Systems Engineering Capstone

Smart Distributed Inventory Management System

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Worchester Polytechnic Institute

SYS585 – Systems Engineering Capstone Experience

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List of Abbreviations

AWS- Amazon Web Server

BPM- Business Process Management

CONOPS - Concept of Operations

COTS - Commercial Off The Shelf

DMSMS - Diminishing Manufacturing Sources and Material Shortages

DOD- Department of Defense

DT&E - Development Test and Evaluation

EAI - Enterprise Application Integration

FLOPS- Functional Operational Requirements

FLSYS- Functional System Requirements

HOQ - House of Quality

IS- Information System

IT- Information Technology

KPP- Key Performance Parameters

LIDAR - Light Detection and Ranging

MBSE - Model Based System Engineering

MMC- Materiel Management Center

OT&E- Operational Test and Evaluation

QFD - Quality Function Deployment

SDIMS- Smart Distributed Inventory Management System

TEMP- Test Evaluation Management Plan

PROJECT DESCRIPTION

Team Members:

[redacted]

Description of the Problem:

Within Inventory Control Management, many enterprises find it difficult to manage inventory and stock of their products. Facing issues such as order quantities and customer lead-time are a few examples. Usually Inventory problems are caused by poor execution, communication, and decision-making. Inventory control can consume many resources within an enterprise as well as cause delays in fulfilling complete orders for customers. An Automated Inventory Control System can heavily affect day-to-day operations for many companies, giving them the ability to fulfill orders completely in a timely manner with little to no lead-time.

Description of the Motivation:

Multi-national production contracts; rapid production cycles; and direct, customizable sales are driving the competitive pressure of today's international business environment. With enormous volumes of material flows, inventories now makeup considerable costs for a company. Minimizing inventory costs while continuing to quickly meet the needs of customers requires an ability to track both sales and inventory, forecast demand, and communicate across the supply chain in real-time. Competitive advantage, therefore, requires an inventory management system capable of controlling these aspects while effectively incorporating the human intuition found throughout the logistical chain.

Problem Statement and Needs Analysis:

In today's hectic and constantly evolving international business environment, it is increasingly difficult to manage sales and inventory. Customers want their products quickly. In a dynamic supply and demand business environment of the Aerospace and Defense sector, many companies struggle to manage the complex and constantly changing defense environment. There is a clear need for inventory management systems that facilitate order management while optimizing inventory.

Although several inventory management software tools and systems exist in the marketplace today, they tend to be complex and expensive. Most importantly, as with any system, they often fail to meet or exceed customer expectations. Our Automated Inventory Management System is intended to be a user-friendly, cost effective, distributed digital system that harnesses the latest cutting edge technology such as sensor fusion, computer vision, and machine learning. Furthermore, the use of the House of Quality (HOQ) throughout our design and development process ensures that our system meets and/or exceeds the voice of the customer.

Research Sources, Tools, Methods:

The following research sources, tools and methods are planned to be consulted and used in the development of the Automated Inventory Management System.

- **House of Quality (HOQ):** This Quality Function Deployment (QFD) tool will be used throughout the system engineering process to ensure design and development is aligned with customer expectations (voice of the customer).
- **High level internet sources**, including google, Wikipedia, Investopedia and the WPI Online Library, will be used to gather research information.
- **Inventory Management Software** that is commercially available on the internet will be consulted to get an understanding of how typical inventory management systems operate.

CONCEPT OF OPERATIONS (CONOPS)

Goal and Objectives of the Inventory Management System:

The Department of Defense (DOD) is responsible for managing a secondary item inventory composed of spare parts, consumables, repairable components, subsystems, bulk items, subsistence, and expendable end items like clothing and gear. The total value of this inventory in 2015 reached $91.7 billion or the equivalent of roughly 15% of the United States military budget.

In general, this inventory management system is part of a broader, global supply chain system involving a broad swath of various independent suppliers, contractors and stakeholders, each with their own motivation and needs. The ultimate purpose of this complex system of systems is to support the capabilities of US forces while minimizing the significant expense of storing unneeded inventory so that budget can be freed up for other defense priorities. The goal, therefore, of this inventory management system is:

> *To reduce secondary item inventory among the services and improve the balance between availability and cost while maintaining optimal readiness and capability of the forces.*

The proposed inventory management system is technology driven. That is to say technological opportunities are the primary motivation for replacing or otherwise updating the legacy system. With new technology, however, it is expected new human processes, interactions and interfaces will also need defined in order to best exploit these technological opportunities and fully realize their benefits.

Although the technology itself plays a central, motivational role, it is not expected to be the primary role in all cases. For example, with certain sub systems, the human elements may require considerable reconfiguring with little or no change to the underlying technology.

The figure below, adapted from a case study titled “Global Distribution Centers, Multilevel Supply Chain Modeling to Govern Complexity” (Gorod, A.), illustrates at a highly, abstract level the system’s intent to merge the flow of administrative control information with the flow of goods to best achieve the overarching goal stated earlier.

