an independent study as it is self-paced and does not have regular class sessions. On occasion, during the semester, a mentor may announce a meeting of interested students to discuss their progress, answer questions and share lessons learned.

Since selecting a suitable project is often time-consuming, you will begin the process during your System Design and Integration course. To be adequately prepared for this course, you will complete a draft of your Systems Engineering (SE) Project Proposal by the completion of your System Test and Evaluation Course. You should expect to spend 150-

Mentor Note: Your Draft Proposal must be completed and approved prior to the start of the formal semester. It will be very difficult to complete the project in one semester if you have not already completed the proposal.

250 hours of independent, individual work to complete the project, so we advise that the SE Project course be the only course taken during the semester. The project schedule is self-paced, so a strong commitment is required to complete the project during the semester (to include pre-course work). It is possible that an additional semester be required to complete the course requirements. In these cases, an "Incomplete" grade can be requested to finish up the deliverables the following semester, without an additional enrollment cost (a grade change fee will be assessed). Your final grade will be reduced by ½ letter grade for every approved extension. After three extensions, you will be required to re-register for the course. A grade change fee will be assessed.

Johns Hopkins University (JHU) has a rule that students are expected to complete their degree requirements within five years. If there is any concern in this regard, the student must contact Dr. Flanigan and provide a significant justification for an extension of the five-year rule.

The most significant challenge of this project course is the need for students to remain committed to completion of their project work on a self-paced, independent basis. While normal work and life conflicts will occur, attention and focus on maintaining your schedule is essential for success. This discipline is an excellent quality for a systems engineer.

Mentor Note: Although sample projects uploaded to Blackboard were chosen based on their content, don't assume that every element of these projects is perfect.

Once approvals of the Proposal is given by your Project Instructor, there are several additional deliverables: Requirements Analysis Report (RAR) / Concept of Operations (CONOPS); Functional Analysis Report (FAR); Conceptual Design Report (CDR); Trade Study (TS); Test Plan (TP); Risk Management Report (RMR); System Specification (A-Spec); Final Report (FR); and an Oral Presentation (OP).

Several prior student project reports are available in their entirety on Blackboard to use as examples and guides during your project. Note that prior reports are provided as a reference only. Do not make any assumptions about the quality of individual deliverables within these projects. As a Systems Engineer, you will need to independently assess the quality of the artifacts and determine applicability to your specific project.

Project communication and administration between the student and mentor shall be conducted via the use of Blackboard. E-mail can be used for initial contact with the project instructor, the course administrator and the mentor(s). The SE Program requires all deliverables to be submitted and assessed on the Blackboard site.

The primary means for interaction between yourself and mentor/instructor will be the JHU supported Blackboard site (hereafter known as the SE Project website). JHU's intent is to provide access to the SE Project website a few weeks after your enrollment in the System Design and Integration course. If you cannot access the course in the website homepage after that time, request access to the SE Project website by providing your JHU ID (also known as your JHED ID) to Jacqueline.Rowe@jhuapl.edu – she will be able to add you to the website.

To begin the process, you will initiate contact with a project mentor during their System Design and Integration course (active mentors can be found on the course website. More information about mentors can be found in *3.1 Project Mentor*). Through a series of draft submissions, the student iteratively develops a Proposal. Once the mentor approves the paper, the student formally submits the paper on Blackboard and notifies his/her Project Instructor via e-mail that it is ready for review. Students should make the attempt to select a mentor and begin the proposal process prior to the semester they are registering for the project in order to maximize the chance of successful completion.

The SE Project website contains several helpful aids for your project and will serve as the means for you to communicate and submit your deliverables. There are these project guidelines, points of contact, multiple completed student projects, and links to tools for your possible use during the project (DOORS, CORE, MS Project, etc.). The SE Project website will provide you with both correspondence and submission tools. More information on the SE Project website can be found within the site itself. The site can serve as an archive for your submissions, although it is prudent for you to maintain copies on your own computer resources. General Internet help can be obtained from the JHU related help site. SE Project website specific questions can be addressed to Christian.Utara@jhu.edu or Jacqueline.Rowe@jhuapl.edu .

In order to complete your project in time to meet end of semester deadlines, you will need to schedule your Oral Presentation before the "last day of classes" date of the semester. Please contact Ms. Rowe or your mentor to do so. Plan ahead, since this is a busy time to schedule all the participants. Not all students will be able to brief in the last week.

SYSTEMS ENGINEERING PROJECT - Guidelines and Requirements

1.0 SCOPE AND REQUIREMENTS

This document defines the purpose, objectives and requirements for the Systems Engineering Project that each Master's Degree in Systems Engineering candidate must complete prior to graduation.

The primary purpose of the project is to demonstrate that the student understands and can apply systems engineering principles to a specific system. The project shall involve the application of the following systems engineering activities:

- Definition of Needs and Objectives
- Requirements Analysis and Concept of Operations
- Functional Analysis
- Conceptual Design
- Trade-Off Studies
- Risk Management
- Test Planning
- System Specification (A-Spec)
- Final Report and Oral Presentation

To serve this purpose, the Systems Engineering Project shall be product oriented, (rather than a research study designed to increase the body of knowledge). The product itself shall be in the nature of a "system" with definable functional subsystems; it will be referred to as the "Project System." The Project System shall address a perceived, definable and practical need. It shall have sufficient scope and complexity to require systems engineering, include challenging technical and engineering components, be unique in that it is not a duplication of an existing successful system, and have a potential value beyond the interest of the student. See Appendices A&B for more information.

A secondary purpose of the project is to provide the student with the experience of planning and organizing a significant task, partitioning the task into a set of subtasks and deliverables, establishing and maintaining a schedule of effort, and delivering written and oral descriptions of the work. To mirror the real world, this self-paced course provides the experiences of work, project, personal conflicts and pressures.

