

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



**Systems Engineering Management Plan, V1**

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Confidentiality: Public

**A&B**

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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. | | |
| **Confidentiality** | Public | |
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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

**Table of Contents**

[1. Introduction 1-](#_Toc29845538)9

[1.1. Document Purpose 1-](#_Toc29845539)9

[1.2. Document Scope 1-](#_Toc29845540)9

[1.3. Document Update 1-](#_Toc29845541)9

[1.4. Program Summary 1-](#_Toc29845542)10

[1.4.1. Program Objectives and Scope 1-](#_Toc29845543)10

[1.4.2. Project Summary and Deliverables 1-](#_Toc29845544)10

[1.4.3. Technical Description 1-](#_Toc29845545)10

[2. Reference Documents 2-](#_Toc29845546)11

[2.1. Industry References 2-](#_Toc29845547)11

[2.2. Acquirer References 2-](#_Toc29845548)11

[2.3. Enterprise References 2-](#_Toc29845549)12

[2.4. Program References 2-](#_Toc29845550)12

[3. Program Organization 3-](#_Toc29845551)13

[3.1. Work Allocation: Work Breakdown Structure 3-](#_Toc29845552)13

[3.2. Organization Structure and Overview 3-](#_Toc29845553)16

[3.3. Role, Responsibility, Authority, Accountability 3-](#_Toc29845554)17

[3.3.1. Program Leadership 3-](#_Toc29845555)17

[3.3.2. Technical Leadership 3-](#_Toc29845556)19

[3.3.3. Teams and Functions 3-](#_Toc29845557)19

[3.3.4. Key Suppliers and Supplier Integration 3-](#_Toc29845558)19

[3.3.5. Associate organizations 3-](#_Toc29845559)19

[3.3.6. Acquirer 3-](#_Toc29845560)20

[3.3.7. User 3-](#_Toc29845561)20

[3.4. Organizational Integration 3-](#_Toc29845562)20

[3.4.1. Working Groups and Boards 3-](#_Toc29845563)20

[3.4.2. Technical Specialty Integration 3-](#_Toc29845564)21

[3.4.3. Identification of Specialties 3-](#_Toc29845565)21

[4. Technical Processes 4-](#_Toc29845566)22

[4.1. Business/Mission Analysis 4-](#_Toc29845567)22

[4.2. Stakeholder Needs and Requirements Definition 4-](#_Toc29845568)22

[4.3. Requirements Definition, Validation, and Traceability 4-](#_Toc29845569)22

[4.4. Architecture Definition and Traceability 4-](#_Toc29845570)23

[4.5. Design Definition and Traceability 4-](#_Toc29845571)23

[4.6. System Analysis 4-](#_Toc29845572)23

[4.7. Implementation 4-](#_Toc29845573)23

[4.8. Integration 4-](#_Toc29845574)24

[4.9. Verification and Traceability 4-](#_Toc29845575)24

[4.10. Transition 4-](#_Toc29845576)24

[4.11. Validation 4-](#_Toc29845577)25

[4.12. Operations 4-](#_Toc29845578)25

[4.13. Maintenance 4-](#_Toc29845579)25

[4.14. Disposal 4-](#_Toc29845580)26

[5. Technical Management Processes 5-](#_Toc29845581)26

[5.1. Project Technical Planning 5-](#_Toc29845582)26

[5.1.1. Major Events: Integrated Master Plan 5-](#_Toc29845583)26

[5.1.2. Work Packages 5-](#_Toc29845584)28

[5.2. Technical Management and Assessment 5-30](#_Toc29845585)

[5.2.1. Technical Performance Management 5-](#_Toc29845586)30

[5.2.2. Continuous Assessment 5-](#_Toc29845587)30

[5.2.3. Other Technical Measurements 5-](#_Toc29845588)30

[5.3. Integration with Cost and Schedule Management 5-](#_Toc29845589)30

[5.4. Decision-Making 5-](#_Toc29845590)31

[5.5. Issue Identification and Resolution 5-](#_Toc29845591)32

[5.6. Risk and Opportunity Management 5-](#_Toc29845592)33

[5.7. Configuration Management 5-](#_Toc29845593)36

[5.7.1. Baseline Definition and Management 5-](#_Toc29845594)36

[5.7.2. Change Management 5-](#_Toc29845595)37

[5.7.3. Requirements Management 5-](#_Toc29845596)38

[5.7.4. Interface Management 5-](#_Toc29845597)38

[5.8. Information Management and Product Lifecycle Management (PLM) 5-](#_Toc29845598)39

[6. Organizational Investment (~ 4 pages) 6-](#_Toc29845599)39

[6.1. Life Cycle Management 6-](#_Toc29845600)39

[6.1.1. Program Policies and Procedures 6-](#_Toc29845601)39

[6.1.2. Program Measurement and Assessment 6-](#_Toc29845602)40

[6.1.3. Continuous Improvement 6-](#_Toc29845603)41

[6.2. Investment Management 6-](#_Toc29845604)41

[6.2.1. Product Line Investment (Portfolio Management) 6-](#_Toc29845605)41

[6.2.2. Supply 6-](#_Toc29845606)41

[6.2.3. Acquisition 6-](#_Toc29845607)42

[6.3. Resource Management 6-](#_Toc29845608)42

[6.3.1. Personnel 6-](#_Toc29845609)42

[6.3.2. Infrastructure 6-](#_Toc29845610)42

[6.4. Quality Management 6-](#_Toc29845611)42

**List of Figures**

[Figure 3-1. Work Breakdown Structure (WBS) 3-](#_Toc29846044)13

[Figure 3-2. A&Bs Organizational Chart 3-](#_Toc29846044)16

[Figure 3-3. Gantt Chart 3-](#_Toc29846044)18

**List of Tables**

[Table 1 Industry Reference Documents 2-](#_Toc29845658)11

[Table 2 Acquirer Reference Documents 2-](#_Toc29845658)11

[Table 3 Enterprise Reference Documents 2-](#_Toc29845658)12

[Table 4 Program Reference Documents 2-](#_Toc29845658)12

[Table 5 Tabular Work Breakdown Structure 3-](#_Toc29845658)15

[Table 6 RACI Matrix 3-](#_Toc29845658)17

[Table 7 Risk Matrix 5-](#_Toc29845658)33

[Table 8 Risk Ratings 5-](#_Toc29845658)34

**Table of Acronyms**

|  |  |
| --- | --- |
| **Acronym** | **Definition** |
| A&B | Autonomy and Beyond |
| AI | Artificial Intelligence |
| AIAA | American Institute of Aeronautics and Astronautics |
| CAD | Computer-Aided Design |
| CDD | Capabilities Development Document |
| CDR | Critical Design Review |
| CEO | Chief Executive Officer |
| CIO | Chief Information Officer |
| CM | Configuration Management |
| CMP | Change Management Plan |
| CTO | Chief Technology Officer |
| DARPA | Defense Advanced Research Projects Agency |
| DDR | Detailed Design Review |
| DoD | Department of Defense |
| EPA | Environmental Protection Agency |
| EVM | Earned Value Management |
| FOD | Free of Debris |
| HR | Human Resources |
| IEC | International Electrotechnical Commission |
| IEEE | Institute of Electrical and Electronics Engineers |
| INCOSE | International Council on Systems Engineering |
| ISO | International Standards Organization |
| IT | Information Technology |
| MDF | Mission Data File |
| MIL | Military |
| MOE | Measure of Effectiveness |
| MOP | Measure of Performance |
| MST | Missouri University of Science and Technology |
| NQE | National Qualifier Event |
| OSHA | Occupational Safety and Health Administration |
| PDR | Preliminary Design Review |
| PLM | Product Lifecycle Management |
| PM | Program Manager |
| PO | Product Owner |
| QA | Quality Assurance |
| RACI | Roles, Accountability, Consulted, and Informed |
| RCA | Root Cause Analysis |
| R&D | Research and Development |
| REV | Revision |
| RF | Radio Frequency |
| RNDF | Route Network Definition File |
| SE | Systems Engineering |
| SEMP | Systems Engineering Management Plan |
| STD | Standard |
| TPM | Technical Performance Measure |
| TRR | Test Readiness Review |
| UAV | Unmanned Autonomous Vehicle |
| U.S. | United States |
| VP | Vice President |
| V1 | Version One |
| WBS | Work Breakdown Structure |
| 3-D | 3-Dimensional |