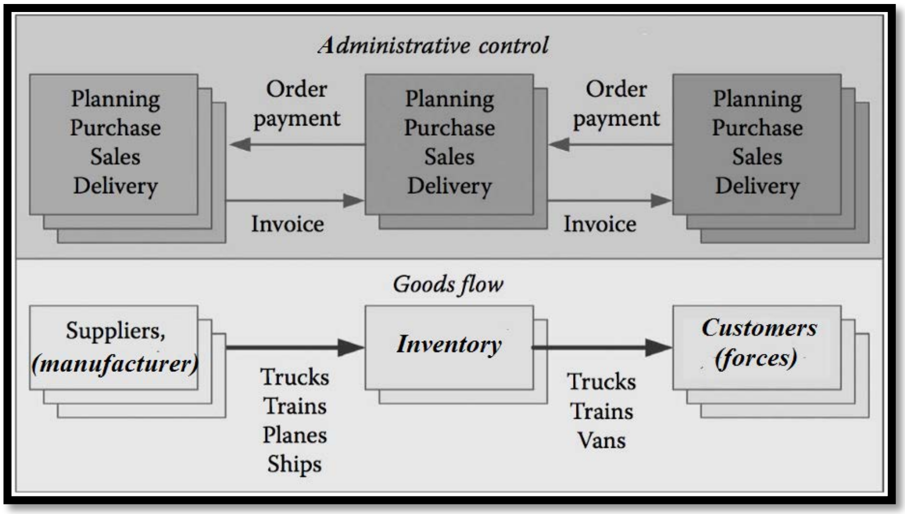

Figure 1: Abstract Illustration of Administrative and Goods Flows Merged by System

Four general objectives will contribute to the overarching goal by affecting both the on-hand and on-order inventories. Those objectives are:

- To improve monitoring
- To improve reporting
- To improve forecasting
- To improve integration

First, improved monitoring means that expiration dates and perishable goods are more effectively tracked and queued for distribution. This intends to make greater use of space and in many instances reducing inventory requirements. A similar rationale follows for those inventory items that are obsolete or no longer needed as well as those that are found to be in excess of requirements. The idea is to reduce and eliminate wherever possible.

Second, with improved monitoring comes improved reporting. Reports that are both more accurate and timely provide greater visibility of inventory. This allows for better planning especially around long lead-time acquisitions, but it also provides leadership with information needed to develop more effective metrics and ensure a more robust justification for inventory items.

Third is improved forecasting. It follows that if monitoring and reporting are improved, forecasting as well will benefit. This is critical to the internal efficiency and strategy of the services. Being able to better forecast allows for leaner and more flexible inventory requirements, adaptable supplier contracts, and greater accuracy related to accounting and work scheduling.

Finally, the fourth objective is improved integration. This objective also aligns with the previous three. Not only does it imply integrating the services but also the integration of upstream and downstream stakeholders into inventory management. Greater levels of integration provide greater opportunities for outsourcing certain aspects of inventory management, leveraging economies of scale, for example, when purchasing and procuring items, and, as well, for jointly managing the inventory itself. Integration also has the effect of reducing lead times for highly specialized items by improving communication of needs to suppliers. In all, joint efforts between the services, greater standardization, and a more fluid exchange among stakeholders are seen as paramount.

Strategies, Tactics, Policies, and Constraints affecting the Inventory Management System:

Initial constraints to this inventory management system will be US Government and DOD leadership commitments. High-level approval will need to be reflect in significant resource allocation and investment strategy for the system.

Guidelines, security concerns, and interdepartmental approvals will need to mirror these high-level commitments not only among the services, who are assumed to be the users, but among stakeholders as well. Wherever possible the new inventory management system will need to consider existing assets such as action plans, guidance documents, performance metrics and policies.

Existing inventory management capacity among the services must also be taken into consideration. The system will most likely require broader collaboration with subsequent changes to existing human recourses, the structure of command and reporting, and even specific job descriptions. Further, a system of this nature carries the potential to change deeply entrenched departmental budgets. Early communication and collaboration from the ground up, with the intent to understand and, where at all possible, build on those long standing perspectives will help assuage the effects of these constraints.

Success at the initiation and development stages will hinge on acquiring a broad knowledge of the many intricacies across all supply chains and establishing standard definitions, methodologies and procedures between the services. Particular attention should be paid to sensitive or security constrained information.

Operational Scenarios and Organizational Responsibilities:

The use case diagram below depicts the organization's activities and interactions among participants and key stakeholders. This use case diagram demonstrates Model Based System Engineering (MBSE) principles and concepts using IBM Rational Rhapsody software. The purpose of the use case diagram is show how the actors (i.e. participants and key stakeholders) interact with the Smart Distributed Inventory Management System to perform functions in order to achieve certain goals.