2.0 ORGANIZATION

The system project can be organized into three primary areas:

2.1 Selection and Approval of Project

Activity: Selection and definition of the Project System, and approval of the Project Proposal

Deliverables: Project Proposal. This product requires approval by the Mentor and the Project Instructor via the SE Project website.

Mentor Note: Although your Mentor will provide you guidance during the development of your proposal, the Project Instructor approves/disapproves these documents. Make sure to leave adequate time for both Mentor and Instructor reviews. Note that your Draft Proposal should be completed by the end of your System Test and Evaluation Course. To register for the SE Project course, your Final Proposal must be submitted on Blackboard.

2.2 Application of Systems Engineering

Activity: The development of the selected "system" through the application of systems engineering tasks.

Deliverables: Reports on intermediate studies termed similar to CDRLs. Each of these products requires approval by your Mentor via the SE Project website.

2.3 Final Report and Oral Presentation

Activity: Assembly of all deliverables into a Final Report and Oral Presentation to the Mentor, Project Instructor and possible other interested parties.

Deliverables: Written Final Report and Oral Presentation, including all project deliverables as appendices.

Mentor Note: The SE Project website (Blackboard) provides a single location for Systems Engineering Project materials, Student/Mentor/Instructor interaction, and documentation submittal/review. Using Blackboard minimizes the possibility that data will be "lost in the shuffle." Refer to the SE project website for office hours (if appropriate), typical review dates, and other communication details. The SE Project website database will be used by the JHU Main Office to assess your progress.

3.0 FACULTY GUIDANCE

3.1 Project Mentor

Members of the Systems Engineering faculty will be available to assist the student in the selection of a suitable Project System and in the execution of the project. During the project selection and proposal preparation, the student will be assisted by a designated project mentor. A comprehensive mentor list can be found on the SE Project website.

Students planning their SE Project should contact any mentor of their choice with their project ideas or contact their Project Instructor directly for additional guidance. Students may select any available Mentor independent of their main campus. Your Mentor will assist you in the selection and definition of a suitable Project System.

The faculty mentor will provide the student with advice and guidance on execution of the approved project. After Proposal approval, the Mentor has approval authority, subject to oversight by the Project Instructor, for all project report submissions. The student is strongly encouraged to seek information and advice from colleagues or authorities with expertise in the domain area of the project.

It is expected that the student and mentor will maintain communications at least every two weeks during the course of the project. Interactions should occur primarily via Blackboard, but telephone and in-person sessions are also appropriate. It is the student's responsibility to maintain contact and notify the mentor of any changes due to travel or other conflicts. All documents prepared by the student shall be posted to Blackboard for review by their Mentor. It is expected that the student will be regularly developing and posting designated reports for mentor comment on Blackboard. This material will later compose sections of the Final Report. There will likely be several iterations for each deliverable based on feedback from your Mentor.

4.0 SELECTION AND APPROVAL OF PROJECT

4.1 Selection of the Project System

Students are encouraged to select their own Project Concept. Ideally, there may be a suitable subject associated with their job, place of employment or community. The project mentor will assist students in the selection of the Project System. Previous Project System final reports are available on Blackboard to stimulate concept ideas.

4.2 Criteria for Successful System Projects

Scope of the Project Product

As stated above, the product (of the project) shall itself be a "system" whose development involves multiple subsystems and technical challenges that require solutions to interdisciplinary system problems. These conditions are necessary to warrant the application of systems engineering rather than of a single discipline. For example, it should not consist primarily of the selection and assembly of commercially available components or software. Exclusively software-oriented systems may be difficult to meet the project objectives. The functionality of the concept should not be simply performed by a mobile application (app). Student should thoroughly search the Internet and patents databases to verify that there are not any existing commercial systems available for their concept. There must be technical challenges requiring systems engineering to achieve a successful product (See Section 8.0 – Requirements for Online Students)

Domain Knowledge

Preferably, the student should already know about the proposed subject or be in a position to acquire detailed knowledge from readily available sources (domain experts). To demonstrate the application of systems engineering requires sufficient depth of understanding as to make it meaningful rather than vague or very general. Projects, about which the student has little personal knowledge, and where potential users may not be immediately available to the student, are generally difficult to carry out because of the extensive research required. On the other hand, if the project is closely work related, it will be necessary to demonstrate the student's unique contributions and to avoid using existing work generated by colleagues or contractors. Previous experience has shown that students who select a work-related project will tend to focus on the design and implementation details, along with this stakeholders, which is not the intent of this project, and will not demonstrate the systems engineering method in their deliverables. In developing a unique system, the student will be expected to interview or survey several domain experts to solicit systems requirements and later to validate them during the project execution.

Mentor Note: It is expected that the student will be required to use a variety of documents and references in support of the development of their Project System. Due to the nature of this project, it is critical that all resources be attributable to their source.

Most word processing packages have some good built in referencing tools that can help you to get started. If you would like to manually produce your references, be sure to capture the following information (at a minimum).

- Author(s)
- Date of Publication (if available) - if a web site reference, include the date it was downloaded
- Title of Publication
- Source of Publication (publisher, location of publisher, or web site)
- If taking a direct quote, include the page number for the quote

APA, MLA, and Chicago formatting styles are acceptable for this course.

Separation from Student's Job

If the project is related to the student's job, it shall be clearly identified as the JHU Systems Engineering Project, and its accomplishment should not depend on any future changes in the job. Security and proprietary issues shall be dealt with before starting. Contact your work supervisor and your mentor if you have questions in this area. Several prior projects have classified origins or applications, but the project environment, application details, customers, etc. can be creatively devised to conduct the project on an unclassified basis. Students are responsible to obtaining public release of any work-related project if it is needed.

