



## **CUBESAT DEVELOPMENT FRAMEWORK**

### **THESIS**

William D. Sousa, Captain, USSF

AFIT-ENV-MS-21-M-272

**DEPARTMENT OF THE AIR FORCE  
AIR UNIVERSITY**

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**Wright-Patterson Air Force Base, Ohio**

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THESIS

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CUBESAT DEVELOPMENT FRAMEWORK

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### **Abstract**

AFIT's Center for Space Research and Assurance (CSRA) has developed several small satellites without a detailed developmental framework in place but future work will focus on CubeSat development with the intent of managing multiple builds concurrently. With the goal of each satellite being completed in three years, a comprehensive process needs to be established. Research revealed that the Department of Defense (DoD), U.S. Air Force (USAF), and National Aeronautics and Space Administration (NASA) guidance on the acquisition and systems engineering processes require more reviews and deliverables than appropriate for the scale of CSRA's projects. The satellite development processes from other universities divulge that some aspects of the much larger DoD, USAF, or NASA processes were borrowed and incorporated into their own. To define CSRA's developmental framework, the processes of these organizations were explored and tailored to meet the specific needs of CSRA. To effectively scrutinize each process, the frameworks were divided into life-cycles, deliverables, and entrance/exit criteria before being tailored. The research provided qualitative data so visual mapping was used to compare and tailor the life-cycles. The deliverables were recorded and organized to develop a comprehensive list that was tailored to only those that are value-added to CubeSat development. Once the appropriate entrance/exit criteria were applied to the life-cycle and deliverables, a fully tailored framework was defined.

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William D. Sousa

## Table of Contents

|                                                   | Page |
|---------------------------------------------------|------|
| Abstract.....                                     | iv   |
| Acknowledgements.....                             | v    |
| Table of Contents.....                            | vi   |
| List of Figures.....                              | viii |
| List of Tables.....                               | xii  |
| I. Introduction.....                              | 1    |
| General Issue.....                                | 1    |
| Background.....                                   | 1    |
| Problem Statement.....                            | 3    |
| Research Objectives/Questions.....                | 3    |
| Research Focus.....                               | 4    |
| Investigative Questions.....                      | 4    |
| Methodology.....                                  | 5    |
| Assumptions/Limitations.....                      | 5    |
| Implications.....                                 | 6    |
| Preview.....                                      | 7    |
| II. Literature Review.....                        | 8    |
| Chapter Overview.....                             | 8    |
| Important Terms.....                              | 8    |
| CubeSat Background.....                           | 9    |
| University Guidance/Procedures.....               | 14   |
| DoD Program Management & System Engineering.....  | 22   |
| NASA Program Management & System Engineering..... | 32   |
| Relevant Research.....                            | 41   |
| Summary.....                                      | 43   |
| III. Methodology.....                             | 45   |
| Chapter Overview.....                             | 45   |
| Research Focus.....                               | 45   |
| Framework Breakdown.....                          | 48   |
| Process Analysis.....                             | 50   |
| Summary.....                                      | 53   |

|                                                 | Page |
|-------------------------------------------------|------|
| IV. Analysis and Results.....                   | 54   |
| Chapter Overview.....                           | 54   |
| Concept Analysis.....                           | 54   |
| Tailoring Life-Cycles .....                     | 55   |
| Tailoring Deliverables .....                    | 88   |
| Life-Cycle Phase Entrance/Exit Criteria .....   | 113  |
| Investigative Questions Answered .....          | 118  |
| Summary .....                                   | 119  |
| V. Conclusions and Recommendations .....        | 120  |
| Chapter Overview.....                           | 120  |
| Conclusions of Research .....                   | 120  |
| Significance of Research .....                  | 121  |
| Recommendations for Action.....                 | 122  |
| Recommendations for Future Research .....       | 122  |
| Summary .....                                   | 124  |
| Appendix A. Complex Life-Cycle Tailored .....   | 125  |
| Appendix B. Simple Life-Cycle Tailored .....    | 129  |
| Appendix C. DoD Deliverables Tailored.....      | 131  |
| Appendix D. NASA Deliverable Tailored.....      | 137  |
| Appendix E. USAF Deliverables Tailored .....    | 144  |
| Appendix F. Complex Deliverables Tailored ..... | 149  |
| Appendix G. Simple Deliverables Tailored.....   | 162  |
| Appendix H. Final Deliverables Tailored .....   | 167  |
| Bibliography .....                              | 171  |

## List of Figures

|                                                              | Page |
|--------------------------------------------------------------|------|
| Figure 1. 1U CubeSat.....                                    | 10   |
| Figure 2. University-Class Mission by Form Factor .....      | 13   |
| Figure 3. Mission Status for University-Class Missions ..... | 13   |
| Figure 4. AAF Pathways.....                                  | 25   |
| Figure 5. Accelerated Acquisition Model.....                 | 27   |
| Figure 6. System Engineering Process.....                    | 28   |
| Figure 7. Technology Readiness Levels .....                  | 30   |
| Figure 8. MTA Framework.....                                 | 31   |
| Figure 9. NASA System Engineering Process.....               | 35   |
| Figure 10. System Engineering V-Model .....                  | 35   |
| Figure 11. NASA Project Life-Cycle.....                      | 38   |
| Figure 12. Framework Breakdown .....                         | 49   |
| Figure 13. CSRA Notional Schedule .....                      | 55   |
| Figure 14. DoD Life-Cycle Model.....                         | 59   |
| Figure 15. DoD Tailored Life-Cycle .....                     | 60   |
| Figure 16. NASA Life-Cycle Model .....                       | 61   |
| Figure 17. NASA Tailored Life-Cycle .....                    | 62   |
| Figure 18. USAF Life-Cycle Model .....                       | 63   |
| Figure 19. USAF Tailored Life-Cycle .....                    | 64   |
| Figure 20. AF MTA Life-Cycle Model .....                     | 65   |
| Figure 21. AF MTA Tailored Life-Cycle .....                  | 65   |

|                                                         | Page |
|---------------------------------------------------------|------|
| Figure 22. Complex Life-Cycle Timelines .....           | 66   |
| Figure 23. Complex Tailored Life-Cycle.....             | 69   |
| Figure 24. USAFA Life-Cycle Model .....                 | 70   |
| Figure 25. USAFA Tailored Life-Cycle .....              | 71   |
| Figure 26. USNA Life-Cycle Model .....                  | 71   |
| Figure 27. USNA Tailored Life-Cycle .....               | 72   |
| Figure 28. MIT Life-Cycle Model .....                   | 73   |
| Figure 29. MIT Tailored Life-Cycle.....                 | 73   |
| Figure 30. NPS Life-Cycle Model .....                   | 74   |
| Figure 31. NPS Tailored Life-Cycle.....                 | 74   |
| Figure 32. Aalborg University Life-Cycle Model .....    | 75   |
| Figure 33. Aalborg University Tailored Life-Cycle ..... | 75   |
| Figure 34. Luleå University Life-Cycle Model .....      | 76   |
| Figure 35. Luleå University Tailored Life-Cycle .....   | 76   |
| Figure 36. CubeSat 101 Life-Cycle Model.....            | 80   |
| Figure 37. CubeSat 101 Tailored Life-Cycle.....         | 81   |
| Figure 38. Simple Life-Cycle Timelines .....            | 81   |
| Figure 39. Simple Tailored Life-Cycle.....              | 85   |
| Figure 40. Comparing Tailored Models.....               | 85   |
| Figure 41. Final Life-Cycle.....                        | 86   |
| Figure 42. Requirements Analysis Entrance.....          | 114  |
| Figure 43. Requirements Analysis Exit .....             | 115  |

|                                |     |
|--------------------------------|-----|
| Figure 44. DD&I Exit .....     | 116 |
| Figure 45. OT&E Entrance ..... | 117 |
| Figure 46. V&V Exit.....       | 117 |

## List of Tables

|                                                     | Page |
|-----------------------------------------------------|------|
| Table 1. Standard CubeSat Limits .....              | 11   |
| Table 2. Description for ACAT I-III Programs .....  | 24   |
| Table 3. NASA Project Categorization.....           | 33   |
| Table 4. NASA Classification Considerations.....    | 34   |
| Table 5. Organizations Interviewed.....             | 41   |
| Table 6. Program Classes.....                       | 48   |
| Table 7. Life-Cycle Phase Colors .....              | 56   |
| Table 8. Complex Events by Organization .....       | 67   |
| Table 9. All Complex Events.....                    | 68   |
| Table 10. Simple Events by Organization .....       | 82   |
| Table 11. All Simple Events .....                   | 84   |
| Table 12. DoD Full Deliverables .....               | 88   |
| Table 13. DoD Tailored Deliverables .....           | 92   |
| Table 14. NASA Full Deliverables .....              | 93   |
| Table 15. NASA Tailored Deliverables.....           | 96   |
| Table 16. USAF Full Deliverables.....               | 97   |
| Table 17. USAF Tailored Deliverables .....          | 99   |
| Table 18. AF MTA Full Deliverables.....             | 100  |
| Table 19. AF MTA Tailored Deliverables.....         | 101  |
| Table 20. Complex Deliverables by Organization..... | 102  |
| Table 21. Tailored Complex Deliverables .....       | 105  |

|                                                     |     |
|-----------------------------------------------------|-----|
| Table 22. Simple Deliverables by Organization ..... | 106 |
| Table 23. All Simple Deliverables.....              | 109 |
| Table 24. Tailored Simple Deliverables .....        | 111 |
| Table 25. Final Deliverables .....                  | 112 |

# **CUBESAT DEVELOPMENT FRAMEWORK**

## **I. Introduction**

### **General Issue**

We do not yet know if space is the “final frontier” as claimed by popular cable television shows, but it is unquestionably the next and most interesting frontier. Like many universities around the globe, the Air Force Institute of Technology (AFIT) has adopted the cube satellite (CubeSat) model of small satellites as a method to teach, learn, and explore. With the goal of completing a CubeSat from start to finish within three years, AFIT’s Center for Space Research and Assurance (CSRA) needs a prescribed program management framework that can be followed from beginning to end of the development cycle.

### **Background**

The Air Force Institute of Technology “is the Air Force's graduate school of engineering and management” (AFIT, 2020). AFIT provides defense-focused graduate and doctorate level education to all branches of the military available to civilian employees, contractors, enlisted forces, and officers. The education provided is not only to better the students in attendance but is ultimately for the students to use their new knowledge to improve the Department of Defense (DoD). In paraphrasing the Dean of Students, AFIT is a military organization with a focus on education (McQuade, 2019).

One direction in which AFIT focuses the student’s education is toward expanding the understanding of space and unmanned space vehicles. The knowledge transfer can be

used to better protect the U.S. way of life, which is highly dependent on the reliability of satellites in an unmanned and uncontested environment. The Department of Aeronautics and Astronautics provides education in aeronautical engineering, astronautical engineering, materials science, and space systems. Prior to the establishment of the Center for Space Research and Assurance in 2012, AFIT students designed, built, and tested the Rigidizable Inflatable Get-Away-Special Experiment (RIGIX) that was further tested on the Space Shuttle Endeavour in 2008. Since forming, CSRA produced AFIT Low Earth Orbit (LEO) Integrated Miniaturized Electrostatic Analyzer (iMESA) Carbon Nano-Tube (CNT) Experiment (ALICE) which launched in 2013, Space Object Self-Tracker (SOS) in 2019, and SkyPad was a payload as part of the U.S. Air Force Academy's (USAFA) FalconSat-8 in 2020. Recently, CSRA has started developing a CubeSat model that will act as a standard satellite bus able to be configured to support a multitude of payloads depending on specific mission requirements (Knapp, 2020).

As described in the *CubeSat Design Specification* (CDS), a CubeSat is a standardized small satellite design that was first developed at California Polytechnic State University (Cal Poly) and Stanford University in 1999. The standardization aspect is in terms of size and weight dimensions. The one-unit CubeSat, known as a 1U, is a 10 cm by 10 cm by 10 cm cube with a mass up to 1.33 kg. This is the building block for larger CubeSats ranging from 2U at 20 cm x 10 cm x 10 cm to 27U at 30 cm x 30 cm x 30 cm. Standardizing the small satellite reduces cost and development time in various ways including using commercial off-the-shelf (COTS) parts instead of custom-built components and easier integration to a launch vehicle. These aspects plus others make it a much more appealing option for schools and independent enthusiasts (Nugent, 2018).

Since this standardized model was first developed, over 1,100 CubeSats have been built globally and launched into low earth orbit (LEO). Of these, at least 94 were developed and operated by the military and 339 from universities (CubeSat, 2020). The popularity to design and build these satellites has expanded from universities around the world and amateur space enthusiasts to government agencies, commercial industries, and even academia as early as elementary schools.