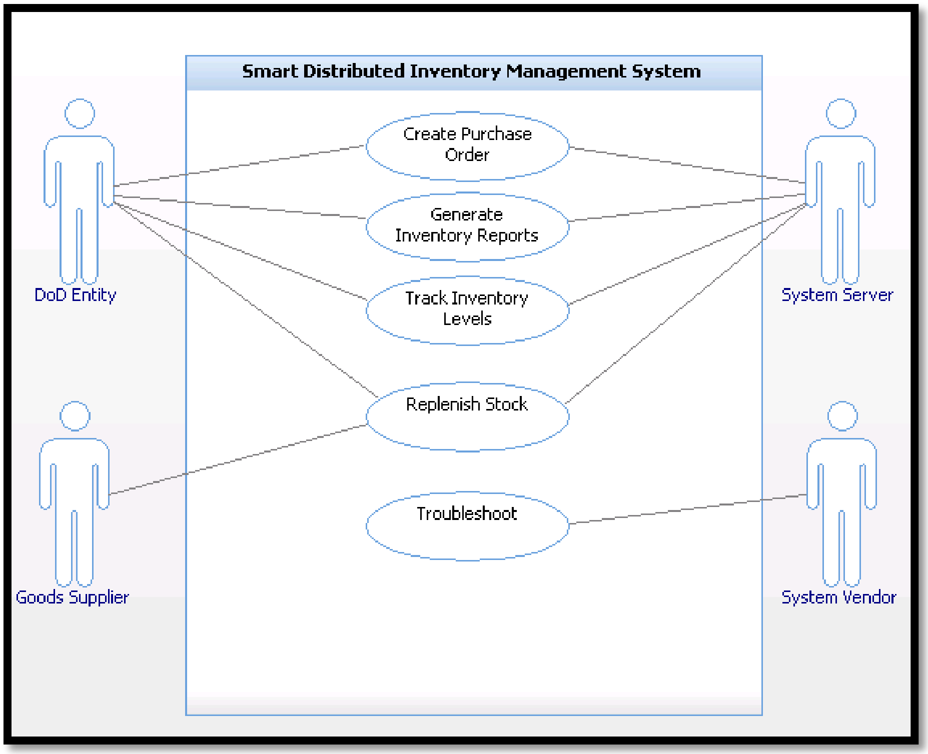

Figure 2: Generalized High-Level Use Case

The clear statement of responsibilities and authorities delegated for the actors in the use case diagram are shown below.

DOD Entity: Organization within the Department of Defense (DOD) responsible for inventory management.

Goods Supplier: Supplier responsible for providing the specific goods to the DOD Entity.

System Server: External computer or cloud based server that processes data and performs functions such as sensor fusion, computer vision and machine learning. Although the system server is considered to be part of the overall system architecture, it is a distributed and external element of the Smart Distributed Inventory Management System.

System Vendor: Manufacturer and developer of the Smart Distributed Inventory Management System responsible for design, test, production and aftermarket support.

Operational Process for Fielding the System:

In order to deploy the system into the field it would require a team effort and structure to support the operational process. Our Support Services Team consist of three organized teams within. The Support Services team includes the Program Manager (PM), Application Specialist (AS), and Deployment Specialist (DS). The Program Manager is responsible for communicating to the customer and answering any questions in regards to logistics and operations. The PM is also responsible for gathering stakeholder contact information and identifying all key actors. This can include maintenance personnel, facility managers, IT personnel, quality, and regional directors.

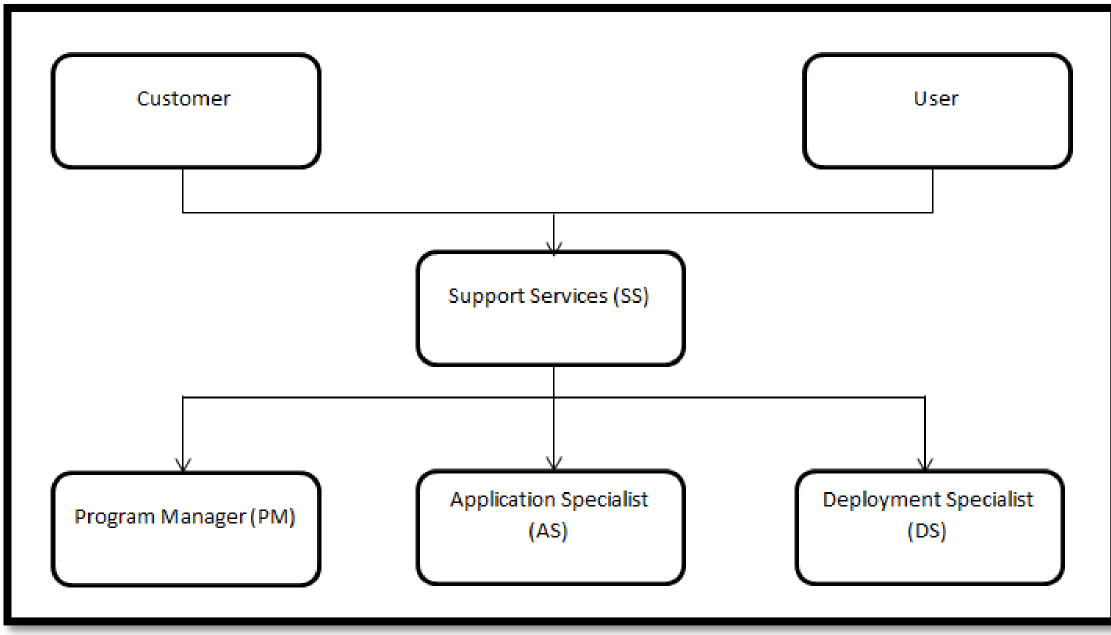

Figure 3: Support Tree Breakdown

The Application Specialist team (AS) is responsible for physically installing the system. Other than the physical install, AS is responsible for a lot of the leg work to be completed prior to system implementation. AS receives information from the PM and then reaches out to the onsite contacts. AS communicates directly to the customer all system requirements that need to be met pre-installation. AS gathers maps of the facility, schedules installation dates and coordinates training sessions with facility personnel on how to operate the system.

