

**RESEARCH REPORT** A&B-R-00101-01



**Systems Engineering Management Plan, V1**

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Confidentiality: Public

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| **Summary**  The need to develop Systems Engineering methodologies is necessitated by the complex processes and developments for large-scale projects, such as the DARPA Urban Challenge. The adherence to safety and design requirements laid out by the challenge provide a foundation for systems engineering methodologies to be realized into a final product.  The needs and requirements for DARPA Urban Challenge systems may differ in their fundamental design and their interpretation of the rules for autonomous unmanned vehicle despite the stringent challenge’s regulations. By applying the systems engineering principles, it is possible to develop a multi-iteration incrementally improved design using the same framework that applies to multi-state vehicle travel. The intention is to help manage the whole life cycle of an unmanned vehicle system. The reference model can then drive the systems engineering management plan. Based on the reference model, unmanned autonomous vehicle (UAV) organizations interested in participating in the DARPA Urban Challenge can develop their management systems according to the systems engineering principles. The goals for using such a reference model are assured safety and shorter development times of UAV systems, subsystems and components.  This report stages the design of a UAV system in terms of a systems engineering approach, utilizing modern technologies for systems engineering planning. Furthermore, foundations for a well-organized SEMP are presented for accountability through the systems engineering design process. | | |
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# Preface

This report has been written within the DARPA Urban Challenge (Safe operation and maneuverment of unmanned ground vehicles in the presence of other moving vehicles) in the context of the MST2020 SE Capstone Program (The Defense Advanced Research Projects Agency Grand Challenge 2007-Present). The DARPA challenge for year 2007 consisted of several tasks of which this report relates to Task 1.1 (Systems Engineering Management Plan [SEMP]) of Work package 1 (Safety Systems Engineering). The members of Task 1.1 were Ryan Patton (A&B) and Benjamin Patton (A&B). The goal of Task 1.1 was *“…to accelerate progress in this area through the demonstration of autonomous unmanned ground vehicles driving safely in a mock urban area with other moving vehicular traffic.*” (An excerpt from the DARPA 2007 Urban Challenge Announcement.)

The goal of this report is to provide the background and a short state-of-the-art study to help create and understand the SEMP.

Task 1.1 as well as the whole DARPA Urban Challenge was guided by the Initialization Group (Automation, organization and human factors) with the following members:

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The authors thanks the Initialization Group for guiding the work and Benjamin Patton for reviewing the report.

St. Louis 2.2.2020

Ryan Patton

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**Table of Acronyms**

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
| A&B | Autonomy and Beyond |
|  |  |
| DARPA | Defense Advanced Research Project Agency |
| R&D | Research and Development |
| SEMP | System Engineering Management Plan |
| UAV | Unmanned Autonomous Vehicle |

# Introduction

## Document Purpose

The Autonomy and Beyond (A&B) project (a DARPA Urban Challenge project) in year 2020, based on the previous 2007 challenge, is to specify a SEMP (Systems Engineering Management Plan) for developmental activities. Autonomy and Beyond (A&B) is a newly founded company working to advance its mission of providing affordable UAVs on a global production scale. The aim is to participate in efforts for maturing autonomous vehicle technologies as part of a competition. The system’s assessment as part of the competition will be analyzed on the system’s ability to finish the course and if so, the time needed to complete the course. The A&B project spans various systems engineering stages taking place across the United States with multiple organizations and learning institutions contributing to its ultimate success. It is imperative to implement a systems engineering approach to control the creative, structured process throughout the product’s life cycle. By doing so, costs will be reduced upfront and long after the system reaches deployment.

The SEMP guides the general framework within the A&B project. All members associated with the A&B project are expected to comply with the SEMP as laid out herein.

## Document Scope

## The content within this document may be applied to all A&B systems, subsystems, and components, both hardware and software, engineered throughout the duration of the program’s challenge. The SEMP acts as the fulfilling document for A&B and any organizations and learning institutions associated with the A&B system to diminish the need for completely separate or complying subordinate SEMPs. All activities, products, processes, tools, controls, integration technologies, proprietary information, intellectual property, security measures, key personnel, and safety guidelines associated with the A&B systems, subsystems, and components will be sufficiently described in the SEMP. By doing so, the systems engineering approach retains control throughout design, development, manufacturing, testing, deploying, and certifying through the eventual maintenance and support phases. Although concurrent autonomous flight and submarine technologies may be applied to the system, the system must adhere to ground navigation.