### **Problem Statement**

With five satellite builds under their belt, CSRA is still in need of a product developmental framework for current and future CubeSat builds. Although AFIT is an educational organization, the school is still in the dominion of the DoD and as such, the degree to which AFIT should follow applicable guides and instructions when designing and developing new hardware for military usage is uncertain. The published DoD system engineering and acquisition guidance was not written for an educational platform scenario and to follow a typical program management track would overburden students and staff with so many requirements that the focus on learning would be lost.

### **Research Objectives/Questions**

This thesis intends to identify a project management approach to space flight-system development that is most appropriate for CubeSat development by CSRA. The objective is to define a CubeSat development model that allows CSRA to produce operational CubeSats within three years from start to finish while fostering student research and participation. The model will be based on DoD acquisition regulations and other applicable guidance. Other guidance includes procedural guidance from the

National Aeronautics and Space Administration (NASA) and best practices identified by universities with similar academia goals.

The Center for Space Research and Assurance's CubeSat program can relate and look to NASA and other universities for guidance, but DoD policy would take precedence. Fortunately, the DoD acquisition processes allow and encourage modification of each program's developmental processes. This research will assess the various project management approaches to determine which may best be suited for CSRA.

### **Research Focus**

This research focuses on regulations, publications, and guidance produced by the DoD, NASA, academic institutions, and commercial entities relating to small satellite program management. In addition, articles concerning CubeSat successes and failures are analyzed for common themes that can be applied to CSRA's development process. These references serve as a means to identify plans and practices that could be used for CubeSats developed by CSRA.

### **Investigative Questions**

In order to define a developmental framework for CSRA, the following questions are posed:

1. What DoD acquisition regulations or other published guidance does CSRA's CubeSat development cycle need to comply with?

2. What developmental reviews, timelines, and documentation exist within other CubeSat developing universities and/or comparable organizations that may be implemented in CSRA?
3. What entrance/exit criteria should be followed for each of the major program reviews for the CSRA CubeSat program?

## **Methodology**

The program management details from the reviewed publications, articles, regulations, and guidance were captured in a matrix for assessment. In order to compare and contrast the different program management types, the frameworks were split into life-cycle, deliverables, and entrance/exit criteria. The life-cycles and deliverables were further divided by the complexity of the program.

The different phases, events, and reviews of each life-cycle are modeled using the visual mapping strategy (VMS) to easier recognize where the different processes overlap and where they differ. Then the required deliverables of each framework are charted and organized to identify parallels between all organizations within similar complexities. After revealing excess steps and documentation, the life-cycles and list of deliverables are tailored to meet the needs of CSRA. Once these are tailored, appropriate entrance/exit criteria are applied based on the reviewed publications.

## **Assumptions/Limitations**

This research is completed with the assumption that staffing levels and budget are not a limiting factor. Staff on hand is anticipated to remain constant while the number of students may vary year to year, but the overall impact to the development cycle is

negligible. While this research aims to limit developmental time, it does not measure cost savings or focus on the budget.

Risk mitigation is a large part of project management, but the specifics to risk identification and reduction are not addressed. It is assumed that CSRA will maintain a robust risk management plan. Furthermore, CSRA currently uses model-based systems engineering (MBSE) when identifying system requirements and tracing them to design plans. This research does not address means of accomplishing these tasks as it is assumed the current standard will be maintained.

## **Implications**

This research results in a comprehensive CubeSat developmental framework that can be utilized by CSRA to plan and monitor progress when designing and assembling CubeSats. Better program management eliminates wasted time and efforts. If CSRA finds this model to be highly valuable, it may be shared with other institutions who are developing or are looking to start developing CubeSats as part of their curriculum.

On a much larger and more optimistic scale, the DoD may realize the benefit of CubeSats for testing incremental technology upgrades and use this model as a foundation for an officially sanctioned framework. By launching more small satellites (SmallSat) at a quicker rate, the warfighter receives the support needed without waiting for an overly complicated satellite that launched behind schedule and over-budget. Since a CubeSat's mission life is relatively short, advancements and upgrades can be made to the replacement as shortfalls are identified; this is unlike the current process since large satellites cannot be modified with the exception to software once they launch.

## **Preview**

This chapter has outlined the objectives and motivation for this thesis. Chapter II describes the processes that are followed by other organizations when developing their satellites and the official acquisition procedures required by the DoD. Chapter III reviews the methods that are used to analyze the quantitative data that is gathered. Chapter IV analyzes the different development models and tailors a model specifically for CSRA's use. The conclusion identifies the potential impacts of this research and suggests future research that can be conducted to improve upon it.

## II. Literature Review

### Chapter Overview

The purpose of this chapter is to better familiarize the reader with CubeSats by reviewing its development and expansion into the academia. It will also detail the various system development methodologies used by the Department of Defense (DoD), National Aeronautics and Space Administration (NASA), universities from around the world, and commercial entities.

### Important Terms

Many of the terms used in the following methodologies are produced by different organizations and are used to express similar concepts. To provide clear context, the following definitions are provided up front:

Acquisition –

- Per Air Force Pamphlet (AFPAM) 63-128: The conceptualization, initiation, design, development, testing, contracting, production, deployment, and disposal of a directed and funded effort that provides a new, improved, or continued materiel, weapon, information system, logistics support, or service capability in response to an approved need (Department, 2014g).
- Per NASA Procedural Requirements (NPR) 7120.5E: The process for obtaining the systems, research, services, construction, and supplies that NASA needs to fulfill its missions (NASA, 2012e).
- Per *Space and Missile Systems Center (SMC) Primer & Handbook*: Within the DoD, an approved and funded activity that defines the skill and manpower levels for the people, develops and produces the products, and develops the processes that make up a system (Department, 2013j).
- As used in this research: The process of conceptualizing, designing, developing, fabricating, testing, and deploying systems to fulfil identified needs.

Framework –

- Per AFPAM 63-128: The overarching management structure that integrates across multiple dimensions, systems, portfolios, and management levels in order to effectively influence and execute life-cycle decisions in response to capability shortfalls (Department, 2014g).

#### Program –

- Per AFPAM 63-128: Systems, subsystems, end items, services, or activities on the AF Acquisition Master List (AML), weapon or business system in sustainment, weapon systems designated in AFD 10-9 (Lead Command Designation and Responsibilities for Weapon Systems), or identified as Services Category activities (Department, 2014g).
- Per NPR 7120.5E: A strategic investment by a Mission Directorate or Mission Support Office that has a defined architecture and/or technical approach, requirements, funding level, and management structure that initiates and directs one or more projects (NASA, 2012e).
- As used in this research: The deliberate investment of resources into a system that has defined requirements, funding, and management.

#### Tailoring –

- Per SMC Primer & Handbook: The process by which sections, paragraphs, and sentences of specifications, standards, and other requirements or tasking documents are evaluated to determine the extent to which they are applicable to a specific acquisition contract and then modified to balance performance, cost, schedule, and risk (Department, 2013i).
- Per NPR 7120.5E: The process used to adjust or seek relief from a prescribed requirement to accommodate the needs of a specific task or activity (NASA, 2012e).
- As used in this research: The process of modifying the requirements of a prescribed framework to balance schedule, cost, risk, and performance to the individual system under development.

### **CubeSat Background**

In 1999, Professor Jordi Puig-Suari from California Polytechnic State University (Cal Poly) and Professor Bob Twiggs from Stanford University set out to develop a standardized small satellite design that could be used for many mission types. The end result was a cube-based satellite (i.e., CubeSat) that would significantly change how

satellite development would be taught around the world. Having a standard design would reduce both development time and component costs while increasing the likelihood of mission success, thereby making the CubeSat ideal for educational institutes. Since this standardization, CubeSats have not only been designed at universities around the world, but also at high schools, middle schools, and even some elementary schools (Nugent, 2018). This design standardization has also increased space exploration at non-educational institutions as government and commercial agencies can conduct more investigative research quicker and cheaper than before.

In its most basic form, a 1U CubeSat, shown in Figure 1, is 10 cm x 10 cm x 10 cm with a mass of 1.33 kg or less and is the building block for all other CubeSats. Depending on the mission requirements, larger CubeSats may be needed to house the satellite's payload. To maintain standardization, the sizes and weights are limited (Nugent, 2018). Based on the standard 1U, some of the different sized CubeSat options are presented in Table 1.



Figure 1. 1U CubeSat (Chin, 2017)

Table 1. Standard CubeSat Limits (Nugent, 2018)

| CubeSat | Size (cm)    | Mass (kg) |
|---------|--------------|-----------|
| 1U      | 10 x 10 x 10 | 1.33      |
| 2U      | 20 x 10 x 10 | 2.66      |
| 3U      | 30 x 10 x 10 | 4         |
| 6U      | 30 x 20 x 10 | 12        |
| 12U     | 30 x 20 x 20 | 24        |
| 18U     | 30 x 30 x 20 | 36        |
| 27U     | 30 x 30 x 30 | 54        |

As part of the standardization, a CubeSat dispenser system was created to act as the interface between the CubeSat and the launch vehicle that would deliver the small satellite into orbit. This Poly Picosatellite Orbital Deployer (P-POD) greatly reduces the amount of planning that needs to go into satellite design because the CubeSat only needs to follow the dispenser requirements, thus ensuring it fits and will exit smoothly. Previously, satellite developers had to customize the mounting hardware depending on the launch vehicle which may not even be known until far into the development cycle. Even as the P-POD is improved, the internal dimensions will not change so developers do not have to update their designs (Chin, 2017).

To ensure CubeSats remain standardized, Cal Poly produced the *CubeSat Design Specifications (CDS)*, which details size, mass, and dimensions. The CDS also specifies mechanical, electrical, and operational requirements along with necessary testing. Following this guide ensures a CubeSat will fit and launch from a P-POD without causing any harm to the launch vehicle (Coelho, 2014).

The standardization led to the CubeSat's initial expansion in universities from 2002 to 2009. By 2010, CubeSats had become common in both academia and the small

satellite world (Swartwout, 2018). Additionally, this growth resulted in the commercial market recognizing an opportunity to produce components designed around the CubeSat specifications. As the commercial off-the-shelf (COTS) market grew, competition drove prices down and CubeSats became cheaper and easier to develop as most satellite bus components could be purchased instead of built. By assembling the bus with COTS parts, developers can focus more attention on the payload.

Researchers found through surveys that student interest in space grew due to the interest in opportunities to innovate, experiment, and get practical experience of building space vehicles; thus, many universities use CubeSats to introduce students to new concepts in exciting and practical ways (Berthoud, 2019). By 2018, 168 schools from 47 countries had built university-class satellites (Swartwout, 2018). To distinguish student led satellite builds from all others, experts in the field designated the term university-class to satellites that meet three requirements (Swartwout, 2018):

1. The build is a fully functional spacecraft; not just a payload attached to a satellite.
2. Students performed a significant portion of the key design decisions.
3. The mission did not overshadow the student's education or training.

As shown in Figure 2, satellite development in universities had grown so much that of the 344 university-class satellites launched between 1994 and 2017, 67% of them were after 2010. Of the 231 satellites launched after the CubeSat expansion of 2002-2009, 75% of those launched after 2010 were CubeSats (Swartwout, 2018).

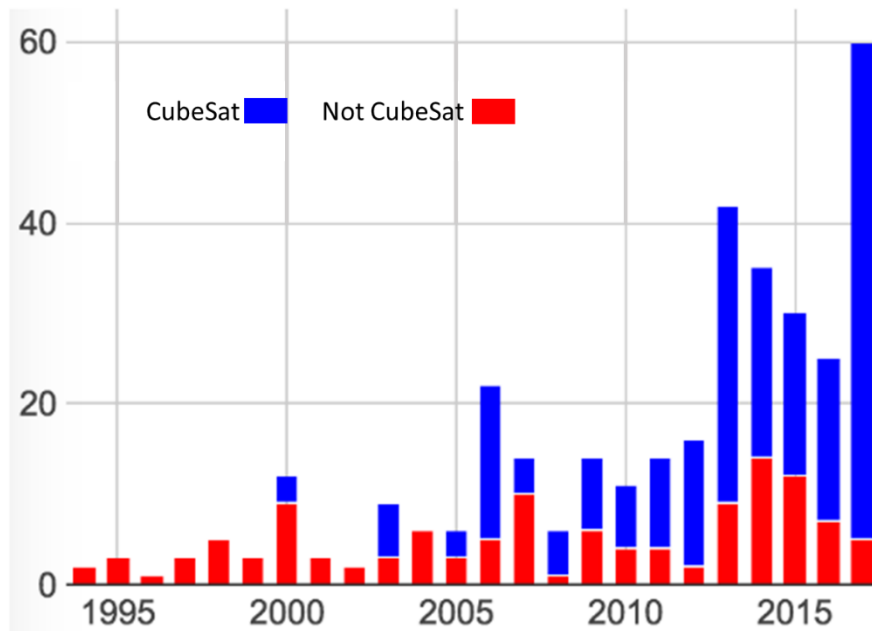


Figure 2. University-Class Mission by Form Factor (Swartwout, 2018)

While university-class satellite development rates grew though, the overall success rates have steadily dropped. Many experts agree that a failure rate of 10-25% is acceptable for university-class missions. Prior to the CubeSat expansion, 56% of the missions executed between 1994 and 2001 achieved full mission success. From 2002 to 2009, the success rate had dropped to 29% and then fell to 13% between 2010 to 2017 (Swartwout, 2018). The specific nature of failures (e.g., partial mission success, early loss, and dead-on-arrival (DOA)) for these same time periods are illustrated in Figure 3.