The Deployment Specialist team (DS) provides customer ongoing support in the event where there is a system malfunction or to answer general system questions post installation as well updates and upgrades to the system. DS closely monitors the system and keeps track of escalated issues via a work ticketing system. DS is also responsible for system maintenance and troubleshooting systematic errors. The ticketing system is also used as a means to further evaluate the system once installed in the field to further evaluate repetitive problems so that we can observe behaviors and can assist in future product development or make enhancements.

System Life Cycle:

The System Life Cycle (SLC) process will be used for initiating, developing, maintaining, and retiring the system (See figure 2). The system life cycle is a tool that can help reduce many issues found in developing a system.

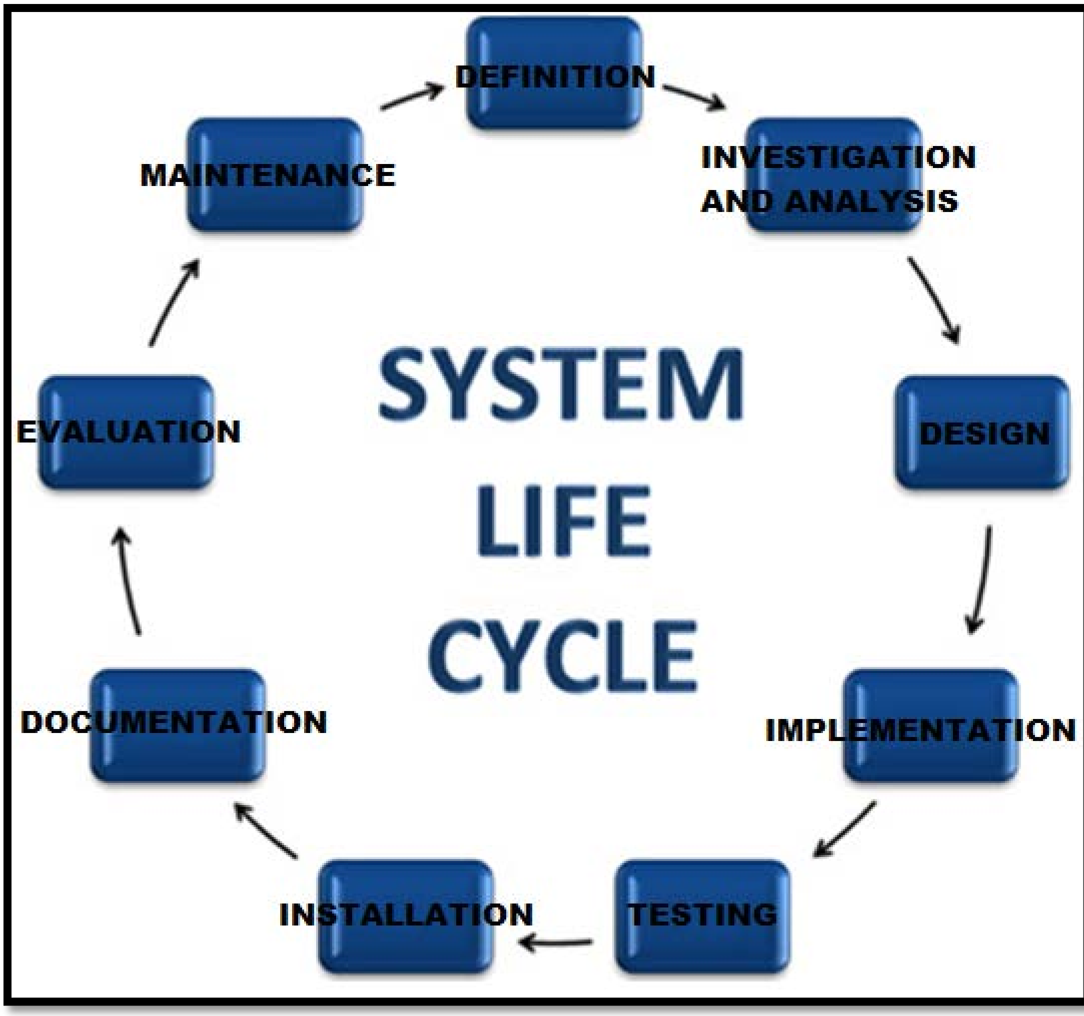

Figure 4: System Life Cycle

Prior to developing the system, we would first define the system's requirements as well as grasp a better understanding of its operational and field of use. Once that is understood, legacy systems can be explored that are currently being implemented in the field or similar systems that can be utilized to arrive at our desired outcome for the Inventory Management System. At least one or more feasible solution must be found prior to moving forward to the Development phase.

While in the developing phase, it is important to conduct multiple Test and Evaluations during the process to help mitigate potential issues that may be found within the system. This can negatively influence scope, budget and time if not executed properly. Test and evaluations should be developed and planned out to warrant system functionality as well as verify system integrity prior to assist in field deployment. Each test should include a procedure as well as acceptance criteria specified by the stakeholder's requirements and developed by the engineering design and test team.

Maintenance of the system will be supported by our Deployment Specialist team. DS will conduct remote inspections via a reporting system. Reports will be generated to insure the system is operational as well as has checks and balances that are in place to verify all is well. Reports will list the Health of the system and display useful information such as equipment battery levels, diagnostic reports, malfunction alerts, etc. The DS team is also responsible for conducting yearly component swap outs for the customer.