## The progress captured throughout the duration of the A&B program will be captured in this routinely updated SEMP to verify the accuracy of the content to A&B’s decisions.

## Document Update

## Throughout the systems engineering process, discoveries may yield improved safety measures, design features, and cost measures not explicitly stated in the original SEMP. Revisions may be made periodically to the SEMP to capture the essence of a constantly evolving, competitive system.

## The completion of the SEMP draft will come in weekly sectional updates following a chronological sequence based on the Contents. The focus of each weekly update will be on adding new material but A&B reserves the rights to edit previously drafted sections of content on an as-needed basis. Revisions made will be documented separately from the SEMP and will undergo official review for entry bi-weekly where a new revised draft will be released.

## Program Summary

## 1.4.1 Program Objectives and Scope

## As part of monitoring the relative success of A&B’s system, objective thresholds are set. A&B’s program covers five main objectives: 1) Complete and deploy the system within budget. 2) Produce completed system for deployment before DARPA Urban Challenge’s earliest qualifying round. 3) Complete the course as laid out by the DARPA Urban Challenge. 4) Achieve a qualifying time within 20% of projected qualifying time. 5) Qualify as a national finalist in the DARPA Urban Challenge. If all five objectives listed above are met, the program will be considered a success. If 3 or 4 objectives are met, the program will be considered satisfactory. Less than 3 objectives met would be considered unsatisfactory.

## 

## A&B intends to set aside pre-existing company funds to devote to the program. The funds will be disbursed from A&B’s research and development (R&D) budget, assuming business at A&B outside of this venture continue to yield their approximate past revenue adjusted for inflation.

## Limitations on the system’s final design mostly stem from the Urban Challenge’s Event Guidelines. In addition, the system must also obey the rules and laws necessary to legally drive a vehicle on the roads of California and Nevada. Special licensing outside of standard state driving licenses may be needed to drive a UAV on roads in California and Nevada as well.

## Although A&B will be the sole monetary investor in the system’s technologies for intellectual property purposes, A&B will work with higher institutions of learning and other non-profit organizations to produce the best product. The individuals and organizations/universities recruited to assist with the program will retain the spirit of integrity and ethical principles required of A&B employees.

## 1.4.2 Project Summary and Deliverables

## Key milestones of A&B’s program will show the progress in keeping with SEMP standards. Major phases of the project consist of:

## March 2020 – SEMP Completion

## June 2020 – PDR

## July 2020 – CDR

## August 2020 - DDR

## October 2020 – Prototype Completion

## December 2020 – Code Cutoff

## December 2020 - TRR

## August 2021 – Testing Completion

## October 2021 – Deployment

## December 2021 - Commissioned

## 

## The milestones listed above represent life cycle phases but are by no means all-inclusive. During the program’s life cycle, periodic assessments will be made to see if schedule adjustments need to be made.

## 1.4.3 Technical Description

## The realization of the system starts with portioning plentiful developmental efforts geared towards knowledge gained from trade studies. Autonomous vehicles are still in various experimental stages and require innovative solutions to prepare for unprepared for challenges on the road, such as extreme weather circumstances or undesignated pedestrian crossings. Each subsystem and aspect of the system deemed crucial for mission success will receive its own in-depth trade study. From the trade studies decision matrices with weighted factors will guide the design decisions.

## Requirements during all the life-cycle phases will be derived by observation of what has brought success to past similar systems. Additionally, informed decisions will achieve innovative solutions in A&B’s approach to its own unique system.

# Reference Documents

## Industry References

The following documents listed in Table 2-1 show applicable, standards, industry handbooks, and other references. References listed as “guidance” provide useful information. References listed as “Compliance” show what must be adhered to. Any reference listed as “Compliance” addresses its compliance below Table 2-1.

Table 2‑1. Industry References

| **Document Number** | **Document Title, Version, Date** | **“Guidance” or “Compliance”?** |
| --- | --- | --- |
| ISO/IEC/IEEE 15288 | Systems and Software Engineering – System Life-Cycle Processes, 2015. | Guidance |
| ISO/IEC 26702 (IEEE Std 1220-2005) | Systems engineering – Application and management of the systems engineering process – September 9, 2005 | Guidance |
| INCOSE Publications V3.1 | Systems Engineering Handbook – A guide for system life cycle processes and activities – August 2007 | Guidance |

## Acquirer References

All Acquirer References seen in Table 2-2 show DARPA Urban Challenge documents as relevant to their appropriate applications.