# 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

### 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.

### 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:

1. March 2020 – SEMP Completion
2. June 2020 – PDR
3. July 2020 – CDR
4. August 2020 – DDR
5. October 2020 – Prototype Completion
6. December 2020 – Code Cutoff
7. December 2020 – TRR
8. August 2021 – Testing Completion
9. October 2021 – Deployment
10. 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.

### 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 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 1.

Table 1 Industry Reference Documents

|  |  |  |
| --- | --- | --- |
| **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 show DARPA Urban Challenge documents as relevant to their appropriate applications.

Table 2 Acquirer Reference Documents

|  |  |  |
| --- | --- | --- |
| **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 3 list company items/policies/processes that apply to A&B’s program.

Table 3 Enterprise Reference Documents

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

## Program References

Table 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 4 Program Reference Documents

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

# Program Organization

## Work Allocation: Work Breakdown Structure

Figure 3 shown below displays the Work Breakdown Structure (WBS) centered around the final product, A&B’s 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, and operations site activities, support equipment, quality, training, data, Information Technology (IT), testing, program management/SE, vehicle design, and Human Resources (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 5 seen below details the WBS in a tabular form through Level 3.

Table 5 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 6 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 6 RACI Matrix

### 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.

### 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 solution’s 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.

### 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.

### 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.

### 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.

### 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.

### 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

### 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.

### Technical Specialty Integration

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.

#### 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 develop and integrate the autonomous technologies with the hardware and develop interfaces for interacting with the vehicle. There will be many sub disciplines of software engineering throughout the project such as backend programmers, frontend 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 monitor the safety processes throughout the life cycle of the product.

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.

#### Integrating Specialties

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

# Technical Processes

## Business/Mission Analysis

By participating in the DARPA Urban Challenge, A&B strives to contribute innovative complete ideas to the field of UAVs. The DARPA Urban Challenge gathers willing companies to participate in the competition for a monetary prize. Although the prize offers substantial money to the winner, DARPA gains significant advancements for a relatively small monetary amount in Darwinian fashion. By setting the bar high and requiring the winner to complete an obstacle course in an urban environment, A&B as well as all the other competitors must construct unique approaches to problems still causing trouble with autonomous driving, such as a passenger darting out into the road without a crosswalk.

Past DARPA challenges will be analyzed to determine the systematic approach bringing past successes and to utilize beneficial technologies into A&Bs own UAV. Consultation of past groups and organizations participating will provide useful insight about how A&B can learn from past mistakes.

## Stakeholder Needs and Requirements Definition

Considering A&B will be funding the entire operation for its own entry, A&B is the sole stakeholder and may set its evolving requirements as the entity sees fit. A&B will come up with all relevant requirements pertaining to schedule, budget, Measures of Effectiveness (MOEs), Measures of Performance (MOPs), and Technical Performance Measures (TPMs). Requirements may need modifications to fit within the guidelines set by DARPA but all other requirements are solely for A&Bs gain in keeping with a systems engineering approach and reducing costs short-term and long-term.

Trade studies will determine requirements’ definitions. Past case studies related to DARPA challenges and commercial autonomous vehicles will give relative measurements for defining the system.

Modeling and simulations will be conducted to ensure competitive progress. Mock demos will be run in-house treating the situation as though key stakeholders need progress updates. Progress will be broken down from the requirements into key features and objectives for each requirement.

## Requirements Definition, Validation, and Traceability

Requirements will be translated and stored in a running Microsoft Word document and Microsoft Excel document. Requirements will be grouped by function. Systems engineers will consult various other engineers on the progression towards validation of each requirement. Systems engineers will also compare in-house design progress to the challenges’ guidelines to make sure the design stays within tolerance on the challenges’ requirements. Design and analysis engineers will work towards actively modeling and simulating all the key aspects of the UAVs design. Since the amount of simulating and modeling is limitless, design and analysis will systematically prioritize the different aspects of the UAV deemed critical to success based on the priorities.

## Architecture Definition and Traceability

The system’s architecture will be broken down 3 levels by systems engineers to visualize all of the relationships between functions and operands. The relationships established in the architecture will tie back to various requirements needing sorting. During the sorting process, the architecture’s functions and operands will tie back into how each requirement is allocated between personnel and system components.

## Design Definition and Traceability

The system’s architecture will guide the system’s design. Communication needs establishment between the interface and remote computers capable of handling and controlling the vehicle. The system needs to be studied before any modifications take place from the purchased Tesla.

## System Analysis

To ensure the UAVs success, analysis will prove the systems capabilities before mock test runs. Simulations will give key indicators about what points of failure to look out for, what the system’s limitations will be, and what minimal performance thresholds to expect. Thermal simulations will point to the temperatures the vehicle and more importantly, the electronic components, can expect to endure. Structural testing will provide baselines for what crash ratings to expect and general endurance measures of the materials used.

## Implementation

Implementation of A&Bs UAV will include procurement, prototype fabrication, software, and low-rate initial production.

A&B will compile a list of established vendors from which they will purchase their aftermarket parts. A&B will analyze alternatives for each part, comparing both quality and cost, to make informed decisions. A&B will actively work to negotiate bulk order purchases and will include room in the budget for replacement parts. Tooling or other equipment may be ordered on an as-needed basis if the cost-benefit of repairing a part vs. ordering another part proves worthwhile. A log will be kept tracking the progress of each part and an active procurement area will be designated for handling product defects. Storage areas in the garage for ordered parts will be designated with neon tape and will receive their own warehouse room to move parts around. Parts may be moved around by hand when no safety risk is posed or by forklifts as needed, following strict safety and licensing rules for operation. Weekly inventory checks will help keep track of all parts to keep the vehicle free of debris (FOD). The actual vehicle will be transported on a company semi-truck, not driven, for warranty purposes and to minimize potential damage.

Machining of any metals and circuitry will be conducted on-site in the garage as needed. After carefully studying the purchased Tesla, modifications may be made for better performance, such as added dash cameras, added roll bar protection, etc… Designated zones will be partitioned where each modification will take place in the garage.

After studying the software built into Tesla’s vehicle, software engineers will work to improve upon the built-in functions. The second floor of the garage will consist of an office environment where software engineers will be allotted two 32” Dell monitors, a docking station, a company laptop with Dell i7 processor, computer mouse, office chair, and necessary cables for configuration. The software engineers will analyze what improvements need to be made, make suggested improvements, and demo their progress every two weeks. Software engineers will work closely with integration engineers during their demos to make sure the hardware poses no issues for configuration.