In the event that the system is End of Life'd (EOL'd), there are protocols and procedures that are put in place to retire the system. The system can remain operational however, the level of support from our end will be discontinued and the customer holds full responsibility for maintaining the system. We can provide work instructions on how to do so as well as procedures for system shut down. If the customer does not wish to have the system remain in place then they may package up the system and return it provided an RMA (Return Material Authorization) and the system will be decommissioned.

SYSTEM REQUIREMENTS

Scope:

The purpose of this specification is to outline the requirements for the Smart Distributed Inventory Management System (SDIMS). The SDIMS is a user-friendly, cost effective, distributed digital system intended to provide an integrated solution for DOD inventory management. It harnesses the latest cutting edge technology such as sensor fusion, computer vision, and machine learning.

Reference Documents:

Below are reference documents that are used for standards and approaches to inventory management:

- DOD Supply Chain Materiel Management Procedures
- DOD Supply Chain Corrective Action Plan
- Certified Supplier Quality Professional Body of Knowledge
- ISO/IEC TR 26905:2006 - Information technology -- Telecommunications and information exchange between systems - Enterprise Communication in Next Generation Corporate Networks (NGCN) involving Public Next Generation Networks (NGN)
- ISO/IEC 26907:2009 - Information technology -- Telecommunications and information exchange between systems - High-rate ultra-wideband PHY and MAC standard
- ISO/IEC 26908:2009 - Information technology -- Telecommunications and information exchange between systems - MAC-PHY interface for ISO/IEC 26907
- ISO/IEC TR 26927:2011 - Information technology -- Telecommunications and information exchange between systems - Corporate telecommunication networks -- Mobility for enterprise communications
- ISO/IEC 27036-1:2014 - Information technology -- Security techniques -- Information security for supplier relationships -- Part 1: Overview and concepts

Requirements Definition:

The user/customer needs are defined below. The user/customer needs provide a basis for developing the system requirements.

Table 1: User/Customer Needs

Needs ID	Customer/User Need	Weight / Importance (HOQ Input)
ND1	Reliable system	4
ND2	Need to be able to receive, stock and dispatch inventory	5
ND3	Need to be able to track inventory	5
ND4	Need to be able to communicate inventory status	4
ND5	Need to integrate coordination of key stakeholders and users	5
ND6	Need to be able to analyze and predict supply and demand (forecasting)	3
ND7	Need to allow for flexible and competitive collective-behavior among external users	2
ND8	Improved Monitoring and Tracking	2
ND9	Accurate and Timely Reporting	3
ND10	Low Cost	5
ND11	User Friendly	3
ND12	Need to have Training/User Manual/Guide/Instructions	3
ND14	Need to operate in harsh environments	3
ND15	Need to have backup power in case of power outages	5
ND17	Need to operate autonomously	3
ND18	Need to be secure	5
ND19	Need to operate on different operating systems	3

The requirements for the Smart Distributed Inventory Management System are shown below. Each requirement is traceable to at least one user/customer need. Our most important requirements are identified as Key Performance Parameters (KPPs). The KPPs are identified based on the color scheme shown below. Using a combination of the House of Quality (HOQ) output (as shown in Appendix A) and our engineering judgement, we identified a total of 10 KPPs that are critical to the success of our project. In some cases, we disagreed with the HOQ output. The reason for this disagreement is due to the fact that the HOQ put more emphasis and weight on the requirements that were mapped to more needs. This resulted in a higher score output. However, using our engineering judgment and experience, we felt that this output was not justified in all cases.

Table 2: System Requirements

ID	Section Heading	Description	Verification Method	Needs Traceability
FL3.1	**Functional Requirements**			
FLSYS3.1.1	*Inventory Tracking*	*The system shall track inventory.*	*Test*	*ND3*
FLSYS3.1.2	*Stock Management*	*The system shall manage 99.9% of inventory stock, including receipt and dispatch of inventory.*	*Analysis, Test*	*ND1, ND2, ND9*
FLSYS3.1.3	*Forecasting*	*The system shall forecast supply and demand.*	*Test*	*ND6*
FLSYS3.1.4	*Status and Reporting*	*The system shall provide inventory status and generate inventory reports.*	*Test*	*ND4, ND9*
FLSYS3.1.5	*Network Communication*	*The system shall communicate with a network server.*	*Demonstration*	*ND5, ND7*
FLSYS3.1.6	*Memory*	*The system shall provide at least 64 gigabytes of memory along with the capability to expand up to 100 gigabytes.*	*Analysis*	*ND2, ND3*
FLSYS3.1.7	*Integration*	*The system shall integrate with other subsystems/components.*	*Demonstration*	*ND5, ND7*
FLSYS3.1.8	*CPU*	*The system shall contain a central processing unit (CPU).*	*Inspection*	*ND2, ND5, ND6*
FLSYS3.1.9	*CPU: Sensor Fusion*	*The system CPU shall support sensor fusion.*	*Analysis*	*ND2, ND5, ND6*
FLSYS3.1.10	*CPU: Computer Vision*	*The system CPU shall support computer vision.*	*Analysis*	*ND2, ND5, ND6*
FLSYS3.1.11	*CPU: Machine Learning*	*The system CPU shall support machine learning.*	*Analysis*	*ND2, ND5, ND6*
FLSYS3.1.12	*CPU: Autonomy*	*The system CPU shall provide autonomous processing capability utilizing machine learning and computer vision.*	*Demonstration*	*ND2, ND5, ND6, ND17*
FLOPS3.1.14	*Quality Checks and Acceptance*	*The system shall quality check and accept inventory units.*	*Demonstration*	*ND2*
FLOPS3.1.15	*Inventory Search and Dispatch*	*The system shall search for, acquire and quality check inventory for dispatch.*	*Demonstration*	*ND2*
FLOPS3.1.16	*Inventory Tracking*	*The system shall continuously update time, location and handling of units flowing upstream and downstream of inventory storage.*	*Test, Demonstration*	*ND3*
FLOPS3.1.17	*Inventory Tracking Storage*	*The system shall continuously update and monitor location and duration of inventory in storage.*	*Demonstration, Inspection*	*ND3*
FLOPS3.1.18	*Inventory Flow Analysis*	*The system shall prioritize inventory for flows upstream and downstream based on demand, storage availability, routing, scheduling, packaging and cost.*	*Demonstration, Test*	*ND6*