Table 2‑2. Acquirer References

| **Document Number** | **Document Title, Version, Date** | **“Guidance” or “Compliance”?** |
| --- | --- | --- |
| Rev 9 | Urban Challenge – Site Visit Guidelines – June 18, 2007 | Compliance |
| Rev 1 | Urban Challenge – Technical Evaluation Criteria – March 16, 2006 | Guidelines |
| Rev 0 | Urban Challenge – Technical Paper Guidelines – January 8, 2007 | Compliance |
| Rev 0 | Urban Challenge Application – Part 3: Site Visit Information Sheet - 2006 | Guidance |
| Rev 0 | Urban Challenge Application – Track A Team Leader – Proof of U.S. Citizenship & Residency - 2007 | Compliance |
| Rev 4 | DARPA Urban Challenge – Frequently Asked Questions – Program Announcement and Application Process – July 11, 2007 | Guidance |
| Rev 15 | DARPA Urban Challenge – Event Guidelines – October 10, 2007 | Compliance |
| Rev 12 | Urban Challenge – Rules – October 27, 2007 | Compliance |
| Rev 0 | 2007 DARPA Urban Challenge – Semifinalist Teams - 2007 | Guidance |
| Rev 1 | DARPA Urban Challenge – E-Stop Guidelines – April 23, 2007 | Compliance |
| Rev 0 | DARPA Urban Challenge – Instructions for Semifinalists – August 16, 2007 | Compliance |
| Rev 10 | Urban Challenge – Route Network Definition File (RNDF) and Mission Data File (MDF) Formats – March 14, 2007 | Compliance |

## Enterprise References

## The Enterprise References seen in Table 2-3 list company items/policies/processes that apply to A&B’s program.

Table 2‑3. Enterprise References

| **Document Number** | **Document Title, Version, Date** | **“Guidance” or “Compliance”?** |
| --- | --- | --- |
|  |  |  |
|  |  |  |

## Program References

## Table 2-4 shows project-specific references controlled by A&B. The documents contain different plans tailored to the specific program instead of company-wide at A&B, such as program management plans, configuration management plans, risk management plans, etc…

Table 2‑4. Program References

| **Document Number** | **Document Title, Version, Date** | **“Guidance” or “Compliance”?** |
| --- | --- | --- |
|  |  |  |
|  |  |  |

# Program Organization

## Work Allocation: Work Breakdown Structure

## Figure 3-1 shown below displays the Work Breakdown Structure (WBS) centered around the final product, A&Bs Unmanned Autonomous Vehicle.

*Figure 3-1. Work Breakdown Structure (WBS).*

Level 1 in the WBS defines the scope of the program as the end product. Level 2 defines the main activities conducted throughout the program to achieve the final product. Level 3 provides sufficient details to capture the essence of considerations given to each Level 2 task.

Level 2 in the WBS consists of 13 critical divisions of labor: maintenance, facilities, safety, operations site activities, support equipment, quality, training, data, IT, testing, program management/SE, vehicle design, and HR. The divisions intend to capture the each major branch of labor which require considerable resources and planning.

Level 3 in the WBS consists of 58 descriptions for Level 2 divisions. The Level 3 descriptions provide enough scope to cover a comprehensive systems approach to defining categorically organized items that require attention and planning. Table 3-1 seen below details the WBS in a tabular form through Level 3.

*Table 3-1. Tabular Work Breakdown Structure.*



## Organization Structure and Overview

## Figure 3-2 shows A&Bs organizational structure and key personnel necessary for a systems approach.

*Figure 3-2. A&Bs Organizational Chart.*

The Organizational Chart shown above lists the CEO as the sole Level 1 personnel. Compared to other organizations, A&B does not consist of a Board of Directors. The CEO takes full accountability for the organization’s success and key decisions are reviewed at the CEOs discretion. A&B foregoes a Board of Directors and a public offering to keep in accordance with its original mission: “Autonomy and Beyond aims to produce uncompromised, affordable unmanned autonomous vehicles for the common person.”

The eleven Level 2 personnel cover the necessary personnel to mirror how the organization functions. A&B stresses developing cheap technology without compromising quality. With large funding going into its production and research and development towards autonomous technologies, the main addition to a conventional organization structure is a Senior Director of AI, showing A&Bs dedication to developing practical technologies ready to be implemented.