Given A&B will be purchasing a Tesla vehicle and will not be building one from scratch, the system needs to pay special attention to how each modification to the vehicle affects the whole system. A rotating schedule of integration will better track how each addition/modification affects the system so if a demo event goes wrong, the problem source can be isolated quickly and fixed.

Each day after attaining the Tesla, A&B will work towards meeting program deadlines and working overtime as needed. Before attaining the Tesla, some production will take place preparing modifications based on best guesses on what will work.

## Integration

A&Bs facilities will consist of a garage and 100-acre test racing track. Other racing tracks may be utilized owned by third parties. The garage will host a warehouse area, circuitry assembly area, retrofit area, modifications/additions zoning areas, software and miscellaneous engineering office environment on the second floor, procurement storage area, classified room if needed, conference room, and executive suite.

Along the testing track, every 20 miles, will be monitoring towers equipped with video surveillance, road maintenance tools, and first aid kits. These towers will provide check points during testing.

Each different area of production will be zoned off with safety tape. Daily toolbox checks will take place to keep the production floor FOD-free. Rearrangement of the production floor may take place depending on integration needs.

## Verification and Traceability

The main verification event for A&Bs UAV will be DARPAs National Qualifier Event (NQE). The NQE will show if the technologies developed by A&B are good enough to qualify for the national event. Up until the NQE, all verification will come from subcomponent demos and test track runs. The test track runs should show improving times and obstacles avoided with each new piece of technology added. With the goal of winning the grand prize, A&B strives to field a UAV with test track run times besting past winners and will include more difficult obstacles than to be expected in the challenge.

## Transition

The company will secure the modified tesla onto a company semi-truck one week before the DARPA Urban Challenge. Upon arriving at the challenge’s destination, A&B will have rented a private storage garage for inspection and tests.

Leading up to the event, A&B will conduct daily stationary tests to determine functionality and any possible points of failure. By the time the vehicle arrives at its storage garage, no further software modifications will be made for improvement but software changes may be needed if they prove to be a possible point of failure.

A&B employees needed at the challenge will be transported by company buses or will set up flight travel arrangements on a company card.

Basic repair tooling, test laptops, data recording devices, and other pieces of technology used for monitoring A&Bs UAV will be brought aboard the buses as well.

## Validation

A&Bs final evaluation event will be how it fares at DARPAs Final Event. With the end goal of ultimately winning the competition, A&B will set reasonable but competitive requirements for winning the Final Event. The designed UAV will be considered exceptional if it wins the Final Event. If the designed UAV fulfills ninety percent or more of its requirements but does not win the Final Event the program will be satisfactory. Incompletion of the course will be considered unsatisfactory.

## Operations

Operations will include the Final Event described previously as well as future testing events with the prototype. In preparation for driving the UAV, many engineers of various disciplines will be capable of fully operating the UAV to not only make future training easier but also to enhance their understanding and role within the context of the program. Official training documents, videos, and exercises will be captured and stored for future knowledge transfer. Step-by-step operation procedures will explicitly state all of the different functions the interface can do with the modified Tesla.

A checklist will be started and revised bi-weekly to determine all of the relevant tests to test the system’s capabilities and the user-system interactional capabilities.

During operational tests, sensors will be attached to monitor aspects of the Tesla’s performance. From the data collection, corrections may be made incrementally. Each testing event will be video-recorded and monitored the entire time. The improvements stemming from test runs will not only come from statistical-proof but video-reference too.

A&B reserves the right to enter the UAV in future events. While A&B aims to use the UAV in the DARPA Urban Challenge as a stepping-stone to full-scale production on a global scale, the initial UAV used in the challenge will continue to test out new features within the R&D department of A&B.

## Maintenance

Once A&Bs UAV completes the DARPA Urban Challenge, the product effectively moves into the maintenance phase of its lifecycle. A&B retains full discretion to enter into other autonomous competitions or use its proprietary technologies as part of other competitions or products. The UAV used for the challenge may also be retrofitted if it is to participate in future challenges or to test out future developing technologies.

After the competition, the UAV will be driven back to A&B facilities on the back of a company-owned semi-truck with coverings over it to not only protect it but also to avoid unveiling technologies A&B wants kept private. Upon returning to a storage garage owned by A&B, the vehicle will be parked and immediately inspected for any damage occurring during the competition or on the return trip. Reserve money will fund any further damage repair to the UAV.

A checklist will provide all of the weekly test procedures the UAV will undergo on a weekly basis to ensure it is still performing as it was originally intended. The UAVs weekly check-up drive will be no longer than 8 hours long on one day and will take place during normal weather conditions conducive to effective driving. A&B will purchase 100-acres of land to construct a test track leading directly from the storage garage. Funds will be allocated for video monitoring the track both during performance and during down-time to keep the track secure and untampered.

A&B reserves the right to rent or lend out the UAV for an agreed upon amount. Further negotiations may be decided by a contract-to-contract basis.

All employees previously falling under A&Bs UAV program will be trained on proper maintenance of the UAV. Separate personnel will be hired specifically for maintenance while previous employees under the program will be absorbed under other departments and programs within A&B.

## Disposal

A&Bs UAV is a prototype for future production on a global scale. The UAV driven for the challenge will not be sold. The prototype will be utilized for future testing and studies.

The life cycle of the UAV is approximately 25 years before disposal. While the prototype will be periodically tested for its controls, fixed for bugs, and retrofitted as necessary, the material structure and outdated technologies of the UAV will make it obsolete by year 2050 at the latest. Since the prototype will be used for other vehicular ventures, the UAV will be test wherever relevant. The prototype will provide useful insight on whether to pursue a particular type of vehicle suited for A&Bs choosing but once a decision is made, prototypes for the specific model going into production will drive further testing and evaluation.

Further studies will be conducted before disposal. A&B will gain knowledge on how the structural components fared over time and where points of failure would most likely be located on A&Bs other models going into production.

By taking apart the UAV component by component to the subcomponent it was inventoried as, each part can be individually analyzed outside of how it once operated in the system. Components needing anti-rust treatment will receive such before their storage. Electronic components will be stored in climate-adjusted, anti-flammable conditions. Each component will be logged in a computer database, taking note of inventory, condition of the part, and any other relevant metrics. All components will be stored in the garage used during maintenance.

# Technical Management Processes

## Project Technical Planning

### Major Events: Integrated Master Plan

Throughout A&Bs SE process, reviews will be scheduled to track the program readiness and ensure major milestones are hit within deadlines.

A Preliminary Design Review (PDR) will be conducted. The PDR will establish the allocated baseline of the system to ensure it is operationally effective. The timing of the PDR will be approved during official scheduling setting and will consist of third-party panel members to objectively evaluate the progress. A post-PDR assessment will be conducted in association with the Critical Design Review (CDR) and will be formally considered by the third-party panel at the CDR assessment. The purpose of the post-PDR assessment will be to reflect the updated design strategy from the CDR.

The PDR deliverables will consist of: (1) an established system allocated baseline; (2) an updated risk assessment for the engineering, manufacturing, and development phase; (3) an updated cost analysis requirements description; (4) an updated program schedule including system and software critical path drivers; and (5) an approved life-cycle sustainment plan updating program sustainment development efforts.