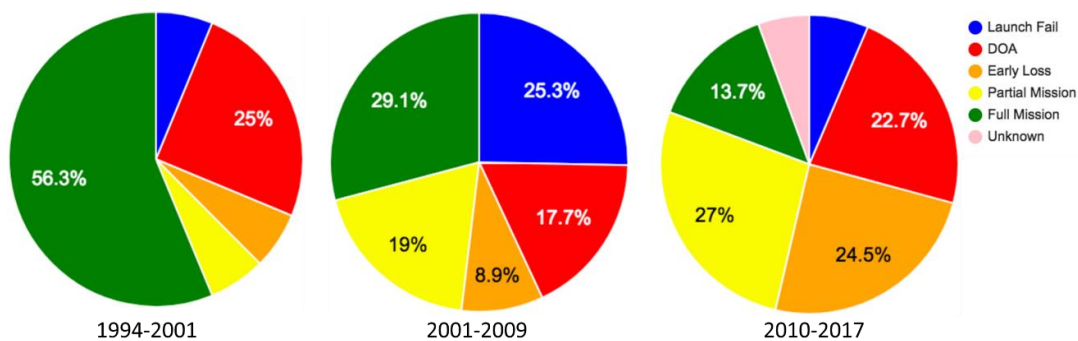


Figure 3. Mission Status for University-Class Missions (Swartwout, 2018)

Subject experts suggest that the greatest contribution to the increasing mission failure rate is from universities developing their first satellite (Swartwout, 2018). For CubeSat development to grow, more universities must start building CubeSats. At one point, every university launched their first satellite so it makes sense that success rates would drop as many unexperienced developers launch their first CubeSat. Through the survey process, a theme among universities was identified with respect to issues relating to student led satellite builds. Common problems involved maintaining student participation; students had too many other responsibilities and the effort required for the satellite development was beyond the credit that would be earned from the related classes (Nieto-Peroy, 2019). Additional problems were from the lack of documentation that students maintained and the constant student turnover. Student turnover every year was a loss of continuity which severely slowed the development timeline. This continuity loss was even worse if the outgoing students also failed to maintain proper design documentation (Faure, 2020).

### **University Guidance/Procedures**

CubeSats have been developed by at least 168 schools from 47 countries; from these efforts, several surveys have been conducted to study the development process (Swartwout, 2018). One such study was conducted by Dr. Straub at the University of North Dakota to find if there is a positive or negative correlation between the duration of time a student spends on a small spacecraft program and the level of benefits received by the students. Benefits were measured by technical skills, design skills, presentation skills, and presentation comfort of the participants. Participants were a mix of undergraduate

and graduate students. The study was conducted to determine the ideal duration of participation to maximize a student's benefit.

Overall, the survey concluded there was minimal correlation between the number of semesters spent on the program and the benefits reportedly received by the student participants. When the data was sorted by undergraduate and graduate level students, it revealed greater correlation between graduate students and the number of semesters involved than it did with undergraduates. The presence of this correlation suggests there is value to longer durations of student participation. No other relevant correlations were found by the study (Straub, 2014)

In 2016, Berthoud surveyed 40 universities for guidance on establishing a CubeSat program; these surveys addressed issues such as planning, learning from other groups who had previously setup a similar program, student continuity, the importance of documentation and project management, integrating the project with curriculum, design simplicity, and testing. The survey results unanimously suggested keeping the CubeSat design simple by only focusing on a single payload. They also advocated for early integration and heavy amounts of testing (Berthoud, 2016).

In 2019, Dr. Berthoud then focused her attention on the programs of Aalborg University in Denmark, Montana State University, and the University of Michigan which had each launched at least four satellites. First, the program goal at Aalborg University is for students to become better engineers. Thus, the projects are always limited to a 1U for simplicity with the intent of finishing within two years. Students start the project during the second year of their undergraduate program and own the project since it is considered extra-curricular. The students make all the major decisions and have access to their own

workspace in the lab. The design and development reviews are unstructured without mandatory standards and no specified documentation requirements.

Conversely, the satellite program at the Montana State University is managed quite differently where a group of 3-30 students ranging from undergraduate to PhD work together with staff engineers to complete a build in 2-3 years (Berthoud, 2019). The students are required to maintain strict documentation and hold several mandatory reviews. The group is not allowed to proceed to the lab to start any implementation until all interface documents have been approved by staff. The program is only complete after extensive testing has occurred.

Lastly, at the University of Michigan, a full-time staff leads a team of students through their two-year satellite development program. The undergraduate, graduate, and PhD students start as volunteers with little accountability and eventually shift into roles with more responsibility once they show commitment and capability since the program is not linked to class credits. The day-to-day operations are led by two graduate students. At the end of each semester, the team generates a report to capture the major concepts, plans, and progress made in the laboratory (Berthoud, 2019).

Similarly, in 2019, North Dakota State University (NDSU) surveyed universities – who had recently launched CubeSats – about issues observed during their CubeSat development, build, and test (Alanazi, 2019). When focusing on unsuccessful missions, the survey identified seven areas that NDSU felt were important to mission success. The survey responses did not provide any data for the seven areas of concern that were found to be statistically significant.

The surveys provided insight to the fact that universities who used reference models had higher success ratings than those that did not. A key to reaching mission success is first identifying the mission objectives. Once objectives are known, models can be designed to meet the specific objectives. Additionally, models allow thoughts and ideas to be recorded and changes to be tracked. The model can include project scope, goals, methodology, and standards which may never otherwise be discussed among students (Alanazi, 2019). Modeling is key with university projects as the students who start the CubeSat may not be the ones to finish.

Some universities have demonstrated such success with CubeSats that students and have authored articles to describe their developmental program. Respectively, the professors at the Massachusetts Institute of Technology (MIT) formulated the Conceiving-Designing-Implementing-Operating (CDIO) model in the 1990s in order to improve students design, teamwork, leadership, and communication skills. The CDIO paradigm is implemented in their CubeSat program over three semesters where students receive hands-on learning. During this timeframe, students are taught concept generation, requirement definition, and initial design before they get to focus on design refinement, hands-on laboratory work, assembly and integration, and testing. By the end of the third semester, students should have a fully built and tested small satellite (Smith, 2011). The program details are further defined in Chapter IV.

Civilian universities are not the only academic institutions interested in space and satellite design. Four of the U.S. military academies have engaged in small satellite development. The Naval Academy, Air Force Academy, Coast Guard Academy, and Military Academy offer a series of courses that ultimately provide cadets the opportunity

to design, test, and build small satellites during a capstone project during their senior year. Each academy has a different process on how this is accomplished with some overlapping similarities. The Naval Academy Small Satellite Program (NASSP) focuses more efforts on the individual student's satellite development than the other three who have all students working together on a more significant satellite build that spans several years.

NASSP follows a modified CDIO model that allows students to conceptualize, design, build, and test a working CubeSat. NASSP has students operate previous student-built satellites that are currently in orbit prior to any new satellite design. The purpose of using their Operating-Conceiving-Designing-Implementing educational framework is to expose the students to every step of the engineering process and get hands-on experience. Over the course of their senior year, cadets start their satellite experience by building a standard bus while learning about the space environment and operations through a series of lectures. By the time they finish the bus, they have a better understanding of space and can select a payload with which they want to work. The students focus their payload research and design based on options provided. Many of the options are incremental changes from what previous students had worked on and need advancement. On average, of the four to five builds that were started, only one will be completed and ready to launch. Most of the CubeSats that do make it to launch happen after the students have graduated because of the nature of getting a small satellite on a launch vehicle (Kang, 2020). Additional details regarding program management are found in Chapter IV.

Within the Air Force Academy's Space Systems Research Center (SSRC), cadets also get to design, build, test, and launch CubeSats. Following prerequisite courses on

satellite design, space environment, operations, etc., students are provided experiential, hands-on learning opportunities with the latest space technology. Once they have the required knowledge, students enter their senior capstone project titled FalconSAT where they get to work on a satellite that will conduct DoD space missions fulfilling the Astronautics Department's motto, "learning space by doing space." The FalconSAT program is sponsored by the Air Force Research Laboratory (AFRL) and is focused on cadet education while achieving real DoD objectives (FalconSAT, 2009).

While the students are taught all the steps of the design, build, test, and operations processes, their hands-on experience depends on the status of the satellite. The previous builds have taken two to four years so several classes will get to participate in specific projects or milestones required to progress the development. The procedural schedule is based on notional launch date. They plan backwards on identifying when specific milestones should be completed before pressing to the next set of procedures. At the end of every semester, students brief senior leadership on the status of the satellite. These presentations focus on the status of components under test and/or the satellite integration instead of acting as official reviews.

This program has been around for several years already, so SSRC has sent eight satellites into orbit (FalconSat-1 in 2000, FalconSat-2 in 2006, FalconSat-3 in 2007, FalconSat-5 in 10, FalconSat-6 in 2018, FalconSat-ODE in 2019, FalconSat-7 in 2019, FalconSat-8 in 2020) with several still operational and FalconSat-X expected to launch in 2022 (Cohen, 2020). The operational satellites provide students with a chance to conduct real space operations since it is also very likely they will graduate before their satellite is launched (Showalter, 2020). Program management is explored in Chapter IV.

The U.S. Military Academy (USMA) at West Point started their first CubeSat, Black Knight 1, in 2010 and launched in 2013. This 1U was a cadet collaboration effort by the Electrical Engineering, Computer Science, Mechanical Engineering, Systems Engineering, and Physics Departments. Black Knight II was started to increase cadet interest in space but ultimately dropped off with staff turnover (Galliand, 2020). In 2016, the USMA began offering space courses while considering establishing a space program. Cadets showed enough interest that a space science major was initiated in 2017 with the first graduate in 2020 (Cutshaw, 2017).

With renewed cadet interest, Black Knight III is under development as the cadets' capstone project. They are currently working on developing a software system to run the bus and communicate with the payloads. The program started from scratch, so they are several years from launch. Since the reinvigorated program is still new, a program management plan has not been established but cadets have briefed a Preliminary Design Review (PDR) and Critical Design Review (CDR) on their software design (Eckstein, 2021). The future of this program is uncertain due to budget constraints.

As the latest to join in small satellite development, the U.S. Coast Guard Academy (USCGA) launched two 2U CubeSats and installed a mobile CubeSat command and control (MC3) in 2018 (James, 2020b). Most of the work on the 2Us were contracted outside of the academy, but they have started a space program which is still evolving. The cadet's academic schedule is similar to the other academies in that they have several prerequisite courses prior to a capstone during their senior year. In 2019, with the assistance of the USNA, the cadets completed the build of three smaller satellites referred to as ThinSats (James, 2020c).

The USCGA plans to have a fully functional space program, but at this point there is no program management in place. The program is still very new and only consists of three staff and nine students, but they do hold regular meetings. The cadets provide project updates to the staff every week and three larger reviews during their year with a major capstone review at the conclusion of the program. Since the build is not completed in one year, the capstone review focuses on what the cadets completed during their tenure. Cadets are encouraged to document everything, but the only formal documentation is the deliverables requested by the launch vehicle provider (James, 2021a).

The Naval Postgraduate School (NPS) started providing students with hands-on satellite experience before the CubeSat was introduced. In 2008, NPS started work on their first CubeSat mission, the Naval Postgraduate School Solar Cell Array Tester (NPS-SCAT). In addition to executing a successful mission, the goal of this project was to gain experience in CubeSat design, construction, deployment, and operations. NPS intended to use this 1U satellite as their baseline design for future CubeSats, hoping it could shorten future development life-cycles down to under two years (Helker, 2014).