Demonstrable Need

The Project System shall produce or lead to a product that has demonstrable value to an identifiable range of "customers", "owners" or "users" (specific individuals should be named in the Proposal and be treated as having this role). Current commercial or military Requests for Proposals may be considered, but the student project shall not be redundant with an ongoing organization's response. The Project System should be, in a sense, potentially marketable. It needs to be "real" and viable in the marketplace. Certain commercial Project Systems may need to include some discussion of business planning factors to help justify feasibility. The Project System shall not be of value only to the student/developer—that lacks the essential aspect of developing and analyzing requirements, i.e., the student cannot be the customer or owner. Failing to meet this *Demonstrable Need* criterion raises doubt as to the value of developing such a system.

Feasibility

If the proposed Project System represents a significant technical advance, it shall be shown to be feasible. There should be at least one implementation of the concept that does not require invention of something entirely new to satisfy the requirements. Failing the *feasibility* criterion makes the project unrealistic. The Project System requirements are expected to be quantitative as much as possible. Hence, real subsystem design specifications should result from the research and trade studies.

Complexity

The Project System should consist of several different subsystems, so that it presents system problems that could not be solved by a single design specialist. In the case of a software-centric system, the application domain shall be sufficiently complex as to require a system approach to its design (the required hardware subsystems shall not be neglected). Ideal systems will have both hardware and software components. On the other hand, the project should not be so complex as to exceed the scope of what can be accomplished in one (or two) semesters for an academic system project course. Early in developing the system concept, the student can evaluate complexity by sketching out a systems conceptual block diagram and noting the number of internal and external interfaces.

System Focus and Scope

The project shall be focused on **systems** engineering rather than on component design. Projects that focus on the design of a device or a software program that accomplishes a relatively limited function are likely to be too simplistic to require "systems" thinking. A detailed process is not itself a system product. If an engineering or software specialist can accomplish the concept, it may not present opportunities to exercise systems engineering skills. Writing a computer program or combining a set of software algorithms should not be significant elements of the work.

Mentor Note: The requirement to develop a system conceptual block diagram in the proposal helps the student think through the feasibility of the project. This diagram should be very high level and not get into any design details. Although the student is expected to deviate significantly from this initial "system concept", thinking through the Project System as a whole minimizes the possibility that a solution will be unattainable. Note that "pre-designing" the system during the proposal phase will demonstrate a lack of understanding of Systems Engineering fundamentals and will be assessed accordingly.

Specificity

While the focus of the project must not be on design details, neither can it be on generalities. The application of systems engineering methods should be on realistic engineering (and sometimes programmatic) issues. The subsystems and components of the Project System need to have a quantitative foundation. For example, in conducting a trade study, the criteria need to be traceable to requirements, objective, and the choices technically comparable and the judgments made on numerical factors as much as possible.

Unsatisfactory Projects

Some examples of unsatisfactory proposed System Projects have included systems requiring only the assembly of commercially available-standard components that could be assembled by a technician; integration of Commercial-Off-The-Shelf components; database systems for storing and accessing data that could be designed by a database specialist or adapted from a commercial product; and in general, component

developments within the knowledge domain of a single discipline (See *APPENDIX B - Frequent Project System Deficiencies*). Systems Projects that are now common in the marketplace should also be avoided, e.g., smart homes, autonomous automobiles, lost children-pets-cars, grocery shopping, etc.

4.3 Project Proposal

The project proposal is a detailed description of the proposed system, a full and formal statement/demonstration of the plan for accomplishing the project. It shall describe the objectives, a preliminary view of the system context, the systems engineering method of approach, the project work statement, the project work breakdown and schedule and the risk management plan. The Proposal is iteratively developed with feedback from the student's mentor. The student schedule should be presented in Gantt chart view (or equivalent) format. The organization of the Proposal is described below. While awaiting comments and approval from the Project Instructor, the student should initiate the project work.

Proposal Format

SECTION 1: System Introduction

Include the name of the system, the student name, the mentor name, and a description of the project. Provide a student biography.

SECTION 2: Need for the System

Describe the capability need or gap of existing systems. Include the references to research on the topic to demonstrate that the student has a clear grasp of the domain problem. Describe the proposed system concept in order to address this need / gap. Justify the importance of requiring this system to address this gap.

SECTION 3: System Architecture/Description of System

A preliminary discussion and illustration of the proposed system shall be presented to provide insight into the possible subsystem components and interfaces and their functionality. The student shall include an initial/preliminary conceptual block diagram and context diagram for the system (see *Feasibility* and *Complexity* above). During the course of the project, the system functions and/or design are expected to change as the systems engineering process is applied. At a minimum, this section should include:

- The System Context Diagram (the white box view of the system)
    - Intended stakeholders that would interact with the system.
    - Intended domain environment that the system would operate in.
    - External systems / organizations that the system would interact with.
- System Conceptual Block Diagram. This diagram is a very high-level block diagram of the system. It should not include any design details. As noted above, *"pre-designing"' the system during the proposal phase will demonstrate a lack of understanding of Systems Engineering fundamentals and will be assessed accordingly.*

SECTION 4: Project Background

Identify 2-4 stakeholders that you intend to interface with during your project and their background that will be relevant to your project. Develop a work breakdown structure (WBS) and identify the timeframe of the major deliverables to include the final presentation date (milestones and schedules). Identify 4-6 risks that you anticipate to consider and address during the project (ensure these risks are under your project control).