The Program Manager will conduct the PDR and will work to resolve critical, system-wide issues. The standard for technical reviews and audits to be performed through the acquisition life cycle will be IEEE 5288.2 “Standard for Technical Reviews and Audits on Defense Programs”. A tentative schedule will be set when the PDR should be conducted to maintain an on-time schedule but it will occur when the allocated baseline has been achieved, allowing detailed design of hardware and software configuration items to proceed. A minimum of 10 percent of the product drawings and associated instructions will be complete, with all safety-critical component drawings complete.

Following the PDR, A&B will conduct a Critical Design Review (CDR). A&B will ensure that the system can proceed into fabrication, demonstration, and test to meet stated performance requirements within cost, schedule, and risk. The CDR satisfies the Capabilities Development Documents (CDD). For key configuration items at each subsystem level, multiple CDRs may be needed to culminate in a system-level CDR. When the product baseline has been achieved and the CDR entrance criteria have been met as laid out herein, the CDR will be conducted to allow fabrication of hardware and coding of software deliverables to proceed.

The system’s final design will be assessed during the CDR as it is captured in product specifications for each configuration item in the system’s product baseline. By doing so, it is ensured that each configuration item has been captured in the detailed design documentation.

The CDR deliverables will consist of: (1) a system initial product baseline; (2) updated risk assessment for engineering and manufacturing development; (3) updated cost analysis requirements description based on the system product baseline; (4) updated program development schedule including fabrication, test and evaluation, and software coding, critical path drivers; and (5) approved life-cycle sustainment plan dating program sustainment development efforts and schedules based on current budgets, test evaluation results, and firm supportability design features.

The Program Manager will tailor the review to the technical scope and risk of the system, and address specifics of the CDR as laid out herein. The standard for technical reviews and audits to be performed for the CDR will be IEEE 5288.2 “Standard for Technical Reviews and Audits on Defense Programs”.

Following the CDR, a Detailed Design Review (DDR) will take place. The point of the DDR is to show evidence that the design will meet specifications, through inspection, analysis, or reference to something proven. In the system architecture, subsystems will address all specifications and a concept update may be necessary. Detailed drawings, schematics, flow charts, etc. will be need to physically and functionally realize the design, from component to subsystem to system.

DDR deliverables will consist of: 3-dimensional (3D) computer aided design (CAD) drawings, mechanical simulations, factory layouts, process flow diagrams, workflow maps, supply chain maps, ergonomic drawings, lean analysis, inventory analysis, implementation plans, MATLAB simulations, schematics, detailed circuit designs, and step-by-step plans to characterize the system against all of the specifications.

The fourth and final review will be a Test Readiness Review (TRR). The TRR will determine if the system is ready to proceed into formal testing by deciding whether the test procedures are complete and will verify their compliance with test plans and descriptions. Between each major test configuration item, including hardware and software, a TRR will be conducted to provide management with the assurance that the system has undergone a thorough test process and will be ready for turnover to the next phase, testing. The scope is related to the risk level associated with performing planned tests and the importance of the test evaluation results to the program success.

TRR deliverables will include: (1) completed and approved test plans for the system under test; (2) completed identification and coordination of required test resources; (3) a judgment that previous component, subsystem, and system test results form a satisfactory basis for proceeding into planned tests; and (4) identified risk level acceptable to the program leadership.

The program manager will conduct and address the TRR as part of verification and validation.

The 4 tests are used to guide A&Bs technical schedule. The focus with the program reviews is to make sure the details of the design receive significant attention because the innovation and ability to win the DARPA challenge will heavily depend on A&B adding competitive features. The TRR will validate the design as it will have sufficiently met the criteria where it will be ready to evaluate how effective the design’s features are during testing.

### Work Packages

The work packages will be the smallest unit of the WBS. Each Level-3 unit will be broken down to their respective work packages.

1.1.1 – 1.1.4 (Spare Parts, Repair Parts, Repair Tooling, Vendor Relations)

Maintenance work packages consist of electronic components, software programs, frame alloys, windshield and passenger windows, solar batteries, operating screen, electronic components, software programs, frame alloys, windshield and passenger windows, solar batteries, operating screen, tires, wheels, transmission, engine, air pressurizer, wrenches, jack, hydraulics, welding materials, anti-fire equipment, splicers, interface screen wiring, frame-bending equipment, transportation, updated documentation, and transportation personnel.

1.2.1 – 1.2.4 (Construction/Conversion/Expansion, Equipment Acquisition, Maintenance, Utilities)

Facilities work packages consist of demolition equipment, building equipment, construction personnel, liquid assets, network connection for online attainment, transportation for physical acquisition, transportation methods to bring on-site, sanitization, debris removal, relevant signs (including safety), and facilities maintenance personnel, electric, water, sewage, network connection, phone connection, and secure network connections.

1.3.1 – 1.3.4 (Equipment/Apparel Purchases, State/Federally Compliant, EPA Compliant, Safety Procedures)

Safety work packages consist of liquid assets, network connection for online attainment, transportation for physical acquisition, transportation methods to bring on-site, safety compliance personnel, state and federal paperwork documentation, state and federal adherence personnel, EPA paperwork documentation, EPA adherence personnel, safety paperwork documentation, and safety personnel.

1.4.1 – 1.4.6 (System Assembly, System Installation, System Checks, Contractor Tech Support, Site Construction/Modification, System Transportation)

Operations Site Activities work packages consist of assembly building, system assembly tooling, assembly personnel, cross-trained technicians and engineers, equipment handling tools, safety equipment, installation personnel, uniform checklist, documentation, specifications, phone connections, contact information, customer relations personnel, engineering plan drawings, estimators, construction equipment, and construction materials, procuring company vehicles, fueling vehicles, registering vehicles, and insuring vehicles.

1.5.1 – 1.5.2 (Test and Measurement Equipment, Support/Handling Equipment)

Support Equipment work packages consist of procuring test and measurement equipment, calibrating equipment, setting up equipment during testing, re-calibrating between tests, demoing before event runs, procuring equipment, setting up equipment when needed, testing equipment beforehand, and handling equipment as needed for proper configuration.

1.6.1 – 1.6.4 (Defect Prevention, Defect Management, Documentation, Customer Support)

Quality work packages consist of identifying defects, tracking defects incorporating defect prevention measures, identifying defects, tracking defects, defect resolution, procuring documentation software, scanning, printing, procuring printers, procuring storage space, tracking documentation, setting up phone lines, contacting customers, tracking customer inquiries, customer support personnel, and handling customer requests.

1.7.1 – 1.7.3 (Equipment, Services, Facilities)

Training packages consist of technical equipment procurement, training materials, training simulations, allocated spared to use for equipment training, service platforms, service software, service teaching personnel, buildings for teaching, equipment for facilities manufacturing, and facilities personnel.

1.8.1 – 1.8.5 (Technical Publications, Engineering Data, Support Data, Management Data, Data Repository)

Data work packages consist of data configuration, data source collection, data verification, data validation, data training, data testing, data cleansing, data analysts, and data configuration.

1.9.1 – 19.4 (Storing Data, Retrieving Data, Transmitting Data, Manipulating Data)

IT work packages consist of data security, security protocols, data configuration, data verification, data validation, personnel security training, data analysis, data flow, and data access.

1.10.1 – 1.10.4 (Test and Engineering Support, Mock Trials)

Testing work packages consist of engineering support personnel, test equipment, trial runs, trial tracks, verification measures, test documentation, facilities configuration for testing, and analysis software.

1.11.1 – 1.11.2 (Requirements Compliance, Funds Allocation)

Program Management/SE work packages consist of program management software, program management compliance, personnel fulfillment, budget management, and schedule management.