ID	Section Heading	Description	Verification Method	Needs Traceability
FLOPS3.1.19	*Inventory Communication*	*The system shall communicate inventory control to internal users.*	*Demonstration*	*ND4*
FLOPS3.1.20	*Inventory Requirements*	*The system shall communicate inventory requirements to external users upstream.*	*Demonstration*	*ND4*
FLOPS3.1.21	*Logistics Requirements*	*The system shall provide logistics requirements to external user downstream.*	*Demonstration*	*ND4*
FLOPS3.1.22	*Inventory Requirements*	*The system shall develop inventory requirements based on end user demand.*	*Analysis*	*ND6*
FLOPS3.1.23	*Real-Time Monitoring*	*The system shall monitor real-time consumption and demand from end users (DOD Services).*	*Test, Analysis*	*ND6*
FLOPS3.1.24	*Economies of Scale*	*The system shall consolidate inventory purchases and inventory storage across end users (DOD Services).*	*Test*	*ND5*
FLOPS3.1.25	*Economies of Scale*	*The system shall consolidate transportation requirements for dispatched inventory across end users (DOD Services).*	*Test*	*ND5*
FLOPS3.1.26	*Rapid Contracts*	*The system shall provide supply contracts which are adaptable by upstream suppliers within a 24-hour period.*	*Demonstration, Analysis*	*ND7*
FLOPS3.1.27	*Rapid Contracts*	*The system shall provide flexible supply contracts which can accommodate collaboration of multiple upstream suppliers.*	*Demonstration, Analysis*	*ND7*
FLOPS3.1.28	*User Collaboration*	*The system shall incentivize collaboration of upstream and downstream external users (suppliers, logistics).*	*Demonstration, Analysis*	*ND7*
FLOPS3.1.29	*Logistics Contracts*	*The system shall provide flexible logistics contracts which can accommodate collaboration of multiple downstream transport operators.*	*Demonstration, Analysis*	*ND7*
FLOPS3.1.30	*Logistics Contracts*	*The system shall provide logistics contracts which are adaptable by downstream suppliers within a 24-hour period.*	*Demonstration, Analysis*	*ND7*
NFAT3.2	**Non-Functional Requirements**			
NFAT3.2.1	*Reliability*	*The system shall have less than 1hr of monthly downtime.*	*Test, Demonstration*	*ND1*
NFAT3.2.2	*Security*	*The system shall require administrative permissions to access data and reports.*	*Test, Demonstration*	*ND18*

ID	Section Heading	Description	Verification Method	Needs Traceability
NFAT3.2.3	*Maintainability*	*The system shall be weatherproof to survive rain, fire, and other natural causes.*	*Test, Demonstration*	*ND14,ND15*
NFAT3.2.4	*Portability*	*The system shall be able to run on multiple platforms and operating systems. (Mac/ Windows,Linux, etc.)*	*Test*	*ND19*
NFAT3.2.5	*Back-up Power*	*The system shall support emegency back-up power.*	*Test*	*ND15*
NFIF3.2.6	*User Friendly*	*The system shall have a user-friendly interface.*	*Demonstration, Analysis*	*ND11*

Table 3: Requirements Legend

Legend
The House of Quality (HOQ) identified this as a Key Performance Parameter (KPP) and Team Alpha agrees with HOQ output.
The House of Quality (HOQ) identified this as a Key Performance Parameter (KPP) and Team Alpha disagrees with HOQ output.
The House of Quality (HOQ) did not identify this as a Key Performance Parameter (KPP). Team Alpha disagrees with HOQ output. This is a KPP.

Table 4: Requirements Key

ID Abbreviation	Description
FL	Functional Requirement
NFAT	Non-Functional Attribute Requirement
NFOR	Non-Functional Operational Requirement

Verification:

The following verification methods and their associated definitions are used in this specification. Section 3.0 maps the verification method associated with each requirement.

Table 5: Verification

Verification Method	Definition
Analysis	The system is verified by means of performing an analysis that relies on using models, performing calculations or utilizing existing test data.
Demonstration	The system is verified by means of performing a demonstration. The demonstration may utilize a pass/fail criteria to show the capability of the system.
Inspection	The system is verified by means of performing an inspection. This may include review of engineering drawings, existing documentation and relies on the use of one or more of the five senses.
Test	The system is verified by means of performing a test. The test is based on a predefined set of objectives and relies on expected measurements and specified set of results.