The student workforce in the TINYScope mission – 6U by NPS – placed individual students in charge of designing, constructing, and testing individual subsystems of the CubeSat. Another student was responsible for the program management which was a struggle because NPS had not garnered much CubeSat experience yet and satellite design was also new to the students. The program manager quickly learned to account for unexpected delays in the schedule. As with most projects at NPS, the team scheduled five major reviews: Mission Requirements Review (MRR),

PDR, CDR, Flight Readiness Review (FRR), and Operation Readiness Review (ORR) (Turner, 2010).

### **DoD Program Management & System Engineering**

The Department of Defense decision support system is comprised of the Joint Capabilities Integration and Development System (JCIDS); Planning, Programming, Budgeting, and Execution (PPBE) process; and the Defense Acquisition System (DAS). JCIDS is the systematic method used to identify, assess, validate, and prioritize joint military capability requirements. The policies and procedures for identifying capability gaps are found in the *Chairman of the Joint Chiefs of Staff (CJCS) Instruction 3170.01*. The PPBE process is used to create resource allocation plans to meet the needs of the National Security Strategy (NSS) (Program, 2019). The DAS manages the U.S.'s endeavors in technology, programs, and product support to maintain security by improving and acquiring products that support the armed forces. Procedures that the DoD comply with to achieve mission objectives are described in DoD Directive (DoDD) 5000.01: *The Defense Acquisition System*, which provides the overarching management principles and policies, and the DoD Instruction (DoDI) 5000.02T: *Operation of the Defense Acquisition System*, which details procedures through the statutory and regulatory requirements (Forward, 2020).

All the publications that comprise the JCIDS, PPBE, and DAS were studied for any acquisition or developmental processes that apply to academia. While these instruction documents provide details to several scenarios, they do not directly specify what is applicable within an academic environment. Because of this, further research was

needed to piece together a feasible approach. The DAS consists of many procedures, documents, and oversight techniques used to develop new hardware and software but not all are necessary depending on the characteristics of the mission gap. The procedures used should be selected and tailored based on the program's urgency, risk factors, and affordability. Major Defense Acquisition Programs (MDAP) and Major Automated Information Systems (MAIS) require the highest level of investment and as such have the most extensive reporting requirement. These program level procedures are listed in the DoDI 5000.02T for Acquisition Category (ACAT) I and ACAT IA. ACATs are sorted by dollar thresholds so programs requiring less extensive procedures fall under ACAT II or ACAT III. The four categories determine the level of review, decision authority, and regulatory and statutory procedures (Department, 2020b). The ACAT designation can be assigned based on Table 2. Based on the ACAT descriptions, CSRA's CubeSat projects classify as ACAT III. This decision is based on the relatively low life-cycle cost of the CubeSats. The remainder of this research will be geared toward ACAT III programs.

Table 2. Description for ACAT I-III Programs (Department, 2020b)

| ACAT                          | Reason for ACAT Designation                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | Decision Authority                                                                                        |
|-------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|
| <b>ACAT I</b>                 | <ul style="list-style-type: none"> <li>MDAP (10 U.S.C. 2430 (Reference (h))) <ul style="list-style-type: none"> <li>Dollar value for all increments of the program: estimated by the DAE to require an eventual total expenditure for research, development, and test and evaluation (RDT&amp;E) of more than \$480 million in Fiscal Year (FY) 2014 constant dollars or, for procurement, of more than \$2.79 billion in FY 2014 constant dollars</li> <li>MDA designation</li> </ul> </li> <li>MDA designation as special interest<sup>1</sup></li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                | <p>ACAT ID: DAE or as delegated</p> <p>ACAT IC: Head of the DoD Component or, if delegated, the CAE</p>   |
| <b>ACAT IA<sup>2, 3</sup></b> | <ul style="list-style-type: none"> <li>MAIS (10 U.S.C. 2445a (Reference (h))): A DoD acquisition program for an Automated Information System<sup>4</sup> (AIS) (either as a product or a service<sup>5</sup>) that is either: <ul style="list-style-type: none"> <li>Designated by the MDA as a MAIS program; or</li> <li>Estimated to exceed: <ul style="list-style-type: none"> <li>\$40 million in FY 2014 constant dollars for all expenditures, for all increments, regardless of the appropriation or fund source, directly related to the AIS definition, design, development, deployment, and sustainment, and incurred in any single fiscal year; or</li> <li>\$165 million in FY 2014 constant dollars for all expenditures, for all increments, regardless of the appropriation or fund source, directly related to the AIS definition, design, development, and deployment, and incurred from the beginning of the Materiel Solution Analysis Phase through deployment at all sites; or</li> <li>\$520 million in FY 2014 constant dollars for all expenditures, for all increments, regardless of the appropriation or fund source, directly related to the AIS definition, design, development, deployment, operations and maintenance, and incurred from the beginning of the Materiel Solution Analysis Phase through sustainment for the estimated useful life of the system.</li> </ul> </li> </ul> </li> <li>MDA designation as special interest<sup>1</sup></li> </ul> | <p>ACAT IAM: DAE or as delegated</p> <p>ACAT IAC: Head of the DoD Component or, if delegated, the CAE</p> |
| <b>ACAT II</b>                | <ul style="list-style-type: none"> <li>Does not meet criteria for ACAT I or IA</li> <li>Major system (10 U.S.C. 2302d (Reference (h))) <ul style="list-style-type: none"> <li>Dollar value: estimated by the DoD Component head to require an eventual total expenditure for RDT&amp;E of more than \$185 million in FY 2014 constant dollars, or for procurement of more than \$835 million in FY 2014 constant dollars</li> <li>MDA designation<sup>5</sup> (10 U.S.C. 2302 (Reference (h)))</li> </ul> </li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | CAE or the individual designated by the CAE <sup>6</sup>                                                  |
| <b>ACAT III</b>               | <ul style="list-style-type: none"> <li>Does not meet criteria for ACAT II or above</li> <li>An AIS program that is not a MAIS program</li> </ul>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | Designated by the CAE <sup>6</sup>                                                                        |

To further direct this research, the most appropriate Adaptive Acquisition Framework (AAF) pathway needs to be identified. The six pathways shown in Figure 4 are general roadmaps for the different types of acquisition within the DoD. Each pathway is tailored to the urgency and dominant characteristics of the product or service being developed which will be further discussed later.

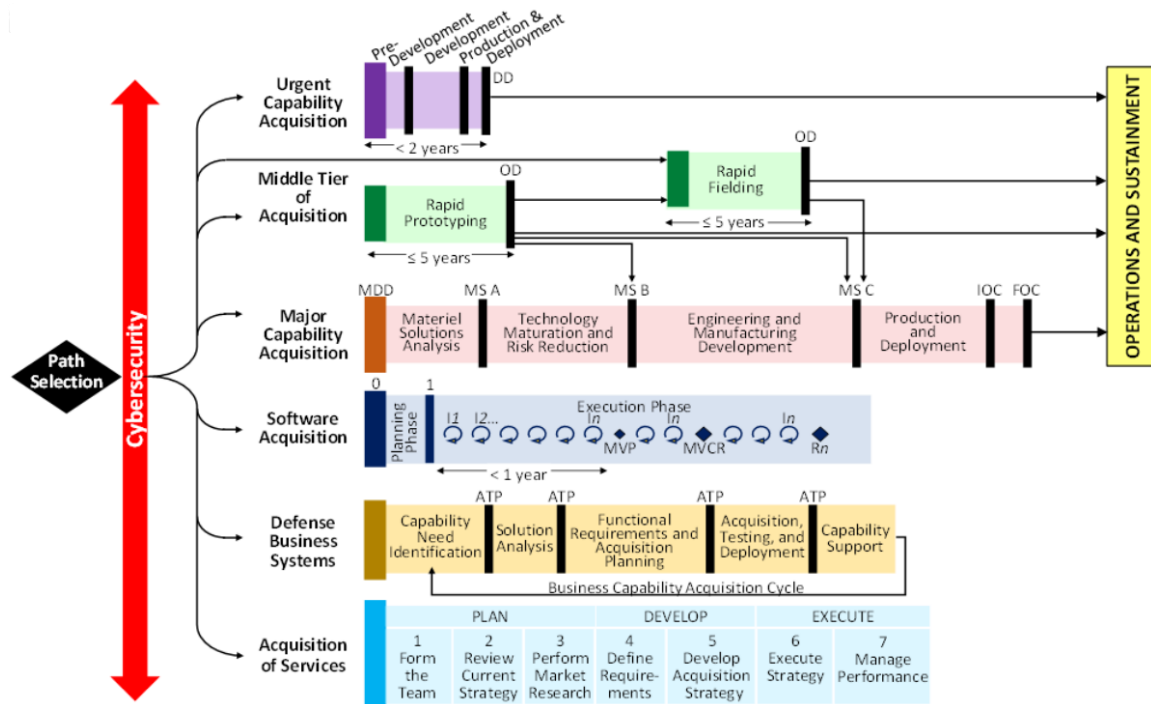


Figure 4. AAF Pathways (Department, 2020a)

The Urgent Capability Acquisition pathway is used to fill an urgent operational need in less than two years. Middle Tier of Acquisition (MTA) is for rapidly developing fieldable prototypes to demonstrate new capabilities or for rapidly producing systems with high levels of technology maturity. A Major Capability Acquisition is that which is most familiar to folks as the means of acquiring military unique programs. The Software Acquisition pathway is in place for rapid and iterative delivery of software capabilities. The Defense Business Systems (DBS) path is used when modifying a commercial or supporting business system to meet the needs of the DoD. The Defense Acquisition of Services pathway is used to obtain services from the private sector such as medical, transportation, and logistics (Department, 2020a)

Although the Urgent Capability pathway is quick, the CubeSat program is not an urgent operational need. Software programming is involved with each project, but it is not

the primary objective so the Software pathway will not be used. The DBS and Acquisition of Services pathways are not appropriate either so this research will further exam the MTA and Major Capability Acquisition pathways.

The Major Capability Acquisition pathway depicted above is a very generic representation of the process. This pathway consists of four phases: Material Solution Analysis (MSA), Technology Maturation & Risk Reduction (TMRR), Engineering & Manufacturing Development (EMD), and Production & Deployment (P&D). Each of these phases are separated by Milestones, which are decision reviews to carefully assess a program's readiness to proceed to the next phase by analyzing the program's status (Department, 2020b). There are many other reviews and important events that occur within each phase along with associated deliverables that will be further examined in Chapter IV.

The phases, events, and reviews of any acquisition life-cycle should be tailored to meet the unique characteristics and risks of any program or project. The DoDI 5000.02T provides six program models that have adjusted the phases and reviews based on the dominant trait of the program. The models are Hardware-intensive program, Defense-unique software-intensive program, Incrementally deployed software-intensive program, Accelerated acquisition program, Hardware-dominant hybrid program, and Software-dominant hybrid program. Since CSRA's CubeSat completion goal is shorter than the standard DoD life-cycle, the accelerated model in Figure 5 is the best fit.

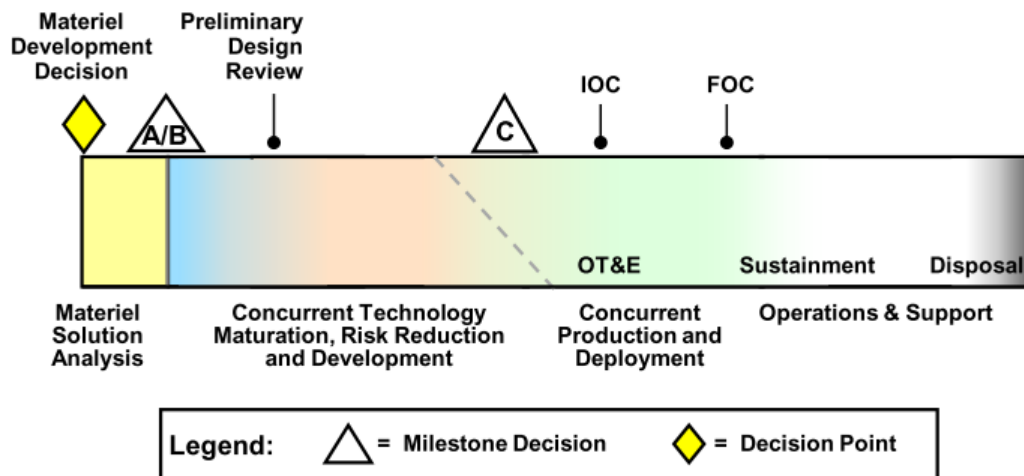


Figure 5. Accelerated Acquisition Model (Department, 2020b)

The Air Force added to the acquisition process with Air Force Instruction (AFI) 63-101: *Integrated Life Cycle Management* and AFPAM 63-128: *Integrated Life Cycle Management*. AFI 63-101 is applicable to all programs listed on the Air Force Acquisition Master List (AML), which monitors the progress of all Air Force programs. These programs still must comply with the statutes identified in DoDI 5000.02T as the AFI only adds to it instead of removing or changing procedures pathway (Department, 2020f).