Level 3 personnel in the Organizational Chart show who is responsible for implementing the flowed down decisions from Level 2 personnel. While Level 2 personnel are mostly accountable for the results of their decisions made, the Level 3 personnel are responsible for implementing the innovative solutions proposed by Level 2 personnel.

## Role, Responsibility, Authority, Accountability

## Table 3-2 displays a Roles, Accountability, Consulted, and Informed (RACI) matrix. The matrix combines the relevant work tasks from the WBS with the key personnel in the Organizational Chart. The intersections define how the key personnel will interact with each task from the WBS to define each role in the Organizational Chart further. Responsible in the matrix is defined as who is or will be doing the task. Accountable in the matrix is defined as who has authority to take decision and will be involved if anything is to go wrong. Consulted in the matrix is defined as anybody who can tell more about the task. Informed in the matrix is defined as anyone whose work depends on the task and who has to be kept updated on the progress. The breakdown of the RACI matrix follows.

*Table 3-2. RACI Matrix.*

## 

## 3.3.1 Program Leadership

## 

## The leadership of the program all flows down from the CEO. The CEO takes accountability for any major success or failures with the program because the CEO is the final authority on any decisions. Notice in the RACI Matrix that some divisions of labor contain multiple personnel accountable in the field. A&B stresses cross-functional communication between different organizational functions and encourages collaboration, especially when conflicts of interest arise. Oftentimes, the direct reports to the Level 2 personnel, the Level 3 personnel, are held responsible for any decision made. The Level 3 personnel may not be hands-on involved with implementing product solutions but their roles are essentially to direct their subordinates on how best to accomplish their tasks in unison.

## The CFO and direct subordinates along with the CEO routinely engage with the customer to ensure program compliance. Although the DARPA Urban Challenge challenges A&Bs organizational function in dealing with an absent client so to speak, the organizational function that successfully produces automotive parts supporting autonomous vehicles will allocate more efforts into DARPA Urban Challenge guidelines compliance. A&Bs CFO, direct subordinates of the CFO, and the CEO will hold a weekly meeting with key DARPA personnel to ensure product realization complies with all guidelines and deadlines are met. As an initiative to engage with the customer, A&B will keep an open-door policy for DARPA personnel to stage visits for progression or compliance updates as they may see fit.

## A&B will solely fund its involvement with the DARPA Urban Challenge. Since A&B strives to commit to further developmental efforts in the field of autonomous vehicles, A&B will prove its dedication by using its own resources towards a competition with no direct payoff. The proprietary technology gained from product development may offset some of the initial investment but A&B is mostly relying on its 2020-2025 projections to confidently allocate a budget of $250 million which includes $50 million in reserves. The monetary resource breakdown follows:

## General Counsel: $20 million

## Finance: $30 million

## HR: $1 million

## IT: $15 million

## Research and Development (R&D): $40 million

## Design and Analysis Engineering: $10 million

## Systems Engineering: $10 million

## Software Engineering: $10 million

## Integration: $5 million

## Testing: $20 million

## Facilities: $5 million

## Data Management: $10 million

## Technicians: $7 million

## Safety: $2 million

## Community Outreach: $0.5 million

## Sales: $5 million

## Supply Chain Logistics: $9 million

## Relations: $0.5 million

## The funds allocations show a disposition towards funding the technical engineering aspects of the program because of the innovative nature of the challenge.

## The $50 million dollar reserve gives a safety net for high-level risks close to key deadlines. Ideally, the product will reach its testing phase before disbursing any reserve funds.

## The aggressive schedule shown below aims to demonstrate product development internally only up until the challenge begins. The schedule follows:

## 

*Figure 3-3. Gantt Chart.*

## A&B will implement an Agile/scrum environment. With the inherent uncertainty that comes with meeting deadlines, an Agile/scrum environment will allow for the tracking of the velocity of overall progress for active deadline management.