1.12.1 – 1.12.12 (Vehicle Frame, Application Software, System Software, Communications, Navigation/Guidance, Central Computer, Fire Control, Data Display and Controls, Survivability, Automatic Handling Control, Auxiliary Equipment, Avionics)

Vehicle Design work packages consist of engineering support, engineering equipment, integration management, tooling, machining, assembly, drawings/schematics, CAD drawings, analysis, and simulations

1.13.1 – 1.13.4 (Talent Acquisition, Dispute Resolution, Contracting Negotiation, Policy Iterations)

HR work packages consist of policy/rules formations, arbiters, HR personnel, up-to-date staffing analysis, and industry pricing knowledge.

## Technical Management and Assessment

### Technical Performance Management

Program Managers will oversee the work packages along with technical leads for implementing the work packages. Management higher on the organization chart reserves the right to make changes to work packages as they may see fit within their respective branches of management.

Technical Performance Measures (TPMs) will be identified during PDR and CDR and refined at later reviews.

### Continuous Assessment

Requirements may be validated before testing through analysis and simulation. Thermal analysis, structural analysis, SPICE analysis for circuits, etc. will be used to verify the to-be-realized design matches how it will most likely perform.

During developmental testing, the focus will strictly rely on what could boost performance time regardless of the technical measures it may generate through analysis and/or simulations. Between each test run, simulations and analysis will be run, making the model as realistic as possible, to determine possible modifications to the UAV to improve time. Analysis will also be run to determine the health of each parts critical to failure.

### Other Technical Measurements

Technical measures will be generated from the requirements and architecture initially. Some technical measures will relate back to top times in past DARPA challenges and projections on competitive vehicles in the coming year’s competition. Some specifications will be set by program regulations, such as frame size, tire size, etc. Some technical measures will be pre-determined by purchasing a ready-built Tesla.

## Integration with Cost and Schedule Management

A&B will follow an Earned Value Management (EVM) program progress management system combined with Agile principles. EVM is needed to curtail schedule lags that may occur to address the proper integration between cost, schedule, and technical progress. To ensure technical progress matches schedule and cost updates, Program Managers below the Vice Presidents and Senior Managers on the Organization Chart will provide oversight. Each technical discipline will receive a PM. By doing so, the PM will have a deeper technical knowledge for schedule delays and will understand on a technical level why the delays are happening if they are technical. The Program Managers will be ranked equally and will require collaboration between each to prioritize differences that may occur. One Senior Program Manager will lead the Program Manager and will accept accountability, promote communication between the Program Managers, and will interact with customers and those higher on the Organization Chart for information relay on progress with cost, schedule, and technical details.

As mentioned, A&B will practice Agile for easier management tracking and progress increments. Program Managers will rely on Product Owners (POs) to engage the customer regularly with any questions they may have on the development of their technical product features they are responsible for. Scrum masters will lead teams under them and work on coordination with management, product owners, and engineers to guide the Agile process.

Different software programs will be needed for implementing EVM with Agile. VersionOne will be used for employees to track and manage their schedules with work needed to be done. Program Managers will use Microsoft’s project management software for key information relay. When applicable, data will be configured with Excel for easy, universal access and manipulation. Git will be used for version control on teams where it is relevant and applicable.

Program Managers will mostly ensure cost tracking is accurate. They will approve employees timekeeping bi-weekly to ensure they’ve charged their hours honestly and accurately. They will receive weekly reports detailing how cost is comparing with technical progress and schedule. They will consult with Scrum Masters and Product Owners on a daily basis to see if any roadblocks are impeding progress that they could help to remove and to find out how they could coordinate with other technical disciplines to accomplish tasks with upstream or downstream dependencies.

Variances in schedule with technical progress may require employees to work overtime. Although A&Bs only goal with the UAV program is to finish one design for the competition, with past and future production goals they have relationships to uphold. Although overtime may be a profits net loss, their relationship with those contributing to A&Bs success will contribute more to profits in the long-run to offset short profit detriments. A&B strives to retain past customers and build relationships with future customers, with customers knowing they can expect A&B to deliver what they have promised on-time and on-budget.

## Decision-Making

Trade studies will be performed for each major design decision and other decisions related to the implementation of A&Bs design.

High-priority trade studies will include: (1) vehicle frame; (2) application software; (3) system software; (4) communications; (5) navigation/guidance; (6) central computer; (7) fire control; (8) data display and controls; (9) survivability; (10) automatic handling control; (11) auxiliary equipment; (12) avionics; (13) test and engineering support; (14) testing verification; (15) testing facilities; and (16) all data functionality. The high-priority trade studies revolve around four WBS level 2 items: Vehicle Design, Testing, IT, and Data. The first 12 items listed flow from Vehicle Design will garner the most consideration and options presented but will be hampered by purchasing a pre-built, functional Tesla model.

Informal trades will be conducted before a PDR. Before PDR, most trade studies will be searching for practical solutions and innovative ideas alike where the potential for implementation is high and any ideas are worth considering.

Up to CDR, a solidified design will take shape and any new trade studies and ideas worth implementing must consider and weigh the benefits of integration with the rest of the system. Decision matrices will be made for each formal trade study performed up to CDR for traceability and understanding on why design decisions are made.

No more formal trade studies will be conducted up to DDR. At DDR the design is thorough and well-reasoned. Any changes up for consideration to the design are only under consideration due to current design flaws with the potential to fail or compromise the performance of the UAV.

For the trade study matrices, each design decision will be weighted. Most design decisions will be fuzzy criteria, allowing for subjectivity and interpretation. For any design decision matrix with options listed and undecided up until CDR, technical specifications may be associated with the fuzzy criteria. The technical performance with its integrated components already decided on will also be considered. By weighing on a percentage decimal scale and rating each fuzzy criteria on a 1-5 scale, one decision will be reached for each design decision. One, in this case, stands for doesn’t meet minimal performance. Two interprets as meets minimal performance in some respects. Three interprets as meets minimal performance. Four interprets as exceeds minimal performance. Five interprets as significantly exceed minimal performance.

The design decision matrices will be produced in Microsoft Excel. The design decision matrices may be updated at any point to reflect the observance of more related fuzzy criteria or during information discovery, weight changes to reflect the desired system performance.

## Issue Identification and Resolution

A&B will conduct root cause analysis (RCA) for all major defects. During the investigation process, three different types of causes will be thoroughly investigated: (1) physical causes where tangible, material items failed in some way; (2) human causes where people did something wrong or did not do something that was needed and may have led to a physical cause; and (3) organizational causes where a system, process, or policy that people use to make decision or do their work is faulty. By investigating the patterns of negative effects, finding hidden flaws in the system, and discovering specific actions that contributed to the problem, root causes can be discovered to prevent their recurrence in the future.

Root Cause Analysis begins with identification. The parties identifying a problem will flow them up to their production manager or directly to Quality Assurance. Quality Assurance will properly document the problem in accordance with DoD standards and store the data. Quality Assurance will then determine the level of impact the problem identification causes, whether the problem is frequently occurring or irregular to warrant a RCA, and the implications of the problem identification. If Quality Assurance weighs the problem objectively using scaled compliance and subjectively through meetings involving the necessary parties and determines a RCA is necessary, the process ensues.