ORGANIZATION AND STAFFING

The figure below provides a general structure of the organization and staffing plan for the project:

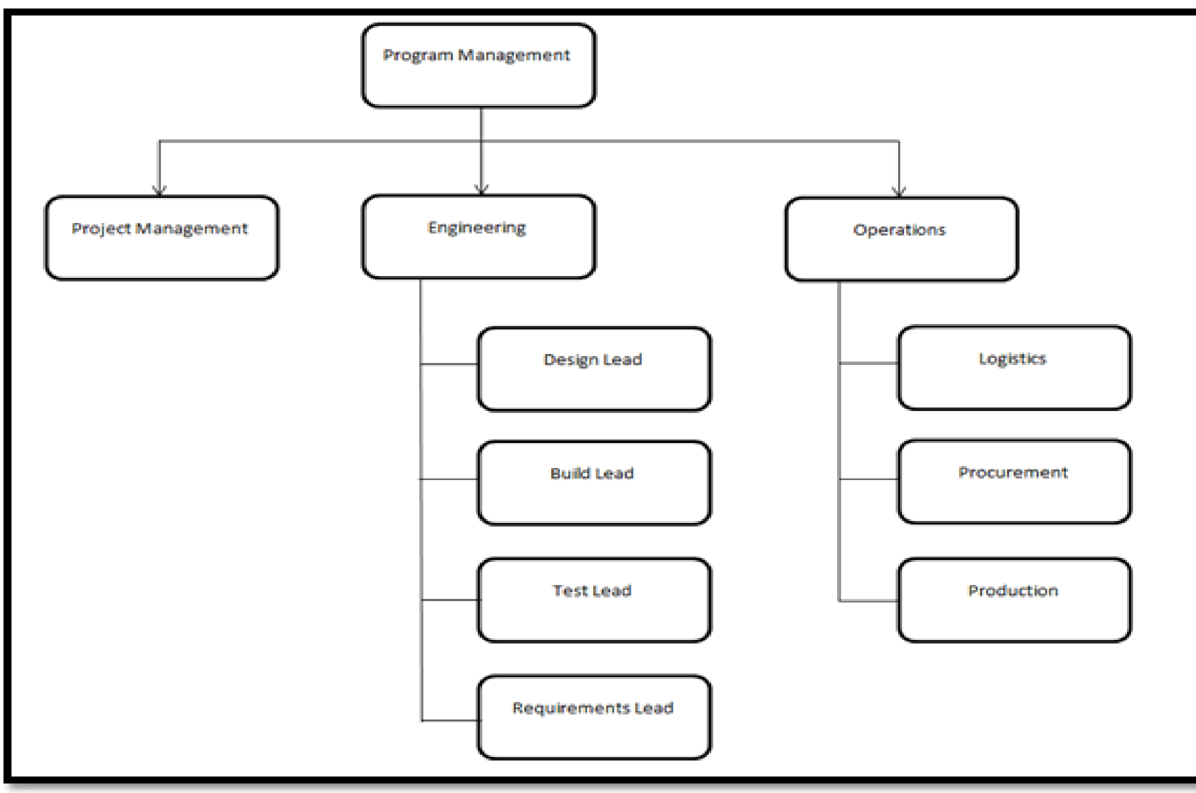

Figure 5: Organization Chart

Project Management:

This role keeps track of project deliverables and contains project to stay within cost, schedule and scope. Manages / mitigates risk and provides resolution to issues.

Engineering:

There are four primary Engineering roles:

- Requirement Lead: Works hands on with project stakeholders on project proposal. Identifies and documents all project requirements.
- Design Lead: Finds a feasible solution based on the information provided by the Requirements Analyst.
- Build Lead: Turns the designed system into a tangible product.
- Test Lead: Ensures that the system is properly tested, operational and operates for its intended purpose of use

Operations:

There are 3 primary Operations roles:

- Logistics: Responsible for maintaining storage and stock.
- Procurement: Responsible for the Purchasing of quality products at good rates.
- Production: Responsible for making the Assembly and Manufacturing processes run efficiently. Also includes planning, organizing, scheduling, estimating, negotiating, and budgeting.

General Planning:

Below is our scheduled plan and Gantt chart that aligns with phase 1 of the project cost estimate table. Future phases would be scaled to allocate more time to specific tasks.

Table 6: Phase 1- Project Schedule

Task	Start Date	Duration (Days)
Initiation	20-Apr	7
Planning	27-Apr	30
Analysis	27-May	60
Systems Requirements Review(SRR)	25-Jul	4
Preliminary Design	29-Jul	120
Preliminary Design Review(PDR)	25-Nov	4
Critical Design	29-Nov	120
Critical Design Review (CDR)	25-Mar	4
Test Planning	29-Mar	7
Test Readiness Review (TRR)	5-Apr	4
Test	9-May	60
Build	9-Jul	180
Implementation	9-Jan	30
Closure	9-Feb	5