The *Space and Missile Systems Center (SMC) Systems Engineering Primer and Handbook* focuses on the acquisition of large DoD systems, especially space, from the system engineer perspective. “Three major differences that make space systems unique and set them apart from a non-space system are: the space environment, unattended operation, and the implications of the ultimate high ground” (Department, 2013i: 3). To compensate for the space environment and unattended operations, the systems engineering approach was designed with multiple loops, thus allowing the program to

circle back and make changes when necessary. The system engineering process and associated loops are depicted in Figure 6.

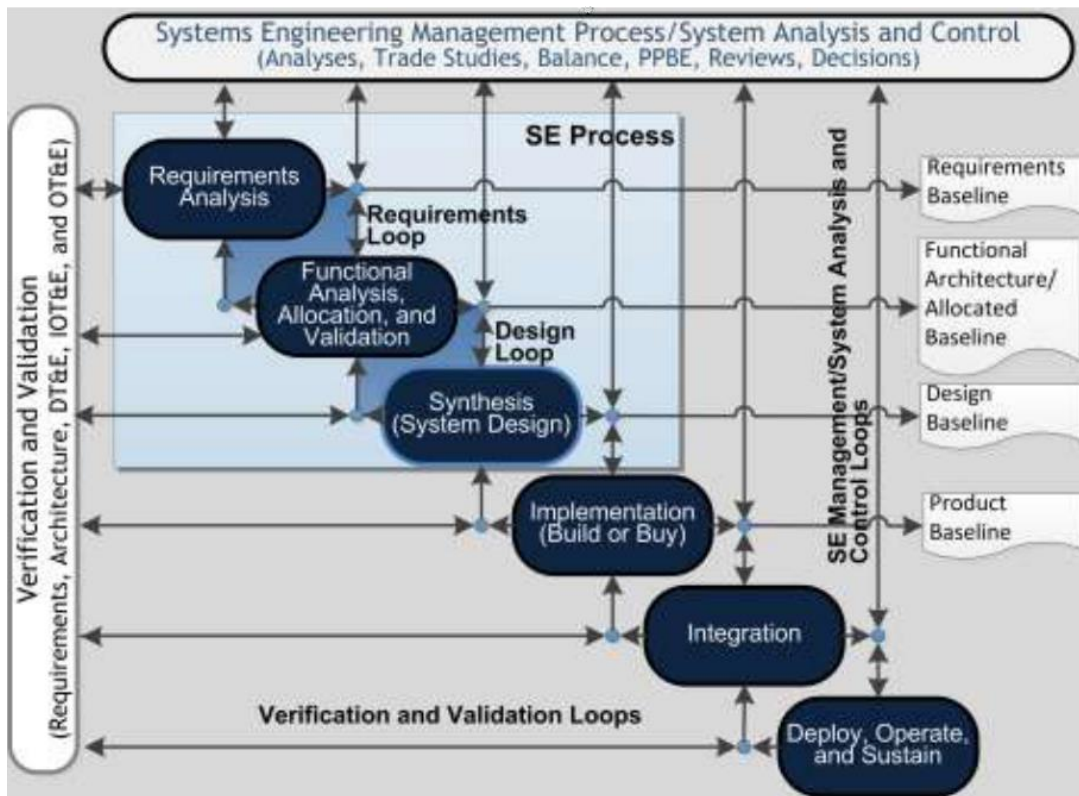


Figure 6. System Engineering Process (Department, 2013i)

As with other framework models, the first step is requirements analysis. The mission gap is broken down into functional and performance requirements that need to be met. The phase ends with documenting performance, functional, architectural, and dependability requirements as the Requirements Baseline. The Functional Analysis, Allocation, and Validation phase defines the functional areas, sequences, and interfaces of the requirements previously identified. The analysis creates the hierarchy system of functional requirements that can be traced from described requirements to the lower-level functions. The phase produces the Functional Architecture Baseline and the Allocated

Baseline. These baselines show requirements traceability to system parts and describes system assembly and interfaces. The Allocated Baseline is established at the PDR.

The Design Solution takes the functional architectures that were developed to meet requirements and translates them into physical architectures including hardware and software. This phase produces the design baseline which gives the build-to technical package used for actual construction. The design baseline is assessed at the CDR. Once ready to move forward with the design, the components are either produced or purchased during the Implementation phase. Once all components are acquired, verified, and validated, they can be assembled and integrated to form the final system in the Integration phase. Even though verification and validation are regularly ongoing, a final assessment is completed once the system is fully assembled to ensure the product meets the requirements and accomplishes the function it was meant to (Department, 2013i).

No matter how a life-cycle is tailored, it is important that a project does not proceed past major reviews or milestones without reaching the appropriate technology readiness level (TRL). TRL metrics are a systematic method adopted by the DoD to measure technology maturity. In a comprehensive review of how maturity assessments were completed for defense acquisitions, Dr. Azizian found that many programs are progressing through phases without meeting the required TRLs. The Government Accountability Office (GAO) has also concluded that programs are entering the next phases when their technology is not ready. It is believed that this is not intentional but due to the fact that the vagueness of the TRL definitions allow programs to have a false sense of readiness (Azizian, 2009). The major decision points associated with TRLs are held prior to entering the EMD phase and P&D phase. At Milestone B, the technology

needs to be at or above TLR 6 and by Milestone C it should be at TRL 7. The TRLs are defined in Figure 7.

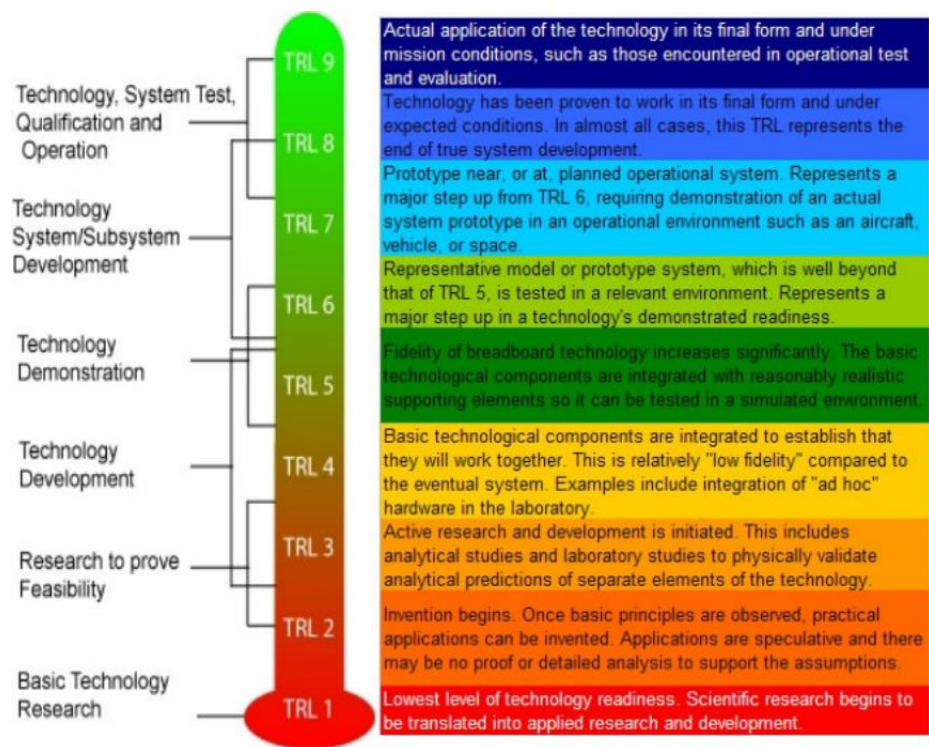


Figure 7. Technology Readiness Levels (Azizian, 2009)

Now that we have examined the Major Tier Acquisition model, let us see how the Middle Tier of Acquisition (MTA) is different. In 2016, the National Defense Authorization Act (NDAA) added Section 804, Middle Tier of Acquisition for Rapid Prototyping and Rapid Fielding. After establishing loose guidance for rapid prototyping and rapid fielding, DoDI 5000.80: *Operation of the Middle Tier of Acquisition* was published to establish policy and procedures for MTA management. Rapid prototyping “provides for the use of innovative technologies to rapidly develop fieldable prototypes to demonstrate new capabilities and meet emerging military needs” (Department, 2019c: 3). Prototypes must demonstrate functionality in an operational environment in five years.

Once a prototype is demonstrated, the project can fall back into a major capability acquisition life-cycle at milestone B or C, or it can proceed to operations depending on its TRL as displayed in Figure 8. Rapid fielding “provides for the use of proven technologies to field production quantities of new or upgraded systems with minimal development required” (Department, 2019c: 3). Production of the to-be fielded technology must begin within six months and completely fielded by five years.

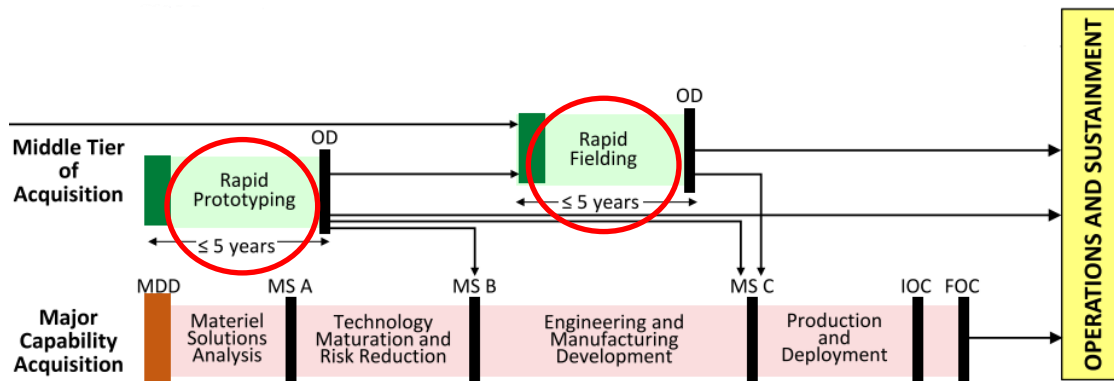


Figure 8. MTA Framework (Department, 2020a)

The Air Force Guidance Memo that details the process reviewed in Chapter IV also highly encourages the use of the rapid acquisition process as the standard for the Air Force unless it is deemed unsuitable (Roper, 2018a). In an attempt to promote this acquisition model, Dr. William Roper Jr, Assistant Secretary of the Air Force (Acquisition, Technology, and Logistics), published a memo detailing seven steps for incorporating it.

1. Have an aggressive goal: start with a goal that exceeds minimum requirements. Allow smart risk-taking and design exploration.
2. Bound your risks: prototyping is better when instituting one upgrade at a time
3. Be aggressive but not greedy: should also make plans for the traditional acquisition model in case the prototype fails

4. Constrain time and budget, not the final performance: avoid minimum acceptable performance
5. It takes a team to go fast: work closely with all parties involved
6. Get a signature from me: approves waivers for rapid acquisition
7. GO FAST (Roper, 2018b)

Lastly, any program that has a high enough TRL and is approved to follow the MTA process is exempt from following the *JCIDS* and DoDI 5000.01 (Department, 2019c).

### **NASA Program Management & System Engineering**

NASA maintains an extensive directory of procedural requirements. NASA Procedural Requirements (NPR) 7123.1C: *NASA Systems Engineering Processes and Requirements*, NPR 7120.5E: *NASA Space Flight Program and Project Management Requirements*, and the *NASA Space Flight Program and Project Management Handbook* contain almost all the knowledge a project manager would need to effectively navigate NASA's labyrinth of processes, documentation, and meetings. NPR 7123.1C provides guidance for implementing systems engineering for programs and projects. NPR 7120.5E describes how NASA formulates and implements space flight programs and projects. It identifies program and project phases, milestones, decision points, and required documentation. The handbook expands on NPR 7120.5E by providing further details for each life-cycle, phase, review, and deliverable. It is structured as a reference document focusing on activities needing to be performed by a program or project manager. Projects are specific investments to fill requirements within a Program that meet a strategic direction of NASA's Mission Directorate.