WBS

This section identifies specific tasks (20 or more) to be performed in the project. These tasks shall be grouped in a Work Breakdown Structure (WBS) showing how they relate to one another. The general purpose of each task shall be indicated. For **each task** the estimated number of **hours of effort** to be required by the student shall be listed to demonstrate that the work has been carefully planned and that the total scope of the project is appropriate. Tasks shall be product-oriented. Each WBS element shall be broken down to increments no greater than 20 hours (10 hours preferred). Use of Microsoft Project (or similar tool, such as OpenProject) for the WBS and schedule is expected.

Milestones and Schedules

The Milestones section shall identify the key dates or events marking project delivery dates and major review points. The schedule shall identify the estimated start/completion dates for each major task. Both the milestones and the schedule shall be traced to the Work Breakdown Structure. Contingencies and backup plans should be evident in the schedule.

Mentor Note: Don't consider the WBS, milestones, and schedule to be purely academic deliverables. The WBS, along with your milestones and schedule, should provide a sound foundation for you to work from throughout the semester. Students that develop a comprehensive WBS/schedule, typically do a better job managing their time. These

For full credit, apply Earned Value Management to your schedule, and update it throughout the semester. Consider schedule as dates and cost as hours applied to the project. Your baseline schedule should define your Budgeted Cost of Work Scheduled (BCWS) and Budget at Completion (BAC). Budgeted Cost of Work Performed (BCWP), Actual Cost of Work Performed (ACWP), Cost Performance Index (CPI), Schedule Performance Index (SPI), and Estimate at Completion (EAC) should be reported at the completion of every deliverable.

Risk Management / Initial Risk Assessment

The method the student will use to identify, monitor, mitigate and manage risk during the project shall be discussed and illustrated. The focus should be on technical risks for the system and student project risks, not normal programmatic risks faced by every project.

Identify 4-6 risks that you anticipate to consider and address during the project, ensure these risks are under your project control. In the Proposal, an initial set of risks shall be included in a table. A risk cube and waterfall chart shall be provided for all of the technical risks identified.

SECTION 5: Systems Engineering Justification

Why would systems engineering be required for the project (e.g. what makes your project warrant a systems engineering approach)? List 3 scenarios that would describe your system operations and interactions that you would engage your stakeholders (this is to get you thinking about the different ways your system will operate). List the top five Measures of Effectiveness (MOE) that can measure your system performance. List the analytical tools and techniques you will use during the project to assess your system performance.

5.0 APPLICATION OF SYSTEMS ENGINEERING

The second, and major, portion of the Project course is devoted to the development of the selected system in accordance with the approved Project Proposal. In this portion of the course, the student will prepare several reports (CDRLs): Requirements Analysis / Concept of Operations, Functional Analysis, Conceptual Design, one Trade Study, Test Plan, and a System Specification (A-Spec). These artifacts will become part of the written Final Report (as appendices) along with the Proposal, other relevant data, and conclusions and recommendations. The student should continually update/maintain the Work Breakdown Structure, Schedule and Risk Management Plan as they progress throughout the project. The contents of these reports are described briefly below.

5.1 Requirements Analysis and Concept of Operations Reports

The development of a new "system" has to be based on a well-formulated set of requirements derived from an analysis of operational needs. Both originating and derived requirements shall be included. Typically, a system project would have 150-200 total requirements. The Requirements Analysis Report should describe the required operational outcomes that have been extracted from the Needs Analysis (often derived from a Mission Needs Statement), and the key system performance requirements (often called Key Performance Parameters) needed to realize the operational outcomes. The reasoning behind each system requirement should be stated. Each requirement shall be labeled or numbered to demonstrate traceability throughout the project. Ultimately, the requirements will be traced to functions, components, trade study criteria, subsystem specifications and validation methods. To the extent possible, the requirements should be

quantifiable, e.g., have numerical parameters listed to show the range or scope required for the requirement. The report shall also state how the accomplishment of each major requirement would be verified. The integrated report incorporates the Concept of Operations (CONOPS) with diagrams, including one or more scenarios or use cases illustrating the system functioning in its operational environment. Depending on the project, the student may consider the use of a tool such as DOORS or CORE to manage the requirements information. Typically, this is the most challenging report as this is the first report of the project. Take specific care to describe the needed capabilities that can be gathered from your stakeholders and can be developed from your scenarios / use cases. The functionality that is required in the use cases can aid you in developing the functional architecture in the FAR.

5.2 Functional Analysis Report

Prior to initiating Functional Analysis, the requirements must be well defined and validated (preferably with the customer/user). As the Functional Analysis begins, the requirements are translated into the functions that must be performed. These functions are ultimately translated or allocated into subsystems. One must visualize the type of system needed to meet the requirements and the subsystem functions that will implement the projected objectives. Various attributes of the system such as System States and Modes, System Functions, and Functional Interfaces are defined. The states and modes considerations will help to ferret out details of interfaces and time-varying requirements. At a minimum, this artifact shall include a functional context diagram, functional flow and functional block diagrams (at least two to three levels), N2 diagrams (as appropriate), and traceability back to requirements (use of a table is helpful). Depending on the project, the student may consider the use of a tool such as CORE to manage the functional architecture and traceability.