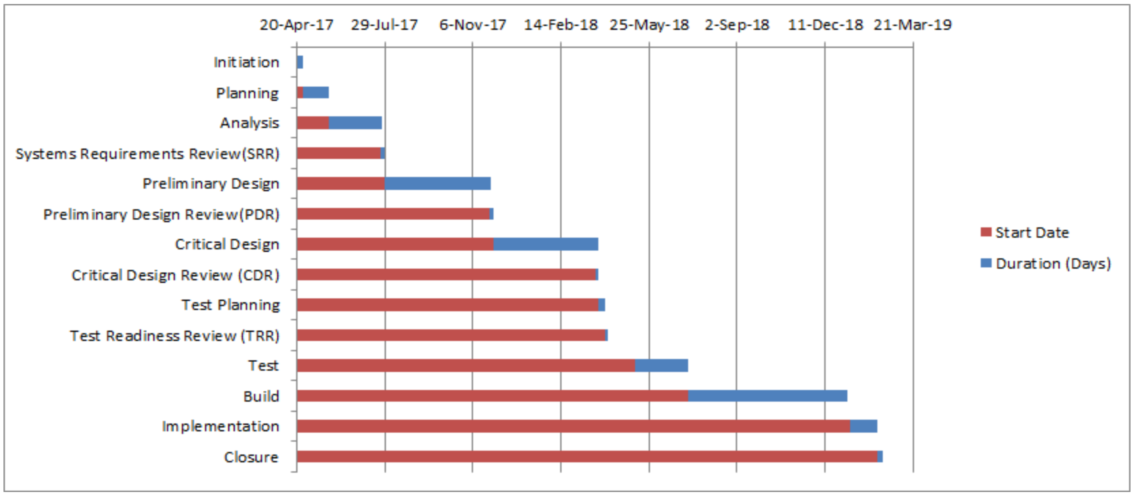

Figure 6: Scheduled Gantt chart

The entire systems will be rolled out across 5 consecutive phases. For the purpose of this report, cost estimations and planning will only involve the first phase, Phase-1. For convenience each of the phases and a short description are shown in the following table.

The Phase 1 system will be applied to only one of the military services and one specific geographic region for inventory management. Phase 2 will develop a system for all of the military services independently and specific to that same region. Phase 3 will extend those same systems to military services in all geographical regions. Finally, Phase 4 will accomplish a full integration across military services for one region. Phase 5, then, will extend that integration of services to all geographic regions to realize the full system benefit.

Table 7: Number of System Phases across Regions and Military Services

PHASE 1 Individual Military Service for one region (Units)	PHASE 2 All Military Services for one region (Units)	PHASE 3 All Military Services all regions (Units)	PHASE 4 Integrate all Military Services for one region (Units)	PHASE 5 Integrate all Military Services for all regions (Units)

(Note, current Phase-1 shown in bold)

The table below provides highly generalized cost estimates across the system in Phase 1. For most line items, shown on the table, the team has identified cost estimates for a group of items. A group of items may be considered such groups as general hardware or software. The cost estimate, therefore, represents a unit lump sum of that group or how much is estimated will be spent on that group to complete Phase 1. The unit cost is multiplied by the number of units to arrive at a sub total.

The later part of the table details how many of each specific technical talent will be needed to complete Phase 1. In these instances the unit costs included a base salary plus 20% to include the full HR cost. Here the number of units required to complete Phase 1 are also estimated. Again the unit cost and number of units are multiplied to arrive at a total estimate. At the bottom of the table, a total estimated system-cost for Phase 1 is provided. The Phase 1 total cost is estimated at just under $400 million dollars.

Table 8: Project Cost Estimate

GENERAL BULK ITEM ESTIMATION	UNIT COST	PHASE 1 Individual Military Service for one region	TOTAL
	(Millions $ per UNIT)	(NUMBER of UNITS)	(Millions $)
Enterprise Application			**$100.05**
Development (non recurring)	100	1	100
Maintenance & Support (annual recurring)	0.05	1	0.05
Testing Facilities - Infrastructure, Assets			**$29.41**
Hosting (annual recurring)	0.1	1	0.1
Security (annual recurring)	1.5	1	1.5
Hardware (misc. lump sum - sensors, robotics, interfaces)	2.5	1	2.5
Maintenance & Support (annual recurring)	0.01	1	0.01
Software (lump sum)	25	1	25
Workstations / etools (lump sum)	0.05	1	0.05
Stakeholder Consultation (annual for average 25 persons - travel, venue)	0.25	1	0.25
System Infrastructure			**$198.40**
Hosting (annual recurring)	0.25	1	0.25
Backup (lump sum)	0.15	1	0.15
Security (lump sum)	20	1	20
Maintenance & Support (annual recurring)	3	1	3
Hardware (lump sum - sensors, robotics, interfaces)	75	1	75
Software (lump sum)	100	1	100
Personnel Training			**$50.00**
E-training (courseware for Phase 1)	40	1	40
Formal class-room (total for Phase 1)	10	1	10
Human Resources			**$5.52**
Configuration Manager (annual)	0.17	1	0.17
Integration Manager	0.17	1	0.17
Contracts / Legal Manager	0.35	1	0.35
Testing Manager	0.17	1	0.17
Program Manager	0.25	1	0.25
Build/Install Manager	0.11	5	0.55
Procurement Manager	0.1	2	0.2
Project Manager	0.1	4	0.4
Engineering Manager	0.18	1	0.18
Operations Manager	0.18	1	0.18
HR Manager	0.08	1	0.08
Systems Architect	0.18	2	0.36
Systems Engineer	0.12	3	0.36
Robotics Engineer	0.1	4	0.4
Integration Engineer	0.1	4	0.4
Test Engineer	0.1	5	0.5
Electrical Engineer	0.1	4	0.4
Computer Engineer	0.1	4	0.4
TOTAL ESTIMATE (Millions $)			**$383**