The RCA process involves five major steps: defining the problem, collecting data, identifying possible causal factors, identifying the root causes, and recommending/implementing solutions. The first step, defining the problem, by looking at what the specific symptoms are and what is happening. The second step, collecting data, involves analyzing the situation fully before moving on to look at factors that contributed to the problem. Consulting experts is recommended and may include customers, responsible parties for implementing a solution, process owners, and people involved with environmental factors. The third step, identifying possible causal factors, aims to identify as many causal factors as possible to dig deeper and not just treat the most obvious causes. The fourth step, identifying the root causes, seeks to find why the causal factor exists and what the real reason is for the problem occurring. The roots of each factor are looked at to dig deeper at each level of cause and effect. The fifth step, recommending and implementing solutions, involves analyzing the cause-and-effect process, and identifying the changes needed for various systems while planning ahead to predict the effects of your solution.

When a RCA case study is complete and findings submitted to Quality Assurance, the Organization Chart head of QA, Program Managers involved, senior Program Manager, and other lower level organizational members involved with the RCA will need to sign off on the report to verify its accuracy.

Following a RCA, corrective measures will be put in place to mitigate the recurrence(s). Quality Assurance, safety, and Program Managers will implement corrective measures within 90 days of the incident to show A&Bs commitment to safety and customer satisfaction.

In addition to corrective actions, preventive actions may be necessary moving forward to mitigate recurrence(s). Following RCA(s), a bi-weekly meeting will be set up to implement preventive measures after surveying the involved parties. A minimum of 30 hours per RCA will be dedicated to preventive resolution(s) actions through meetings, surveys, etc. to figure out what could be improved to prevent the causes from occurring again.

## Risk and Opportunity Management

A risk assessment will be conducted and a risk matrix will be documented detailing the ranking or prioritizing of hazards. Factors deciding the hazard risk will be employee exposure and potential for incident, injury or risk.

The following Table 7 exemplifies a typical implemented Risk Matrix to be utilized by A&B once risks have been identified.

Table 7 Risk Matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Probability | High |  |  |  |
| Medium |  |  |  |
| Low |  |  |  |
|  | Low | Medium | High |
| Severity | | | | |

The x-axis Severity category will contain three severity levels:

1. High: major fracture, poisoning, significant loss of blood, serious head injury, fatal
2. Medium: sprain, strain, localized burn, dermatitis, asthma, injury requiring days off from work
3. Low: an injury requiring first aid only; short-term pain, irritation, or dizziness

The y-axis Probability category will contain three probability levels:

1. High: likely to be experienced once or twice a year by an individual
2. Medium: may be experienced once every five years by an individual
3. Low: may occur once during a working lifetime

The intersection of Probability and Severity will determine the risk level. Some risk measures require corrective actions, coded by color as follows in Table 8:

Table 8 Risk Ratings

|  |  |
| --- | --- |
| **Description** | **Color Code** |
| Immediately Dangerous |  |
| High Risk |  |
| Medium Risk |  |
| Low Risk |  |
| Very Low Risk |  |

The ratings resemble:

Immediately Dangerous: stop the process and implement controls

High Risk: investigate the process and implement controls immediately

Medium Risk: keep the process going; however, a control plan must be developed and should be implemented as soon as possible

Low Risk: keep the process going, but monitor regularly. A control plan should also be investigated

Very Low Risk: keep monitoring the process

Each risk will be analyzed separately, with members from safety and technical leads collaborating to confirm measures to mitigate each risk. Other systems will be studied to draw conclusions about what works for said related systems. The order of prioritization follows suit to the color coding received in the Risk Matrix, going from darker shades to lighter shades (Immediately Dangerous to Low Risk).

Risk mitigation measures will be put in place for each risk identified. An active spreadsheet will flow from the Risk Matrix to connect a bullet point list of Risks to their respective Mitigation Strategies. In addition to Mitigation Strategies, another category on the list will be Closeout Criteria to show a definitive measure that Risks may be mitigated by following their Mitigation Strategies.

Twenty-One “Musts” identified below support DoD and civilian agency projects and programs. The list is not all-inclusive but represents A&B follows to meet minimum conditions needed to initiate and continuously execute risk management successfully [1].

1. Risk management must be a priority for leadership and throughout the program's management levels. Maintain leadership priority and open communication. Teams will not identify risks if they do not perceive an open environment to share risk information (messenger not shot) or management priority on wanting to know risk information (requested at program reviews and meetings), or if they do not feel the information will be used to support management decisions (lip service, information not informative, team members will not waste their time if the information is not used).
2. Risk management must never be delegated to staff that lack authority.
3. A formal and repeatable risk management process must be present—one that is balanced in complexity and data needs, such that meaningful and actionable insights are produced with minimum burden.
4. The management culture must encourage and reward identifying risk by staff at all levels of program contribution.
5. Program leadership must have the ability to regularly and quickly engage subject matter experts.
6. Risk management must be formally integrated into program management
7. Participants must be trained in the program's specific risk management practices and procedures.
8. A risk management plan must be written with its practices and procedures consistent with process training.
9. Risk management execution must be shared among all stakeholders.
10. Risks must be identified, assessed, and reviewed continuously—not just prior to major reviews.
11. Risk considerations must be a central focus of program reviews.
12. Risk management working groups and review boards must be rescheduled when conflicts arise with other program needs.
13. Risk mitigation plans must be developed, success criteria defined, and their implementation monitored relative to achieving success criteria outcomes.
14. Risks must be assigned only to staff with authority to implement mitigation actions and obligate resources.
15. Risk management must never be outsourced.
16. Risks that extend beyond traditional impact dimensions of cost, schedule, and technical performance must be considered (e.g., programmatic, enterprise, cross-program/cross-portfolio, and social, political, economic impacts).
17. Technology maturity and its future readiness must be understood.
18. The adaptability of a program's technology to change in operational environments must be understood.
19. Risks must be written clearly using the Condition-If-Then protocol.
20. The nature and needs of the program must drive the design of the risk management process within which a risk management tool/database conforms.
21. Risk management tool/database must be maintained with current risk status information; preferably, employ a tool/database that rapidly produces "dashboard-like" status reports for management.

As always, the most effective way to mitigate risk is preventive safety measures. Documentation and training sessions will routinely be provided and reminded to members working in higher safety risk positions to make sure they know what applicable safety measures they can follow. Safety engineers will ensure compliance by members on-site. Safety personnel will keep in regular contact with Occupational Safety and Health Administration (OSHA). By doing so, A&B will proactively establish safety protocols and foster an open relationship with OSHA, showing A&Bs prioritization of safety.

Active documentation spreadsheets open to all employees showing active safety risks will establish an openness to preventing and staying safe. Posters/flyers/banners will be attached throughout A&B facilities to serve as safety reminders for application measures and for conscientious reminders for workers to focus on safety in their daily tasks. For consecutive periods with no accidents reported, A&B will host celebratory events or will distribute company apparel free of charge to all employees. The active spreadsheets detailing risks and accidents will retain anonymity to drive a cultural shift away from whistleblowers.