5.3 Trade Study

The systems engineering method uses trade-off analysis or analysis of alternatives as the means for making significant technical and program decisions and in mitigating technical risk in the product design. In the Project, there should be a number of informal trade studies, of which at one shall be carried out and reported in detail. Although not explicitly required, capturing the results of your informal trade studies is highly encouraged. The hierarchy of analyses of alternatives includes early consideration of approaches to top-level design to a study of alternatives for detailed subcomponents. For the formal study, it is best to focus on those system components where specifications and quantitative information exists to adequately assess the trade space. In reporting the trade study, it is necessary not only to describe the technical or component alternatives considered, the quantitative selection criteria, their relative weighting and scoring; but

the **rationale** for each of these selections, assignments and scoring shall also be documented. Thus, the reason for selecting each of the alternative solutions to be considered and each criterion shall be stated and traced to requirements. Weights assigned to criteria shall be justified, as well as the relative scores given each alternative for each criterion. Finally, a sensitivity analysis shall be performed. The significance of the results shall be discussed in the light of that analysis. In conducting the sensitivity analysis, it is helpful to successively zero-out each of the criteria to identify any possible bias in the analysis. There are a number of tools that could be used for this effort. If a tool is used, the student should discuss and thoroughly understand the input, parameter space and output of the tools.

Mentor Note: Before you start developing your formal trade study, review your notes from class. You should already have a step-by-step process to perform a trade study in hand. A few helpful hints:

(1) Identify your requirements related to your trade study up front.

(2) Make sure to trace each selection criterion to requirements, or provide a justification / rationale for its use.

(3) If you don't have an objective weighting method in place, use the pair-wise comparison method.

(4) Watch your significant digits!

5.4 Conceptual Design

Functional Analysis normally defines the functions that the system needs to perform in order to meet the performance requirements. A vision of how the functional architecture might be realized by hardware and software components constitutes a Conceptual Design of the proposed system. Interfaces shall also be defined and optionally an Interface Control Document can be generated. A physical context diagram, physical block diagrams and allocation diagrams are typical products. The conceptual design shall also include traceability to functions and requirements (as appropriate). In most

instances, physical interfaces should also be traced back to functional interfaces/interactions, captured during Functional Analysis. Depending on the project, the student may consider the use of a tool such as CORE to manage the physical architecture and traceability.

5.5 Test Plan

The test plan describes a selected portion of your system capability and develops a plan for which to evaluate your system's performance. As the project is largely in the conceptual design phase, it is not intended to dive deeply in the test environment and details, but to facilitate consideration of the test portion of the systems engineering method. The test plan should include the pertinent requirements that will be included in the test, test environment, equipment that would be needed to monitor and analyze the test, test subjects / expertise to conduct and analyze the test, desired results to determine if the test was successful, and the metrics intended to be collected.

5.6 System Specification (A-Spec)

The system specification embodies the functional requirements to be realized by the implementation of the conceptual design into hardware and software so as to meet the system operational requirements. It is normally a key product of the system conceptual design phase. It will vary from the initial requirements by revisions made during the project and the outcomes of previous artifacts. The specification shall be written in a formal structure, showing traceability to the requirements, covering system definition, required quantitative characteristics, support requirements, and any special requirements such as safety and human interfaces. The student shall also include (as appropriate) any concerns the designer may need to take into account, such as incomplete analysis, unstable requirements, business or technology factors that went unaddressed and areas of design flexibility within the requirements envelope. As appropriate, the student can provide special instructions to the system designers/developers. The system specification should include requirements metrics. At a minimum, the report shall include:

a) # of initial requirements (from Requirements Analysis Report)
b) # of final requirements (from A-Spec/System Spec)
c) #/% of qualitative requirements
d) #/% of quantitative requirements

6.0 FINAL REPORT AND PRESENTATION

The culmination of the Project System is the submission of a formal written Final Report and an Oral Presentation describing the student's work on the project.

6.1 Final Project Report

The Final Report should consist mainly of an assembly of the Concept/Proposal and reports submitted during system development, with introductory and concluding sections to put all of the parts into a coherent context. The Proposal and reports previously submitted do not have to be rewritten. The report shall be included in the final deliverable. The suggested organization of the Final Report is as follows:

Table of Contents

Project Objective and Approach

This section shall include a summary statement describing the purpose and general description of the Project System.

Significance and Scope of the Work

This section shall include the student's perception of the significance of the work from the perspective of the products and results produced by the project.

Project Proposal

This section shall capture a brief summary of the process used to develop the Proposal. It shall refer to the appendix that captures the actual document.

Requirements Analysis and Concept of Operations Reports

This section shall capture a brief summary of the process used to develop the Requirements Analysis Report. It shall refer to the appendix that captures the actual document.

Functional Analysis Report

This section shall capture a brief summary of the process used to develop the Functional Analysis Report. It shall refer to the appendix that captures the actual document.

Trade Study Report

This section shall capture a brief summary of the process used to develop the Trade Study. It shall refer to the appendix that captures the actual document.

Conceptual Design Report

This section shall capture a brief summary of the process used to develop the Conceptual Design Report. It shall refer to the appendix that captures the actual document.

Risk Management Report

This section shall capture a brief summary of the process used to manage risks throughout the semester. It shall refer to the appendix that captures the actual documentation related to risk.

Test Plan

This section shall capture a brief summary of the test plan and the portion of the system capability that will be evaluated. It shall refer to the appendix that captures the actual document.

A-Specification Report

This section shall capture a brief summary of the process used to develop the A-Spec. It shall refer to the appendix that captures the actual document.

Schedule Assessment

Mentor Note: As one might expect, you will "learn lessons" throughout the semester. Maintain a log of these lessons learned. It's much easier to copy/paste from your lessons learned log than it is to recall these lessons at the end of the semester.

This section shall use EVM to compare the planned versus actual task (hours) and schedule (dates) metrics. Any significant deviation(s) from the planned values shall be documented.

Mentor Note: Since you will be required to assess planned versus actual task/schedule performance on your project, it is critical that you establish a method to track your progress (both in hours and dates) throughout the semester. Make sure to keep your metrics updated throughout the semester!

Lessons Learned

This section shall capture observations/lessons learned from the student's perspective during execution of the project.