The level of managerial requirements and oversight a project receives is dependent on the project's scope and complexity. A project is assigned to one of three categories based on: (1) the project life-cycle cost estimate, usage of radioactive material, and whether the system is for human space flight; and (2) the priority level, which is related to the importance of the activity, the degree of uncertainty of new technologies, and risk classification (NASA, 2012e). Life-cycle cost and priority level relation is illustrated in Table 3. Based on these criteria, each CubeSat being developed by CSRA would fall under Category 3. Risk classification levels are assigned so projects can apply the appropriate management controls, system engineering processes, and risk mitigation (Risk, 2014). Based on the classification criteria presented by Table 4, CSRA's CubeSats are a Class D.

Table 3. NASA Project Categorization (NASA, 2012e)

| <b>Priority Level</b> | <b>LCC &lt; \$250M</b> | <b>\$250M &lt; LCC &lt; \$1B</b> | <b>LCC &gt; \$1B,<br/>significant<br/>radioactive material,<br/>or human<br/>space flight</b> |
|-----------------------|------------------------|----------------------------------|-----------------------------------------------------------------------------------------------|
| High                  | Category 2             | Category 2                       | Category 1                                                                                    |
| Medium                | Category 3             | Category 2                       | Category 1                                                                                    |
| Low                   | Category 3             | Category 2                       | Category 1                                                                                    |

Table 4. NASA Classification Consideration (Risk, 2014)

| <b><u>Characterization</u></b>                                       | <b><u>Class A</u></b>                     | <b><u>Class B</u></b>                            | <b><u>Class C</u></b>                              | <b><u>Class D</u></b>                              |
|----------------------------------------------------------------------|-------------------------------------------|--------------------------------------------------|----------------------------------------------------|----------------------------------------------------|
| <b>Priority (Criticality to Agency Strategic Plan)</b>               | High priority                             | High priority                                    | Medium priority                                    | Low priority                                       |
| <b>National significance</b>                                         | Very high                                 | High                                             | Medium                                             | Low to medium                                      |
| <b>Complexity</b>                                                    | Very high to high                         | High to medium                                   | Medium to low                                      | Medium to low                                      |
| <b>Mission Lifetime (Primary Baseline Mission)</b>                   | Long, > 5 years                           | Medium, 2-5 years                                | Short, < 2 years                                   | Short, < 2 years                                   |
| <b>Cost</b>                                                          | High                                      | High to medium                                   | Medium to low                                      | Low                                                |
| <b>Launch Constraints</b>                                            | Critical                                  | Medium                                           | Few                                                | Few to none                                        |
| <b>In-Flight Maintenance</b>                                         | N/A                                       | Not feasible or difficult                        | Maybe feasible                                     | May be feasible and planned                        |
| <b>Alternative Research Opportunities or Re-flight Opportunities</b> | No alternative or re-flight opportunities | Few or no alternative or re-flight opportunities | Some or few alternative or re-flight opportunities | Significant alternative or re-flight opportunities |

NASA's system engineering process and acquisition process consist of separate phases and steps but occur simultaneously. The system engineering process is divided into two parts, shown in Figure 9, and was modeled around the system engineering V-model displayed in Figure 10. The System Design Process includes Stakeholder Expectations Definition, Technical Requirements Definition, Logical Decomposition, and Design Solution Definition; this coordinates with the left side of the V-model. The Product Realization Process is comprised of Product Implementation, Product Integration, Product Verification, Product Validation, and Product Transition, which aligns with the right side of the V-model.

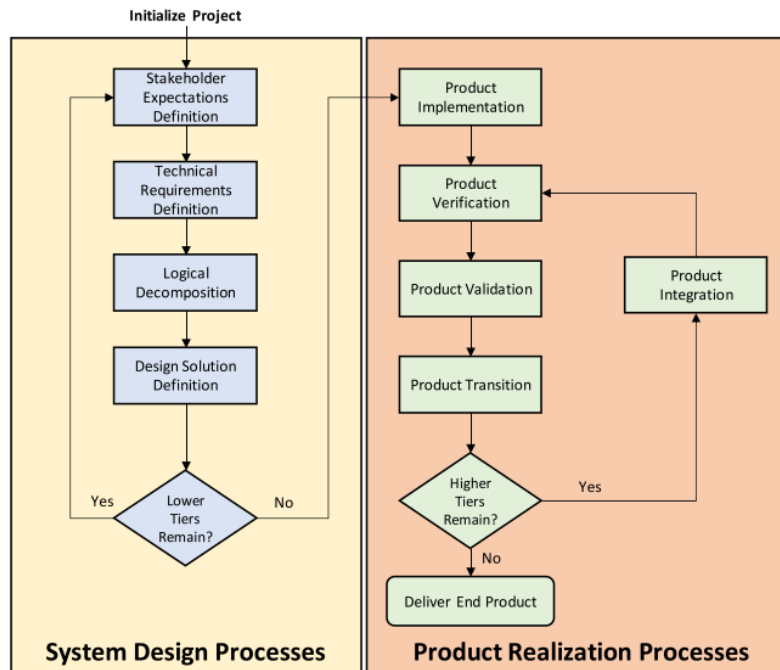


Figure 9. NASA System Engineering Process (NASA, 2020g)

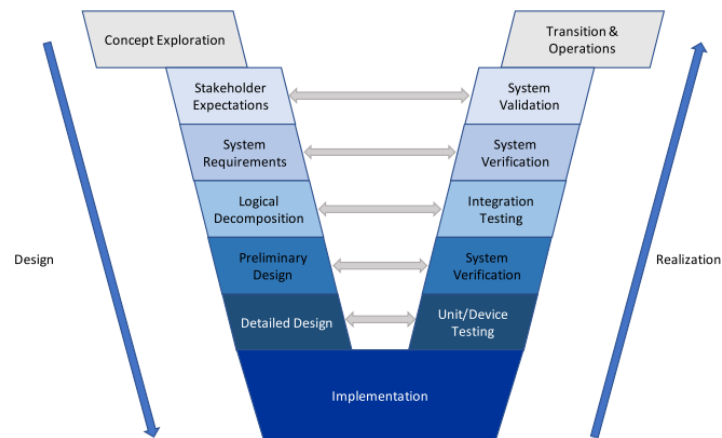


Figure 10. System Engineering V-Model (NASA, 2020g)

The Stakeholder Expectation Definition represents stakeholders' expectations of the system to include affordability, user interfaces, operational environment, user abilities, and other factors that impact the system design. These expectations are transformed into measurable requirements expressed in "shall" statements during the

Technical Requirements Definition. The baselined expectations are used later for validating that the completed system meets the needs expressed.

Logical Decomposition is the decomposition of the requirements to improve the understanding and relationships between the functional, behavioral, performance, and temporal requirements. Next, the logical decomposition is translated into possible design solutions during the Design Solution Definition. The possible solutions are analyzed to determine the best alternative to satisfy requirements. The final design solution is used to generate the end product.

With a design in place, Product Implementation generates subsystems by buying or making the needed components. After the subsystems have been verified and validated, Product Integration can transform these lower-level components into the desired end product.

The end system is verified and validated during Product Verification and Product Validation. Verification demonstrates that the product meets the system requirements. Validation confirms that the product fulfills the mission gap for which it was intended. Finally, a completed and tested system is ready for customer use. Product Transition is the process of turning over the product to the customer and providing training on usage (NASA, 2020g).

As mentioned earlier, the acquisition process is parallel to the system engineering method that was just reviewed. NASA uses a four-part process for managing both programs and projects: formulation, approval, implementation, and evaluation. Formulation is identifying how the project supports strategic goals, and implementation is executing approved plans for the development of the project. These are the major life-

cycle phases that cannot be traversed without approvals at key moments. The evaluation aspect is a constant processes of monitoring system readiness with formal evaluations occurring during key decision point (KDP) approvals.

Each KDP is an event for the Decision Authority to determine if the project is ready to advance to the next life-cycle phase. A variety of factors contribute to the decision to include:

technical maturity; continued relevance to Agency strategic goals; adequacy of cost and schedule estimates; associated probabilities of meeting those estimates (confidence levels); continued affordability with respect to the Agency's resources; maturity and the readiness to proceed to the next phase; and remaining program or project risk (safety, cost, schedule, technical, management, and programmatic). (NASA, 2014d)

An individual KDP's outcome will be published in decision memorandums. A KDP may conclude with different levels of approval or denial to enter the next life-cycle phase.

Approval can be granted "as is" or pending resolution of identified actions. If approved, the decision memorandum will include follow-up action items and details to the expectations, cost, and schedule of the project during the next phase. Denial can occur if the project is not ready and needs more time or can terminate a project if it is no longer necessary or determined not to be feasible. This decision memorandum will address why the project is not moving forward (NASA, 2012e).

NASA's required life-cycle phases, gates and events, major reviews, and documents are similar between programs and projects. Similar to how the DoD provided life-cycle models, NASA also provides life-cycle plans for five different program types and one for projects. The life-cycle phases for a project start with Concept Studies and progress through Concept & Technology Development; Preliminary Design &

Technology Completion; and Final Design & Fabrication, System Assembly, Integration & Testing, Launch & Checkout before reaching Operations & Sustainment. To transition from one phase to the next, management must grant approval at KDPs.

Several life-cycle reviews (LCRs) are held throughout the phases and act as major milestone events leading to the KDPs as depicted in Figure 11. LCRs were designed to provide appointed assessments of the project's formulation and implementation status and health. Decision authority during life-cycle reviews is based on the project category so the Mission Directorate Associate Administrator (MDAA) would be the decision authority for CSRA's CubeSat projects (NASA, 2012e).

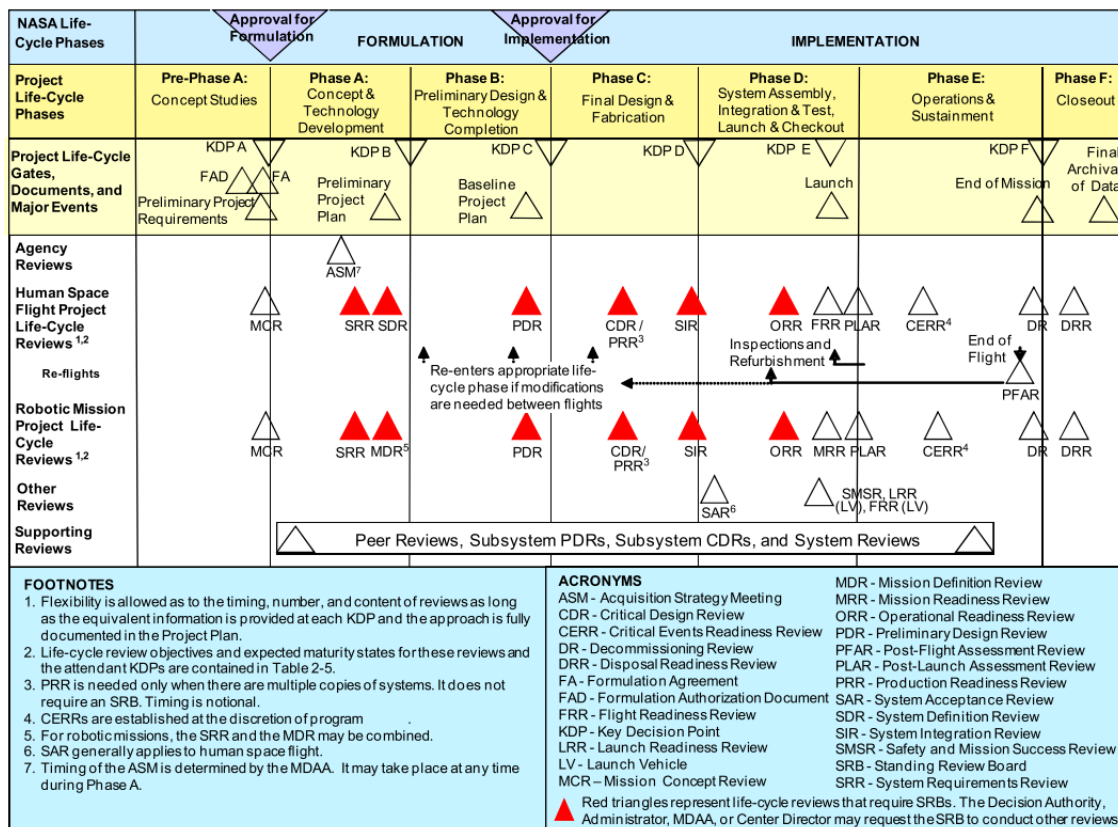


Figure 11. NASA Project Life-Cycle (NASA, 2020g)

The project life-cycle phases occur within the overarching NASA phases Formulation and Implementation. Within these life-cycle phases are various reviews and important events. The reviews, events, and associated deliverables will all be further examined in Chapter IV.