## 3.3.2 Technical Leadership

## The technical leaders tasked with implanting the engineering features behind the UAVs design consist of the Chief Designer, Senior Director of AI, and CTO along with the CTOs subordinates. The Chief Designer is tasked with crafting the system’s architecture, plays a key role with tracing the design to program requirements, and further breaks down the distribution of technical tasks to lower level engineers within an Agile/scrum framework. The Chief Engineer ensures the integration of various subsystems and components into the system. The Senior Director of AI takes the lead on R&D efforts and proposes innovative solution designs deemed best for winning the DARPA Urban Challenge. The Senior Director of AI will propose three unique solutions to pick from after the R&D phase and will follow through with the chosen solutions integration. The CTO directs all engineering functions and their specialized units. Under the CTO are the Director of Engineering, VP of Engineering, VP of Materials Engineering, and VP of Powertrain Hardware Engineering. The Director of Engineering and VP of Engineering direct the guidance of all engineering efforts outside of hardware and materials which includes weights engineers, software engineers, communications engineers, infrared/electrical engineers, data management engineers, navigation/guidance engineers, test engineers, data scientists, systems and integration engineers, thermal engineers, safety engineers, noise engineers, cybersecurity engineers, and product lifecycle management engineers. Materials engineering and powertrain hardware engineering consist of their own organizational flowdowns to stress their importance but operate in the same precedence set by the general Director of Engineering and VP of Engineering.

## 3.3.3 Teams and Functions

## All of the various functional engineers listed above fall into five functional categories: avionics, testing, management, software, and systems. The purpose of the categories is to provide enough breadth to achieve function-based teams. Specialized engineers will work with other specialized engineers in their field in keeping with the Agile/scrum framework. Engineers will maintain a system-level approach and avoid the compartmentalization of their tasks by participating in integration and key milestone events.

## 3.3.4 Key Suppliers and Supplier Integration

## A&Bs success in the DARPA Urban Challenge relies on its collaboration with suppliers. A&B will work with Microsoft, MikTex, Adobe, Siemens, MATLAB, Dassault (SolidWorks), ANSYS, and various other companies to attain software licenses company-wide. Dell will supply computer parts. The recommended design strategy will determine if a customized vehicle will be manufactured in-house but given the rigorous timeline, A&B will put down a deposit for a Tesla Cybertruck to modify as the company desires. If the release of the Cybertruck does not stay on its predicted timeline, A&B will purchase the newest edition Tesla Model X. Purchasing a vehicle already containing autonomous technologies eases the stress of tight production deadlines and allows for reverse engineering to improve on existing technologies within a Tesla product.

## 3.3.5 Associate Organizations

## Some supplying organizations A&B rely on may receive their parts from China or countries in the Middle East. Given the United States’ tensions with such countries, alternative vendors may be sought out as a backup plan. Tentative plans will be made with backup vendors to ensure they can meet production needs in case they are needed.

## 3.3.6 Acquirer

## Maintenance handles acquiring the various products needed for system realization using supply chain logistics. Each planned product delivery date will be given a 4 week buffer before the part is needed for utilization or integration. As often as possible, domestic vendors will be the ideal option for ordering parts from as long as they are within a 50% margin of international vendors. A&B will purchase a fleet of semi-trucks whole-priced to reduce transportation costs from supply.

## 3.3.7 User

## The user will be professional test drivers familiar with the developer technologies within A&Bs organization during the testing phase. Unless the DARPA Urban Challenge stipulates standard driver guidelines at a later date revision, the choice lies with A&B who to pick as their product user up to the competition. Although the UAV is unmanned, the UAV will be controlled remotely during testing where driver capabilities may produce a calculable advantage. If during testing, engineers without professional driving experience produce better test results due to their familiarity with the technicalities of the system, they may be subject to test driving the system with their consent. During the actual challenge’s trial runs, the data collected during testing with a user will produce superior handling qualities by the software operating the handling qualities.

## Organizational Integration

## 3.4.1 Working Groups and Boards

## A&B will encourage team-lead collaboration during phases of integration. When applicable, each team separated by function will work independently but several teams will work full-time towards integration within systems. Different integration teams will focus their efforts towards different aspects of integration based on the functionality of each team. More teams may need establishment as the program develops but initially integration teams will include hardware-software integration, interface control group, human-system integration, data configuration, and vehicle reverse engineering configuration.

## Hardware-software integration will focus their efforts towards general challenges with integration and will solve integration issues as they pop up, working with various team functions during the process.

## The interface control group’s focus revolves around creating an easy-to-use, interactive platform for controlling the autonomous vehicle.

## The human-system integration group looks out for challenges involving how humans will interact with the system. For example, humans may need to flip switches to start up the system initially. The human-system integration group will work closely with safety personnel to account for potential safety risks and find ways to mitigate them.