Evaluation and Next Steps

This section shall provide conclusions on the value of the project to the student as well as to the intended users. Include a discussion of any possible follow-on activities, plans or potential toward system realization.

Recommendations

This section shall include the student's suggestions on how the value of the System Project course might be improved.

Appendices

A full compilation of the artifacts produced in support of this project, including the oral presentation materials.

6.2 Oral Presentation and Critique

In addition to the written Final Report, the student will give an Oral Presentation using summary viewgraphs. This presentation is expected to last 75 minutes, including questions and answers. The presentation should include 15 to 30 viewgraphs and the student should be prepared to discuss the project with the reviewers. Any special exhibits or products should also be provided. The examiners will generally include the Course Instructor and Project Mentor. Of particular interest is a discussion of lessons learned from the project.

Public students shall provide two notebooks and two CDs of ALL the CDRLS, including the Oral Presentation, to the Mentor and the Project Instructor. Public students shall also

upload a final version of their deliverables to Blackboard by the date of the scheduled presentation.

Online students shall upload all final materials to the Blackboard site no later than 48-hours in advance of their scheduled online presentation.

7.0 SCHEDULE

To complete the project by the end of a scheduled semester, it is necessary to have the subject of the work well in mind a few months prior the start of the course. It is a requirement to submit your Final Proposal on Blackboard prior to registering for the course. A full semester will be required to do the bulk of the work. Since the project is self-paced and other priorities sometimes intervene, only about 30% of students complete the work as defined in their planned schedule. Be realistic but work hard to be committed to complete the course and your degree requirements in one semester. The following is a notional overall schedule:

Timeline	Activity
System Design and Integration Course	Gain access to the SE Project site Identify a mentor and connect to mentor in Blackboard
System Test and Evaluation Course	Explore subjects for project Discuss project concept with mentor Complete SE Project Proposal draft to mentor
Registration for Course	Final SE Project Proposal submitted to instructor
2	Submit Requirements Analysis Report/CONOPS
4	Submit Functional Analysis Report
5	Submit Trade Study Report
7	Submit Conceptual Design Report
9	Submit Test Plan Report
10	Submit A-Specification Report
11	Submit Final Report and Presentation
12-14	Present Project to Instructor

8.0 REQUIREMENTS FOR ONLINE STUDENTS

Online students will use Blackboard as their primary mechanism for interacting with their mentors. In addition, students and mentors can use the Adobe Connect tool as a mechanism for real-time interaction.

All online students will perform their final oral presentation via Adobe Connect. Therefore, online students and their mentors are required to have, as a minimum, a computer headset (headphones and microphone) and a computer video camera. Prior to their final presentation, students should test their computer with Adobe Connect to prevent any last minute problems. An Adobe Connect session has been exclusively set up for this purpose. The link to this session is included here:

http://connect.johnshopkins.edu/sm4_test/

9.0 GRADING RUBRIC

The focus on student attention in the System Project course should be on demonstrating your SE knowledge and skills. The "journey" is the most important aspect of this experience. Nevertheless, after the completion of the Oral Presentation, the University requires that a grade be given for the student performance. The course instructor and the mentor will assign a grade based on the student body of work and the level of understand of systems engineering demonstrated during the oral presentation. The thinking and input for the assigned grade is based on the table found below:

Criteria	Novice (0-49)	Competent (50-85)	Proficient (86-100)
Understanding of Core SE Principles (Method of Assessment – Oral Defense)	Unable to describe basic systems engineering principles, processes, and practices.	Able to describe basic systems engineering principles, processes, and practices. Unable to explain how these principles apply to their SE Project and to applications in general.	Able to describe systems engineering principles, processes, and practices. Able to apply these principles to elements of their SE Project, and can describe application of the principles to
Defense of SE Project (Method of Assessment – Oral Defense)	Unable to effectively explain/describe project artifacts. Unable to justify decisions made throughout the project. Unable to answer questions specific to the project artifacts.	Explains/describes project artifacts with difficulty. Justifies a majority of decisions made throughout the project. Struggles when defending some portions of the Successfully answers questions related to project artifacts with difficulty, sometimes requiring assistance from the	Effectively explains/describes project artifacts. Anticipates questions and answers them before they are asked. Provides solid justifications for decisions made throughout the project. Successfully defends approach. Promptly and effectively answers questions, demonstrating clear knowledge of the project artifacts.
Effective Leadership (Method of Assessment – Student/Mentor Interactions)	Does not initiate conversations/interactions with mentor. As project lead, does not demonstrate effective project management skills. Does not deliver products for review within the prescribed timeline. Does not proactively maintain progress on project. Project progress stalls regularly.	Successfully uses Blackboard tools to interact with mentor. Does not provide status updates to mentor unless requested. Although does not achieve milestones established in proposal, continues to make steady progress on project Uses basic methods to assess project progress.	Initiates conversations/meetings with mentor as required. Proactively provides status updates to mentor. Provides prompt feedback to mentor/instructor inquiries. Applies appropriate SE tools (both process and software) to project efforts. Manages work to project plan established in proposal using EVM techniques. Analyzes progress and documents/justifies any deviations from plan.
SE Project Quality **Project Concept & Proposal** (Method of Assessment – Artifact Review)	Project Concept and Proposal require multiple revisions prior to submittal due to poor quality. Project concept is weak. Justification for use of systems engineering to address concept is poor.	Project Concept and Proposal meet the intent of the SE Project Guidelines. Artifacts provide a basic understanding of the proposed project. Artifacts partially document the appropriateness of project. Project Management artifacts are complete, but may not be reasonable for the proposed project.	Project Concept and Proposal are fully compliant with the SE Project Guidelines. Artifacts clearly present the proposed project. Artifacts document the appropriateness of project. Project Management artifacts are well thought out and reasonable for the proposed project.
SE Project Quality **Requirements Analysis Report** (Method of Assessment – Artifact Review)	Topical coverage of requirements only. Majority of requirements are self-generated. Traceability of requirements to their respective sources is not provided.	Important operational requirements are captured. Requirements are elicited from documentation or are self-generated. Stakeholder involvement is not apparent. KPPs are documented. CONOPS is complete, but is not used to support any downstream SE activities.	Thorough operational requirements analysis. Requirements are elicited from multiple sources, to include stakeholders. Requirements are well formed, and KPPs are justified. CONOPS is complete, and is used as an input to other SE activities. Traceability of requirements to their sources is fully documented.
SE Project Quality **Functional Analysis Report** (Method of Assessment – Artifact Review)	Functional analysis is incomplete. Functional architecture does not make sense. Traceability of functions to requirements is not provided.	Functional analysis is complete. Functional decomposition is evident, however some areas are not adequately decomposed. Some functions are not fully integrated into the architecture. Functional architecture can be traced with difficulty. Traceability of functions to requirements is complete.	Functional analysis is thorough. Functional decomposition is appropriate for project. Functional architecture is well thought out, and demonstrates tight binding and loose coupling. Traceability of functions to requirements is complete. Gaps are properly addressed.
SE Project Quality **Conceptual Design Report** (Method of Assessment – Artifact Review)	Physical analysis is incomplete. Physical architecture is not based in reality. Traceability of components to functions is not provided.	Traceability of components to functions is provided. Physical decomposition is evident, however some areas are not adequately decomposed. Physical architecture captures all major functional areas. Physical interfaces do not capture the physical implementation.	Full traceability is documented, to include components to functions and physical to functional interfaces. Gaps are appropriately addressed. Physical decomposition is appropriate for project. Physical architecture is complete. Hardware and software CIs are thoroughly described. Interfaces describe physical implementation.