## Configuration Management

Configuration Management (CM) within A&Bs scope consists of:

* Identification and involvement of relevant stakeholders
* Setting of CM goals and expected outcomes
* Identification and description of CM tasks
* Assignment of responsibility and authority for performing the CM process tasks
* Establishment of procedures for monitoring and control of the CM process
* Measurement and assessment of the CM process effectiveness

At a minimum, A&B identifies the following tasks as necessary:

* Identifying the configuration of selected work products that compose the baselines at given points in time
* Controlling changes to configuration items
* Building or providing specifications to build work products from the configuration management system
* Maintaining the integrity of baselines
* Providing accurate status and current configuration data to developers, end users, and customers
  + 1. Baseline Definition and Management
       1. Configuration Identification

Within A&Bs context and culture, it must adhere to or incorporate applicable policies, procedures, and standards to accommodate acquisition and subcontractor situations. Throughout the process, configuration items will be managed and controlled. Steps involved include establishing a procedure for labeling items and their version to provide a context for each item within the system configuration and to show the relationship between system items.

* + - 1. Configuration Status Accounting

Configuration Status Accounting calls for establishing baselines, changing control, configuration auditing, establishing constraints and guidance, accounting for organizational issues, and measuring with proper tools.

Establishing baselines means assembling configuration items in a way that specifies how a system will be viewed for the purposes of management, control, and evaluation. The baseline(s) will be fixed at a specific point in time in the system life cycle and represent the current approved configuration. Formal change procedures dictate any suggested changes.

The change control process in response to an engineering change proposal links the step necessary for configuration steps across the enterprise and various organizational capacities.

Configuration audits regulate, standardize, and facilitate adherence to applicable CM plans by independently evaluating the current status of configuration items to determine conformance.

Constraints and guidance in CM stem from policies, procedures, and standards set forth at various organizational levels within A&B subject to influencing or constraining the design and implementation. In A&Bs case, the acquirer, DARPA, or supplier, vendors, may contain provisions affecting the CM process as well as their associated tools, methods, and other processes used in system development. ISO/IEC/IEEE 15288 2015 and ISO 10007 2003 standards will guide A&Bs system life cycle processes.

An organizational context is critical for successful CM planning, management, and implementation process. The organizational elements provide a fundamental understanding why constraints are placed upon it.

* + 1. Change Management

A&Bs Change Management Plan (CMP) occurs throughout the whole product life cycle to help control change effects during the execute and control stage. By doing so, program management takes active measures to avoid overruns in cost and schedule, scope creep, poor quality, etc. Participation in the CMP involves team members, program managers, stakeholders, DARPA, and upper members in the organizational chart funding the project.

A&Bs CMP defines change management roles, a change control board, a process for implementing changes, change request forms, change request logs, a software tool for change implementations, and an auditing compliance team.

A senior program manager will be guiding and hold ultimate authority on the CMP. Any employee will be capable of submitting a request to a configuration management team dedicated to handling requests. The configuration management team will then analyze the request and decide the relevant parties who needs to review each configuration change on a case-by-case basis. If a configuration change is reviewed by the necessary parties and deemed necessary for implementation, the senior program manager for configuration management, all project managers involved with the request, employee(s) submitting the request, and configuration management team members conducting the review all must sign off to authorize the change. The parties routinely involved with configuration changes will attend a bi-weekly meeting to assess configuration change update requests. CFEngine will be the software resource for submitting configuration changes and tracking them throughout their life cycle.

* + 1. Requirements Management

Requirements management collects, analyzes, refines, and prioritizes the product requirements so they may be properly planned for delivery. The ultimate goal for managing requirements is to ensure the organization can validate and meet the needs of the customers. A&B will be tracking requirements to ensure compliance with DARPA guidelines and to track the progress of the design requirements. Requirements progress means establishing open lines of communication between projects team members and DARPA so they may be adjusted throughout the project’s course. Through daily communication, better workload and priority balances are established.

A&B will organize requirements as either functional or non-functional. Functional requirements are expected to satisfy specific user needs. They fundamentally describe the business requirements along with the capabilities the intended product can perform.

Non-functional requirements describe qualities of the product, including usability, performance, reliability, and security. They may also describe technical requirements.

A&B strives to address requirements issues early in the product life cycle to avoid design problems stemming from poor requirements. At later stages in the product life cycle, the design issues will be more difficult and expensive to resolve. A&B will dedicate 10% of total program costs to requirements processes to avoid cost overruns.

Some pitfalls A&B will avoid in regards to their requirements:

1. Incomplete requirements
2. Didn’t involve users
3. Insufficient resources/schedule
4. Unrealistic expectations
5. Lack of managerial support
6. Changing requirements
7. Poor planning
8. No longer needed

The requirements process will follow the same procedures as described in Section 5.7.2 Change Management.

* + 1. Interface Management

Interface management describes the activities of defining, controlling, and communicating information needed at the common boundary where direct contact between two different cultures, devices, entities, environments, systems, etc. and multiple contractors, subcontractors, and clients take place. Project interfaces will connect the points between parties or elements, assuming all entities are working towards a common, agreed-upon goal to complete the project. Interface management decreases the changes of miscommunication, lack of communication, or the inability to stay within scope, budget, and schedule to deliver lower risk.

A&B will incorporate the following principles into its own Interface Management processes:

1. Tight control of dynamic interfaces to achieve project cost, schedule, and scope targets.
2. Static project interfaces kept clearly defined through the life of the project.
3. Organizational factors allowing inhibition requiring project integration.
4. Project organization structures needing to change as the project develops.
5. Early, firm design control for effective project control
6. Design/production interface rating the most critical project interface and the most difficult to manage.
7. The required amount of project management effort resulting in a function of project size, speed, and complexity.

Interface management processes will follow similar procedures as described in Section 5.7.2 Change Management.

## Information Management and Product Lifecycle Management (PLM)

Product Lifecycle Management (PLM) describes the process by which A&B will handle the product as it moves through the typical stages of its product lifecycle consisting of development and introduction, growth, maturity/stability, and decline. PLM includes the manufacturing processes and marketing. The end result is to streamline activities to produce a product that outperforms its competitors, is highly profitable, and lasts as long as consumer desire and technology permit.

A&B intends to gain the following benefits:

* Improved product quality and reliability
* Reduced prototyping costs
* More accurate and timely requests for quote (solicitation from suppliers)
* Quick identification of sales opportunities and revenue contributions
* Savings through the re-use of original data
* A framework for product optimization
* Reduced waste
* Improved ability to better manage seasonal fluctuation management
* Improved forecasting to reduce material costs
* Maximized supply chain collaboration

Quality Assurance will review each major sprint task for defect observance. Defects in hardware and software will receive the highest priority. Quarterly data audits will retain the integrity of the data.

# Organizational Investment

## Life Cycle Management

### Program Policies and Procedures

Each functional division within A&Bs UAV program will follow unified policies and procedures detailed for unity and cohesiveness program-wide. A secure platform with administrator approval will grant members access to the policies and procedures in place. When necessary, members may be asked to sign documents stating they will comply with said policies and procedures. The fault is on the employee for complying with policies and procedures. Employees are encouraged to seek out the help of HR with any questions they may have regarding policies and procedures.

General best practice policies and procedures will be available on the secure platform which should be updated regularly to ensure the material is the most up-to-date. HR will enforce and counsel policy and procedure disputes. External arbiters will be sought in a conflict of interest situation and legal action may be pursued when needed.

### Program Measurement and Assessment

While the Technical Assessment measures define how the design development of the UAV will be measured and tracked, A&B will enact various other program measures and assessments to track the overall health of the program. Trackers will be put in place to gain a better understanding of the following categories: employee engagement, employee satisfaction, employee performance, A&B enterprise process improvement internal, and A&B enterprise process improvement external.