Although the life-cycle phases, LCRs, KDPs, and required documentation are very detailed and specific, tailoring of the project is expected to provide better implementation. Tailoring may consist of combining, omitting, or applying an agile approach to reviews, thus allowing projects to perform only activities that are needed for mission success. A requirement can be removed/waived if permission is granted by the requirement owner as identified by the Compliance Matrix in the Project Plan. The organization that established the requirement is the owner and can approve requests for tailoring upon confirmation that the new plan complies with the requirements of NPR 7120.5E (NASA, 2012e).

There are several areas that typically need tailoring or can be easily tailored. The most obvious requirements to drop are those that are not applicable to the project due to category, cost, materials, or mission type. Combining deliverables can reduce the volume of paperwork if appropriate. Along the same lines, reviews can be combined. Any approved changes are documented in the project's Formulation Agreement and the Project Plan to relay the tailored plan along with rationale. A full list of requirements for category 3 projects can be found in Tables I-4 and I-5 of NPR 7120.5E. These requirements will be analyzed later (NASA, 2014d).

Category 3 projects with an anticipated life-cycle cost under \$150M have additional tailoring guidance published in a memorandum from the NASA Associate

Administrator titled Guidance and Expectations for Small Category 3, Risk Classification D Space Flight Projects with Life-Cycle Cost Under \$150M. This guidance is intended to reduce the burden on a project by mitigating unnecessary requirements on small projects with limited resources. The major changes implemented are the removal of the Formulation Authorization Document (FAD) and Program Plan, as well as the use of an Independent Review Team in lieu of a Standing Review Board (SRB) (Lightfoot, 2014).

In addition to its own satellite program, NASA offers rides into orbit as part of the CubeSat Launch Initiative (CSLI). *CubeSat 101: Basic Concepts and Processes for First-Time CubeSat Developers* was written by experts at Cal Poly and NASA for persons designing, building, and preparing a CubeSat for flight. It is intended for developers that are working with NASA's CSLI – a program that offers to transport qualified CubeSats into orbit – but it is just as useful for any anyone else whether designing their first or sixty-fifth CubeSat. To be eligible to participate in CSLI, a CubeSat's mission must clearly demonstrate benefit to NASA by supporting at least one objective of their Strategic Plans (Chin, 2017). The most recently updated Strategic Plan is from 2018 with strategic objectives that align with one of four goals: expand human knowledge through new scientific discoveries, extend human presence deeper into space and to the moon for sustainable long-term exploration and utilization, address national challenges and catalyze economic growth, and optimize capabilities and operations (NASA, 2018a).

Since CubeSat 101 was written for inexperienced developers and CSLI attempters, it contains instructions for some processes that are not applicable to CSRA so they will not be reviewed. The guidance provides details on concept development, merit and feasibility reviews, CubeSat design, mission coordination, licensing, documentation,

hardware fabrication and testing, readiness reviews, and integration. These processes will be reviewed in Chapter IV.

## Relevant Research

In 2017, ten academia, five industry, and eight government CubeSat developers were interviewed as part of a study to determine which aspects of mission assurance can significantly improve mission success (Venturini, 2017). The list of those interviewed is available in Table 5. The study was completed to give insight to designers, developers, suppliers, and customers.

Table 5. Organizations Interviewed (Venturini, 2017)

| Academia (10)                           | Industry (5)                                                    | Government/FFRDC/UARC (8)                                |
|-----------------------------------------|-----------------------------------------------------------------|----------------------------------------------------------|
| California Polytechnic State University | Atmospheric & Space Technology Research Associates, LLC (ASTRA) | The Aerospace Corporation                                |
| Georgia Institute of Technology         | Blue Canyon Technologies                                        | Air Force Research Laboratory                            |
| Massachusetts Institute of Technology   | The Boeing Company                                              | Massachusetts Institute of Technology Lincoln Laboratory |
| Montana State University                | Millennium Space Systems                                        | NASA Ames Research Center                                |
| Saint Louis University                  | Planetary Resources                                             | NASA Goddard Space Flight Center                         |
| University of Michigan                  |                                                                 | NASA Wallops Flight Facility                             |
| University of Southern California       |                                                                 | Space and Naval Warfare Systems Command                  |
| United States Naval Academy             |                                                                 | Space Dynamics Laboratory                                |
| U.S. Air Force Academy                  |                                                                 |                                                          |
| Utah State University                   |                                                                 |                                                          |

When comparing the datasets and comments from the organizations interviewed, the research group identified 40 common themes that they were able to group into eight theme categories.

- scope creeps occur quickly
- emphases should be placed on process documentation
- government and industry review cycles such as PDR and CDR were followed

- less formal, more meticulous, peer reviews are valuable
- beneficial to focus on more critical risks than all of them
- system design should be simple but thorough
- emphasized the importance of test, especially full-system functional tests
- used COTS whenever available to reduce time and risk

The interviewees also provided many recommendations for others who develop or want to develop CubeSats.

- Define the scope, goals, and success criteria at the program start
- Plan for ample time to integrate, verify, and test
- Conduct risk-based mission assurance
- Build and experience team
- Stock COTS components
  - Knowing what components work best and having them on stock reduces time and risk
- Conduct four mission assurance tests, at minimum
  - Day-in-the-Life (DITL)
  - Communication link with ground station
  - Power system charge and discharge
  - Thermal and vacuum testing
- Do not overly trust specifications of vendors' system datasheets (Venturini, 2007)

In a brief by Dr. Pauline Faure of the Aerospace Engineering Department at Cal Poly to address CubeSat low mission assurance, a system engineering plan was described

to help first-time developers succeed. The plan is similar to both the DAS and NASA processes. The first step is to define the stakeholders and their needs. Who are they and how are they involved? What is important? Based on the stakeholder needs, define system requirements using “shall” statements. Each requirement will define the what and not the how. The Work Breakdown Structure (WBS) can be created while the system requirements are broken down into their smallest elements. Maintaining requirements traceability is key to verification later. With a complete project breakdown, interfaces can be clearly defined and a realistic schedule can be completed.

The NASA Project Life-Cycle from Figure 11, was used to explain schedule and milestone planning. Faure suggested that schedules be built in reverse, starting at the due date and working back to determine when processes must be completed. Adding buffer time to the schedule was greatly stressed. The need for design reviews was expressed, but specific reviews were not discussed even though the charts that were presented showed MCR, SRR, SDR, PDR, CDR, SIR, ORR, and FRR scattered within the example timelines (Faure, 2020).

## **Summary**

In summary, Chapter II provided a brief history of CubeSats and how their popularity grew within the academia world. The success rate of university class satellites has been on the decline for several decades partially due to the invention of the CubeSat. Many universities have attempted their first satellite build with a CubeSat and have not experienced positive results. This justifies the need for a defined framework to ensure the CubeSat build is triumphant. The chapter also described the development process used by

several universities along with the recommendations they gave for establishing and managing similar programs. Additionally, program management and system engineering processes from the DoD, USAF, and NASA were reviewed. Each define and divide the development process into different phases containing events and reviews to be accomplished for a successful build. Milestones and Key Decision Points are used to ensure the program does not proceed to the next phase until specific criteria are met.

### **III. Methodology**

#### **Chapter Overview**

The purpose of Chapter III is to describe the process behind the creation of the acquisition framework for Center for Space Research and Assurance's (CSRA's) CubeSat program. To assess and tailor the program management of other organizations, the frameworks were split into life-cycles, deliverables, and entrance/exit criteria. Additionally, the organizations were categorized based on program complexity allowing appropriate comparisons. Comparisons were accomplished using the qualitative analysis approach of visual mapping and charting to identify patterns.

#### **Research Focus**

The research for this thesis started by searching for information from any organization that had developed CubeSats. Some commercial agencies that produce CubeSats have shared limited information regarding their development process or program management. Because commercial organizations have access to different resources than CSRA and since little knowledge from these organizations was shared, little effort was spent searching for their management procedures. On the contrary, many students authored their theses or published articles that included the management specifics of CubeSat programs of which they were involved. Additionally, several universities published studies on CubeSat successes and failures which included details on program management, lessons learned, and recommendations.

The focus areas of this research were the details linked to each agency's program management framework. This included identifying life-cycle phases/stages, milestones,

reviews, major events, timelines, and deliverables. Not all desired information was available for many of the agencies, but various details were gathered for:

- U.S. Air Force Academy (USAF)
- U.S. Military Academy (USMA)
- U.S. Naval Academy (USNA)
- U.S. Coast Guard Academy (USCGA)
- Naval Postgraduate School (NPS)
- Massachusetts Institute of Technology (MIT)
- Montana State University (MSU)
- University of Michigan (U-M)
- Aalborg University in Denmark
- Luleå University of Technology in Scandinavia

Additionally, the same information was collected for much larger organizations that have published numerous regulations, instructions, and guidance documents to provide details of their program management and system engineering processes. These organizations and publications include:

- Department of Defense (DoD)
  - *Joint Capabilities and Development System* (JCIDS)
  - *Operation of the Department Acquisition System* (DoDI 5000.02T)
  - *Defense Acquisition Guide* (DAG)
  - *Operation of the Middle Tier of Acquisition* (DoDI 5000.80)
- National Aeronautics and Space Administration (NASA)

- *NASA Systems Engineering Processes and Requirements* (NPR 7123.1C)
- *NASA Space Flight Program and Project Management Requirements* (NPR 7120.5E)
- *NASA Space Flight Program and Project Management Handbook*
- U.S. Air Force (USAF)
  - *Integrated Life Cycle Management* (AFI 63-101)
  - *Integrated Life Cycle Management* (AFPAM 63-128)
  - *Space and Missile Systems Center (SMC) Systems Engineering Primer and Handbook*

The DoD, NASA, and USAF utilized multiple publications to relay the extensive amount of detailed information needed to manage a program from concept to deployment, but these publications will not be analyzed individually. Because each instruction adds different pieces to the same puzzle that forms the process, the overall process is reviewed for each of these three organizations.

The size of operations and level of complexity between some of the agencies differ significantly. Because of this asymmetry, not all organizations were compared to each other. To better recognize similarities and differences between organizations, they were classified as simple and complex. The two classes are differentiated in Table 6. The CubeSat 101 was classified as simple because it was written for the academia environment and amateur CubeSat developers. This separation allowed a better comparison between the equivalent processes. This balances the assessments initially, but ultimately the simple programs were compared to the complex ones to identify if differences exist between the two.

Table 6. Program Classes

| Simple      | Complex |
|-------------|---------|
| USAFA       | DoD     |
| USMA        | NASA    |
| USNA        | USAF    |
| USCGA       |         |
| NPS         |         |
| MIT         |         |
| MSU         |         |
| U-M         |         |
| Aalborg     |         |
| Luleå       |         |
| CubeSat 101 |         |

### Framework Breakdown

The program management framework is not a single element but is multilayered. To better assess and compare the different layers, the framework was separated into the three categories of life-cycles, deliverables, and entrance/exit criteria as depicted in Figure 12. Life-cycle includes the phases, events, reviews, milestones, and timelines. Deliverables consists of all the documentation that is produced during the satellite development. Entrance/exit criteria are the requirements that must be met to advance within the life-cycle.

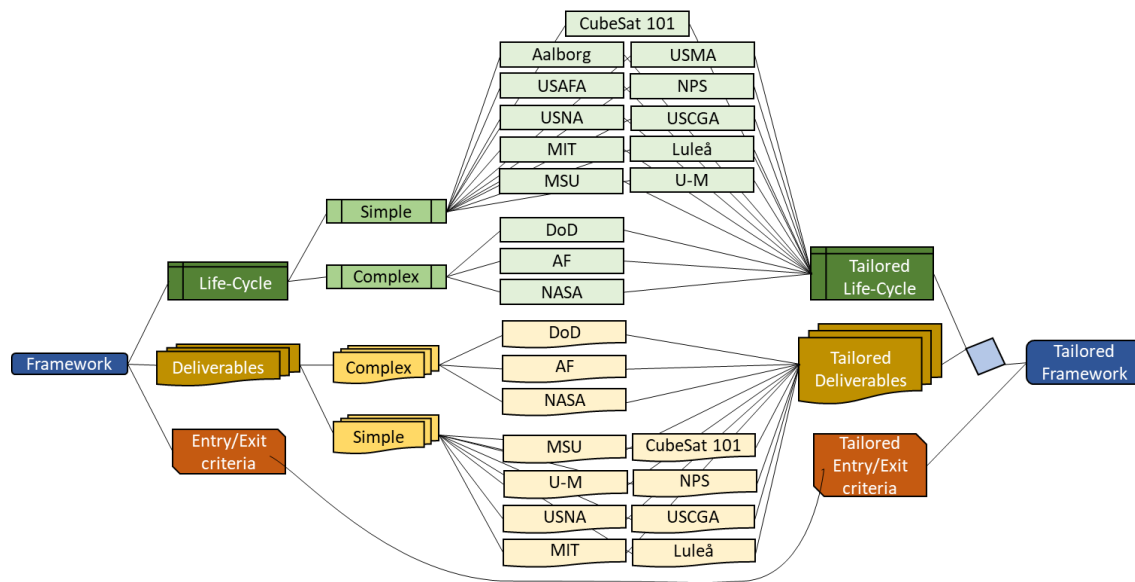


Figure 12. Framework Breakdown

The life-cycles of USAFA, USMA, USNA, USCGA, NPS, MIT, MSU, U-M, Aalborg University, Luleå University, and the CubeSat 101 are reviewed and compared as the simple class. The life-cycles of DoD, USAF, and NASA are reviewed and compared as the complex builds. The simple and complex are evaluated to develop a life-cycle tailored to the needs of CSRA.