[Continued on Next Page]

Criteria	Novice (0-49)	Competent (50-85)	Proficient (86-100)
SE Project Quality **Trade Study** (Method of Assessment – Artifact Review)	Trade study is not adequately justified. Trade study approach is ad hoc and does not follow a prescribed process. Research is not demonstrated. Analysis is subjective.	Trade study is appropriate for the project. Selection criteria are valid but not fully justified. Weighting is performed, but approach is not fully justified. Utility curves are used, but have errors. Trade study analysis is complete. Sensitivity analysis is incomplete. Recommendations and follow-on actions are not provided or are not reasonable.	Trade study is justified by requirements and risk. Selection criteria are valid and justified. Weighting method is justified and used appropriately. Utility curves are properly formed. Trade study analysis is comprehensive. Sensitivity analysis is performed. Recommendations and follow-on actions are documented.
SE Project Quality **System Specification** (Method of Assessment – Artifact Review)	Topical coverage of requirements only. No requirements growth/refinement from the Requirements Analysis Report. Requirements are subjective. KPPs are not provided.	Requirements have been refined from the Requirements Analysis Report. Requirements metrics are presented. KPPs are documented.	Requirements have been refined from the Requirements Analysis Report. A large percentage of the requirements The SE process used throughout the project has driven requirements growth. Requirements fully describe the Requirements metrics are presented and explained. KPPs are documented, adequately justified, and are quantitative
SE Project Quality **Test & Evaluation Plan** (Method of Assessment – Artifact Review)	T&E Plan is incomplete. T&E Plan is not based in reality. Traceability of T&E Plan to Conceptual Design is missing.	Verification Cross Reference Matrix is included for the final requirements set. Test Environment(s) are documented. Test Resources are identified.	Full traceability is documented, to include test planning to conceptual design and requirements. T&E Plan is consistent with the VCRM. High level test metrics are captured. High level intended test results are documented.
SE Project Quality **Risk Management** (Method of Assessment – Artifact Review)	Risks are superficial. Risk analysis is incomplete and inconsistent with standard approaches. No risk waterfall is included.	Risks address some of the major risk areas on the project. Risk analysis is consistent with best practices, but includes errors/inconsistencies. Initial, current, and final risk profiles are not captured. Risk waterfall is included but is not complete or consistent with associated risk.	Risks address all major risk areas on the project. Risk analysis is thoughtful, complete, and consistent with best practices. Initial, current, and final risk profiles are captured. Risk waterfall is included and is complete.
SE Project Quality **Final Report & Presentation** (Method of Assessment – Artifact Review)	Assessment of project, artifacts, and self-assessment are superficial or are not included. Final package is missing artifacts. Final versions of documents are not included. Final package is not provided prior to the presentation.	Assessment of project, artifacts, and self-assessment are included. Final package includes all required artifacts, but there are problems with configuration management. Final package is complete and provided prior to the presentation.	Assessment of project, artifacts, and self-assessment are thoughtful and consistent with project. Final package is complete, properly formatted, and uploaded to the Blackboard deliverables area prior to
Semesters to Complete	5 points are automatically deducted (per semester) for late completion		
Total			
Configuration Control Version 003_00 Dated: 24 JUN 2017 Last Updated By:			

APPENDIX A - Selection of Project System Topics

General Attributes

As stated in the instructions for the Systems Engineering Project, the subject selected must be capable of demonstrating the student's ability to apply the methods of systems engineering learned during the curriculum to a practical problem. These methods include:

Requirements Analysis and Concept of Operations

Functional Analysis

Conceptual Design

Trade Studies

Risk Management

Test and Evaluation

A-Specification

Project Management

In order to permit the application of systems engineering principles, the subject itself shall:

(1) be a **system**-like **product**

(2) have potential **users** who **need** (or would pay for) such a product

(3) be **feasible** with existing technology

(4) involve **risks** and technical challenges in its accomplishment

Work Related Projects

Students are encouraged to select a project that is related to their work when circumstances permit. This category represents the majority of system projects carried out to date. In a work-related project, the student has access to information concerning the user environment, needs, opportunities, constraints and other important domain

knowledge. Sometimes, such projects also provide an opportunity to contribute to the student's workplace.