A&B would like to foster the development of its talent internally as much as possible, both to keep costs down for retaining experienced members and for keeping contributing employees within A&B. Employee engagement is about taking proactive steps for finding ways to keep employees motivated and happy. A&B wants each employee to feel personally responsible and accountable for their contributions to keep the connection of each member contributing to the full end-product. Various surveys will be distributed throughout the year for program employees to fill out as accurately as possible so employee engagement can be quantified with sections for qualitative inputs as to what can be improved for employee engagement. Along with employee engagement comes employee satisfaction where similar surveys will be distributed for filling out. Management will be encouraged to reach out frequently to find as many non-quantifiable variables at play leading to employee disengagement and job dissatisfaction. Initial surveys after 3-6 months into the commencement of the program will establish a baseline to show how the numbers may change every 3 months with the distribution of more surveys. After 12 months, the data gathered from the program’s survey will be compared to enterprise-wide surveys across all of the programs at A&B to see how employee engagement and satisfaction compare.

Employee performance will be tracked to avoid falling behind schedule and to recognize any blockers that may come up in the near future to impede performance. While product assessments can shed light on employee performance, they do not give the full picture such as uneven distributed workloads between employees and teams, the effort given to retain schedule, how program spending affects various disciplines’ performance, etc.

Process improvement assessments within A&B will gather A&Bs domain experts enterprise-wide to gather relevant data on how the UAV program could improve its current practices and establish new practices. While upper-management in the UAV program may be aware of issues within the program, by gathering domain experts enterprise-wide the likelihood of coming up with innovative solutions increases drastically. A yearly internal process improvement will take place during the first quarter so changes suggested by the process improvement council may be implemented by the end of the second quarter. In addition to an internal process improvement assessment, A&B will also contract out work to a reputable firm for suggesting external process improvements. By doing so, A&B eliminates company bias during assessment and can look at internal problems within A&B with a fresh take. The external process improvement will also take place during the first quarter every year so those suggested changes can be implemented by the end of the second quarter.

Additional measurements and assessments may take place as the need arises throughout the duration of the program.

### Continuous Improvement

Selected business measurements will help the program maintain its integrity throughout its life cycle. A&B hopes to incorporate as many relevant metrics as possible while creating a cordial atmosphere where employees feel comfortable voicing their concerns.

Assorted data management teams will distribute their information through the proper pipelines to retrieve applicable metrics. VersionOne will track employee performance and team metrics, capable of backtracking for the discovery of trend performances.

A&B will aim to track as many metrics as possible while retaining a neutral mindset free of retaliation against targeted improvement areas in the program. Metrics targeted for tracking include individualized employee performance, team performance, engineering divisions’ performance, and program performance. The hours spent on each task, how time was spent on each task, the number of days taken to complete the task, and other similar measures will be actively tracked and archived through VersionOne. A&B will strongly promote open lines of communication to value each employee’s contribution and work with them through problems rather than encouraging a culture of aggressively tracking metrics to weed out weak performers.

By tracking metrics, A&B will better understand how time is allocated for each engineering division, what dependencies to getting tasks done are holding back schedule, the relationships and cross-engineering between different functional teams, what functional teams need targeted improvement and what can be done to help them, how close the program as a whole is staying on budget, schedule, and technical development, etc. The ultimate goal of metrics tracking is to pool as much data as possible that can be understood logically to see general trends over time leading to better efficiency over time and avoiding common pitfalls along the way inherent in any program.

A&B reserves the right to include performance bonuses/incentives for high-performers on an individual level and higher.

## Investment Management

### Product Line Investment (Portfolio Management)

A&B will allocate a certain portion of the UAV program’s funding for R&D through which new or improved products and services will be developed. Money within R&D will be balanced between improving existing methods, pursuing existing methods with proven track records of working on similar products, trying completely new methods and innovative hardware/software solutions on a small scale, and studying applicable problems in a research laboratory environment. After going through R&D testing successfully, the new innovation will go through consultation with technicians to discuss the practicality of implementing the solution. If the program manager approves the updated design, implementation will begin as soon as effectively possible.

A&B will allocate a certain amount of time and budget for individual employees to pursue innovations and will be recognized/rewarded for their contributions. By setting aside time periods for innovation, employees will feel comfortable pursuing new solutions which do not directly contribute to immediate financial/developmental payoff.

### Supply

A&B birthed the specific program for entering the DARPA Urban Challenge and will incorporate any approved innovations into its final design. The technologies developed in the UAV program will be implemented across the enterprise, one of the main benefits of entering the competition.

Potential investors may stay tuned to the outcome of the DARPA Urban Challenge and want to invest in particular technologies developed by A&B or fund additional investing in A&Bs UAV program. A&B is open to the possibility of continued investment in the program and will use the DARPA Urban Challenge to gauge interest in acquirer interest. A&B reserves the right to enter its UAV in additional competitions with monetary incentives and will continue to develop autonomous vehicle technologies as long as the technologies are financially feasible for the organization. Separate technologies implemented in the product may be marketed separately and the UAV may be marketed as a whole for interested parties.

### Acquisition

A&B will use existing suppliers currently used across the enterprise to provide parts for the program to maintain good relations. When certain parts need procurement from a new vendor, Supply Chain Logistics teams will seek out companies specializing in the part(s) and receive quotes before making a selection. The Supply Chain Logistics teams will consult the technical dimensions of the part(s) for ease of integration and functional use before making a decision with price in mind. To reach agreement with new suppliers, A&B may promise future orders to the new supplier for discounted prices on the UAV program’s order(s).

## Resource Management

### Personnel

A&B will work to provide training material and personnel where needed. An initial onboarding process will initiate new employees to the company culture and to their program’s inner-workings. Although most training will occur as the employee learns their day-to-day job from more experienced people doing their specific role, archived documents will be provided to describe technical details of various tasks for transparency and quicker development times. Employees are encouraged to meet with their manager on a monthly basis to address any concerns with their job or adjusting to their new role in general.

### Infrastructure

Employees will be encouraged to make a case for any new infrastructure need by A&B. Previous infrastructures from other programs within A&B will be utilized on the UAV program where logic follows.

Initial setup for the A&B UAV program will be planned out as best as possible in an attempt to account for everything the program may need. When tools, facilities, databases, networks, and support services need revision or additions, suggestions will be flowed up to the proper members in the organizational chart with expertise in the area to determine the urgency of the need and the potential benefits from implementing the revision/addition.

## Quality Management

Quality Assurance will comply with applicable ISO standards and will actively seek out other relevant standards to come up with a comprehensive list covering all quality standards. A&B wants to deliver products and services conforming to documented specifications within cost. Although quality engineers specifically cover compliance and policy/procedure adherence, each member is responsible for putting quality first in their work.

While Quality Assurance will have many procedures and analysis methods for intertwining with safety and product development, the following goals and objectives cover the scope of quality:

1. Drive the value of safety as a value to never be compromised in all aspects of the organization
2. Zero lost time injuries
3. Illness/injury rates below national average
4. No breaches of environmental compliance
5. No damage to facilities or equipment results from violation of safety, health, and environment requirements or willful neglect.

The following military and commercial standards and guides will be adhered to:

1. MIL-STD-45622A
2. MIL-STD-882C
3. MIL-STD-1629A
4. SMC Standard SMC-S-003T
5. Volume set of AIAA S-102 Mission Assurance
6. TBS Decision Analysis Guide

Quality Assurance will work to convey regular messages enforcing quality standards and driving a routine, unwavering focus on quality. Quality will not be considered a reactionary measure but a proactive measure.

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