## The data configuration group will work closely with IT and various engineering disciplines to format data in a way so it integrates easily within the system. The autonomous system may rely on past data to help train the system and vast amounts of data may need to be sorted, cleaned, organized, and formatted for integration. Any data generated from the vehicle will need to go through similar procedures for easy access and reference.

## The vehicle reverse engineering configuration group will find a balance of solutions between A&B-approved innovative solutions and a purchased autonomous Tesla. After purchasing a Tesla to use as a baseline autonomous vehicle for improvement, engineers will be needed to understand the technologies in place and how they can best be manipulated for improvement.

## 3.4.2 Technical Specialty Integration

## 3.4.2.1 Identification of Specialties

## Various engineering disciplines will be included such as weights engineers, software engineers, communications engineers, infrared/RF engineers, electrical engineers, data management engineers, navigation/guidance engineers, test engineers, data scientists, systems and integration engineers, materials engineers, safety engineers, noise engineers, cybersecurity engineers, and product lifecycle management engineers for a comprehensive, well-rounded system.

## 3.4.2.2 Tasks of Technical Specialists

## Weights engineers will come up with various ways of reducing the overall weight of the vehicle for future marketability.

## Software engineers will be to develop and integrate the autonomous technologies with the hardware and to develop interfaces for interacting with the vehicle. There will be many sub-disciplines of software engineering throughout the project such as back-end programmers, front-end programmers, analysis programmers, developers, etc…

## Communications engineers will take steps towards establishing and easing communication measures with the vehicle and remote computers.

## Infrared engineers will determine the thermal limitations of the vehicle for improved safety by controlling fire damage and potential explosions.

## Electrical engineers will design circuits, determine electrical capacity to function properly, and determine hardware connections. Part of the electrical engineers job will include extensive analysis in Spice.

## Data management engineers will manage the pipelines of data.

## Navigation and guidance engineers will work towards developing the handling qualities of the vehicle.

## Test engineers will set up the test environment and establish methods for verifying the tests correlated to the vehicles preparedness for the challenge.

## Data scientists will find and analyze all data to establish relationships between the data and hardware/software.

## Systems and integration engineers will take necessary steps to ensure system integration.

Materials engineers will fine-tune the materials to be as lightweight yet durable as possible.

Safety engineers will

Noise engineers will develop methods for reducing noise stemming from the vehicle for future marketability.

Cybersecurity engineers will ensure the software and proprietary devices used by employees are protected.

Product lifecycle management engineers will ensure compliance and schedule throughout the duration of the program.

## 3.4.2.3 Integrating Specialties

Specialists will generally be organized by the 5 functional units as described earlier. Specialization organization charts are in the development process.

# Technical Processes

## 4.1 Business/Mission Analysis

## 4.2 Stakeholder Needs and Requirements Definition

## 4.3 Requirements Definition, Validation, and Traceability

## 4.4 Architecture Definition and Traceability

## 

## 4.5 Design Definition and Traceability

## 4.6 System Analysis

## 4.7 Implementation

## 4.8 Integration

## 4.9 Verification and Traceability

## 4.10 Transition

## 4.11 Validation

## 4.12 Operations

## 4.13 Maintenance

## 4.14 Disposal

# Technical Management Processes

## Project Technical Planning

## 5.1.1 Major Events: Integrated Master Plan

## 5.1.2 Work Packages

## Technical Management and Assessment

## 5.2.1 Technical Performance Management

## 5.2.2 Continuous Assessment

## 5.2.3 Other Technical Measurements

## Integration with Cost and Schedule Management

## Decision-Making

## Issue Identification and Resolution

## Risk and Opportunity Management

## Configuration Management

## 5.7.1 Baseline Definition and Management

## 5.7.2 Change Management

## 5.7.3 Requirements Management

## 5.7.4 Interface Management

## Information Management and Product Lifecycle Management (PLM)

# Organizational Investment

## Life Cycle Management

## 6.1.1 Program Policies and Procedures

## 6.1.2 Program Measurement and Assessment

## 6.1.3 Continuous Improvement

## Investment Management

## 6.2.1 Product Line Investment (Portfolio Management)

## 6.2.2 Supply

## 6.2.3 Acquisition

## Resource Management

## 6.3.1 Personnel

## 6.3.2 Infrastructure

## Quality Management

# Summary and Conclusions

# References

# Appendix 1.

# Appendix 2.

**Appendix 3.**

# Appendix 4.

# Appendix 5.

# Appendix 6.