Examples:

(1) Conceptual Design of a Sonar Self-Noise Field System

(2) Advanced Port Ship Protection System

(3) Lighting Protection for an Antenna Range

CAUTION: There shall be a clear distinction between the student's workplace project and the JHU project. The execution of the JHU project must not depend on the progress or status of the workplace project. The work conducted shall be that of the student. Also, the JHU project shall not depend on classified or proprietary information which would restrict submission of project reports.

Community Related Projects

A number of interesting projects have been based on community needs and such projects usually provide ample access to users and other domain knowledge. However, the requirement that the problem must be "system-like" narrows the opportunities to special cases, which require the application of systems engineering.

Examples:

(1) Systems for the Development of an advanced School Local Area Network

(2) Management System for the Soccer Association of Howard County (teams, coaches, referees, schedules, equipment, tournaments, etc.)

(3) Remodeling a large church (lighting, acoustics, choir, building costs, etc.)

New Device Projects

Some students have an idea of a device (small system) that they believe might be marketable.

Examples:

(1) Automating the Analysis and Data Storage of Neurotransmitter Tests

(2) A Tactile Display for Blind Computer Users

(3) Transit Information Display Device

(4) Fisheries Scientific Computer System

(5) Automated Panel Assembly Device for a Radar Application

CAUTION: The device shall be sufficiently complex for application of systems engineering. The device shall be technically feasible and affordable and there must be a credible community of potential users. The student must have adequate knowledge of the technology and potential of the device.

Personal Projects

In very rare cases, projects have been based on personal needs but they are not recommended. As in the case of work-related projects, they have the advantage of domain knowledge. To be suitable for a Project System they need to have sufficient system-like scope to demonstrate systems engineering principles. The student (and family) shall not be the sole customer – the results must be of value to a community of potential users.

Examples:

Sailboat System in Preparation for Circumnavigation

Official Clock and Scoring System for High School Games

Reality and Originality

Except in special cases, the proposed Project System shall be real and the student's approach shall be original. Where the student wishes to deviate from reality for security or other reasons, or choose a problem that has been addressed previously, a case should be made and approval obtained to pursue the approach. In all cases, the project shall be wholly the work of the student, and any deviations shall be fully realistic.

APPENDIX B - Frequent Project System Deficiencies

The following paragraphs list common deficiencies in selecting subjects for the Project System and carrying it through to completion. Such cases lead to extensive resubmissions, resulting in delay of graduation of students for whom this is their final course. To make good use of past experience, students should review their project concepts against the cases described below. Project Mentors should also consider these examples when examining student concepts and proposals.

1. Inadequate system product

   Project product not clearly defined; not suitable to illustrate application of SE principles

   Product too simple, and/or solution too obvious to require SE approach

   Project focuses entirely on a minor component of a system

2. Project overly ambitious

   Project too ambitious to be accomplished within a reasonable time and effort

   System very large and/or complex

   Proposal of treatment overly detailed

3. Insufficient knowledge base

   Insufficient available information on project characteristics

   Project is new idea without prior experience or knowledge base

   Student has limited personal knowledge of project requirements and/or technology

   Excessive reliance on interviews to obtain knowledge

4. Overemphasis on product design

    Emphasis on product design rather than systems engineering

    Project involves writing a computer program

5. Too closely tied to student's work project

    Product identical to part of student's current job

    Project may be adversely affected by changes in schedule or content of job

    Confusion between objectives of JHU project and company objectives

    Security or proprietary complications

6. Project only of potential value to student or family

    Student is sole "customer" for project

    Requirements solely provided by student

7. Inadequate treatment of subject

    Student underestimates the thoroughness of planning, execution and writing required

    Application of too few SE principles

    Reasoning in applying principles not explained

    Write-ups are cursory, superficial

    Key items required in project specifications omitted or slighted

8. Inadequate execution of project

    Poor Proposal plan

    Failure to follow plan

    Inadequate communication with mentor

Revision History

Version	Date	Changes
006_00	Jan 2010	1) Reduction of the trade studies/analysis of alternatives from two to one. 2) Explicit inclusion of use of a risk waterfall to demonstrate risk mitigation of a technical risk during the course of the project. 3) Addition of more project mentors. 4) Requirement for CD at final oral briefing with all CDRLs. 5) Inclusion of mentor commentary throughout document. 6) Initiated configuration management (versioning).
007_00	Jan 2011	1) Moved mentor list from document to online tool.
007_02	Oct 2012	1) Transition to Blackboard 2) Explicit inclusion of use of a risk waterfall to demonstrate risk mitigation of a technical risk during the course of the project 3) Additional comments for students enrolled in 803, 805, 806, 807, and 808.
008_00	Jan 2016	1) Combined Project Concept and Proposal into one document. 2) Made the Risk Management Report mandatory. 3) Made the Test and Evaluation Report mandatory.
009_00	Jun 2017	1) Removed 800-series specific requirements (concentration specific mentors) 2) Updated the grading rubric to address late submissions. 3) Modified timeline to include pre-course work. 4) Modified proposal format. 5) Addressed changes to the proposal conceptual block diagram. 6) Included EVM as a component of project scheduling and execution. 7) Added a reference to the Thesis option. 8) Included Revision History table.