The deliverables of USNA, USCGA, NPS, MIT, MSU, U-M, Luleå University, and the CubeSat 101 are reviewed and compared for the simple group. The deliverables of DoD, AF, and NASA are reviewed and compared for the complex builds. The simple and complex are evaluated to develop a list of required documents tailored to the needs of CSRA.

None of the organizations from the simple list provided any insight to their entrance/exit criteria so the tailored criteria must come from the complex processes. The tailored entrance/exit criteria are applied after the life-cycle and deliverables are tailored in order to confirm applicability.

## **Process Analysis**

A qualitative process analysis approach was taken when reviewing life-cycles and deliverables to find patterns that lead to success. There are many ways that processes can be analyzed to develop theories, all of which aim to find and understand patterns between experiences. This is difficult because within each scenario are events with different variables that shape the results.

One approach for finding patterns within a series of events is the visual mapping strategy (VMS). This is a technique from Lean thinking used to analyze the flow of materials and information to eliminate waste and identify value-added events (Darwish, 2010). VMS organizes large quantities of information into a tight space that can be more easily analyzed. Visual representations allow simultaneous display of dimensions, precedence, parallel processes, and time. The mapped life-cycle models in Chapter IV illuminate phases, timelines, and major events. The phases are color coordinated for easier recognition between models. Additionally, each phase is representative of its portion of the life-cycle as they are all sized to scale with the timeline.

Mapping allows readers to visualize multiple activities brought together with a common language, thus allowing smarter evaluations. Mapping specific variables is not a theory but is an abstract conceptualization allowing commonalities between events to be understood (Langley, 1999). Once mapped, the researcher can look for common sequences of events to build a theory and recognize waste.

In 1996, Womack proclaimed there are three types of activities: those that add value, those that are necessary but add no value, and activities that do not add value and are not necessary. This final activity type is regularly referred to as waste (Womack,

1996). VMS can be used to identify value added activities while reducing waste. By asking engineers how much of their day was value added, Joglekar concluded that roughly 40% of engineering efforts are typically wasted (Joglekar, 2000).

Through the mapping of the identified organizations' life-cycles, this research intends to minimize wasted time in CSRA by tailoring the model for best results. All life-cycles are first mapped "as-is" showing phases, events, reviews, milestones, and timelines as a means to assess and compare the models.

In addition to VMS, the individual events and reviews were chronicled on a spreadsheet to obtain a full list of events and capture the frequency an event occurred within the multiple agencies. Not all agencies titled their events and reviews the same, but the purposes of each were assessed in order to most accurately align them. While high frequency does not directly translate to value added, it is worth noting which events occur across multiple platforms.

With every organization's life-cycle mapped and listed, tailoring was started to remove the waste by waiving or combining events and reviews. Firstly, any event or review that was not applicable to CSRA was waived to reduce the overall list. Some generic reviews that are not applicable are those that involve contracting work to an external agency for mass production. Then the remaining events and reviews were compared against each other to identify similarities and examine the possibility of combining them. The high frequency events were reviewed first because it probable that they are useful since they were used by so many organizations. The intent of combining events and reviews is to ensure that important material is discussed at an appropriate level while not also holding an abundance of reviews.

When tailoring the timelines of the life-cycles, the recommendations of other universities to integrate early and conduct a lot of testing were taken into consideration. CSRA's goal is to complete each CubeSat build within three years so the life-cycle was set to this timeline. Because other universities have completed their satellite builds in less time, it is conceivable that CSRA can complete each satellite in three years. The reviews were tailored to as few as practical without compromising the program integrity. There was no relationship between the tailored reviews and the timeline.

The charting process used for events and reviews was the same method that was employed for reviewing the extensive list of deliverables that accompanied each framework. Descriptions of each deliverable were used to align the requirements from the various organizations. Not all deliverables had descriptions readily available, but they were assessed based on usage context to establish a completed record. Similar to the life-cycle review, patterns of usage and common themes were recognized based on frequency.

Reducing waste without compromising documented knowledge was key to tailoring the deliverables. As was done before, the first step in tailoring the deliverables was to waive the documents not needed for CSRA's CubeSat development. Additionally, by identifying patterns and similarities in the purpose of each document, many of the deliverables can be combined. By doing so, important information is still recorded but with less actual documents. This saves time and effort in the development of each document and saves time when sorting through the different documents to find necessary information.

After the life-cycles and deliverables were tailored to meet the needs of CSRA, the entrance/exit criteria were evaluated. The criteria were developed to ensure the

appropriate technology readiness levels were reached and documentation was accomplished by the most appropriate periods of the life-cycle. The criteria assessed and tailored were only available from the complex programs and were not tailored in the same fashion as the life-cycle or deliverables. The entrance/exit criteria were not assessed until the end because it needs the life-cycle and deliverables established first. Combining the entrance/exit criteria to the tailored life-cycle and deliverables completes the newly tailored framework.

### **Summary**

Qualitative analysis was used to recognize patterns among the different frameworks. The VMS was applied in this research to model the life-cycles of each organization found in the articles or publications reviewed. Deliverables were charted to identify similarities and patterns between the agencies. Tailoring reduced the number of deliverables by waiving documents that were not applicable and combining documents with similar purposes. After the life-cycles and deliverables were analyzed and tailored, the entrance/exit criteria were applied to create a new developmental framework for CSRA's CubeSat program.

## **IV. Analysis and Results**

### **Chapter Overview**

The purpose of Chapter IV is to assess the frameworks of each organization reviewed in Chapter II. The methodologies described in Chapter III were used to assess each organization's life-cycle which were then tailored for possible use by Center for Space Research and Assurance (CSRA) for developing CubeSats. After all the complex and simple life-cycles had been reviewed and tailored, the deliverables that accompany the processes were reviewed and tailored. The many suggestions offered by experienced organizations in Chapter II were also considered during tailoring. The reasoning for the tailoring approach is explained for each organization.

### **Concept Analysis**

In the eyes of the U.S. Air Force (USAF) and National Aeronautics and Space Administration (NASA), CSRA's CubeSat program is not an acquisition program because it is not on the Air Force Acquisition Master List (AML) and is not a strategic investment by a NASA Mission Directorate or Mission Support Office. Because the CubeSat program is not officially an acquisition program, the Department of Defense (DoD) and USAF regulations and instructions are not applicable so none of the phases, events, or deliverables in this research are mandatory.

Even though CSRA is not required to follow any of the guidance reviewed in this research, the CubeSat program will still benefit from adopting a developmental framework that is tailored specifically to the projects. CSRA's goal is to fully develop a CubeSat within three years, with one being completed each year. This plan would allow

multiple classes the opportunity to contribute to the different CubeSats actively in development. Figure 13 is a notional Integrated Schedule for Education, Mission, and Research that was presented at the 2020 Small Satellite Conference in Logan, UT (Keys, 2020). Without the mandate of following the regulatory guidance, the framework to regularly obtain this goal can be tailored without the imposed limitations.

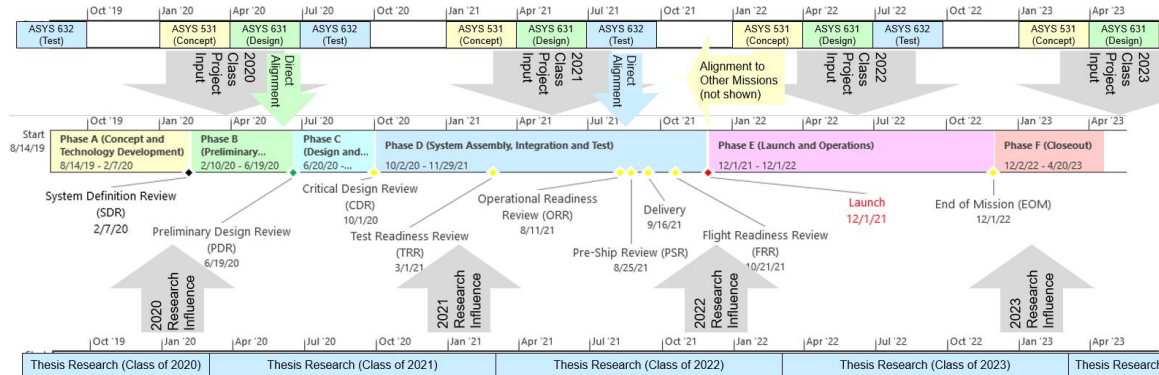


Figure 13. CSRA Notional Schedule (Keys, 2020)

When reviewing each agency's process to determine if they can be tailored to better suit CSRA, some clearly have more decision points, reviews, and documentation requirements than others. There is no single process that is suited for all development projects; if there were, all organizations would gravitate towards implementing it. Each model has its own strengths and weaknesses, but by borrowing pieces from the various acquisition class paths, we can tailor one that is ideal for CSRA.

## Tailoring Life-Cycles

The individual life-cycles as described by each organization were modeled using VMS as described in Chapter III. Also mentioned in Chapter III, the agencies were organized by the level of complexity, referred to as complex and simple. The phases of each life-cycle are color coordinated to best align with Table 7. The life-cycles do not all

have the same phases but adding a color for every variation defeats the purpose of the coordination, so some are color coded as close as possible.

Table 7. Life-Cycle Phase Colors

|                               |
|-------------------------------|
| Concept /analysis             |
| Technology<br>Development     |
| Early Design /<br>Development |
| Final Design /<br>Development |
| Fabrication /<br>Integration  |
| Production / Test             |
| Operations                    |

Before we can tailor a life-cycle, we need to examine the “as is” life-cycle from each organization. First, all the complex life-cycles were examined starting with the DoD. Chapter II explained that the DoD life-cycle is divided into four phases and now we will go into further detail.

After completion of an Initial Capabilities Document (ICD) identifying the capabilities that are required to fill a mission gap, the Analysis of Alternatives (AoA) is initiated to examine ways to meet these requirements. The capability requirements are not static and are expected to change as circumstances and situational knowledge change. The Material Development Decision (MDD) confirms the product needs and directs execution of the AoA as the DoD enters the Materiel Solution Analysis (MSA) phase.

The purpose of MSA is to further explore the concepts of the AoA to translate validated capability gaps into system-specific requirements. This includes developing Key Performance Parameters (KPPs) and Key System Attributes (KSAs) that will be

recorded in the Capabilities Development Document (CDD). The CDD is derived from the ICD during the development and trade-off of system requirements. Trade-off analysis compares different capability levels to cost so engineers can determine the major design parameters that have the best cost-to-performance ratio.

The MSA phase ends with the Risk Reduction Decision, referred to as the Milestone A review. Milestones and program decision reviews carefully assess a program's readiness to proceed to the next phase by analyzing the program's status, the current phase's exit criteria, and the next phase's entrance criteria. With Milestone Decision Authority (MDA) approval, the program is authorized to enter the Technology Maturation and Risk Reduction (TMRR) phase.

During TMRR, the program management office follows the Acquisition Strategy to ensure that the technology needed to fill the mission gap is advanced to the point that the risk of failure is negligible. The technology advancement and risk reduction may be done in-house or awarded via contract. Concurrently, CDD Validation occurs to review the proposed requirements trades and ensure the requirements are technically achievable, affordable, and testable.

The CDD Validation, including the KPPs and KSAs, guide efforts leading to the Preliminary Design Review (PDR). The PDR is for the MDA to assess the maturity of the system design by reviewing requirements trades, prototypes, and technology demonstrations. An approved PDR becomes the baseline for the system design. The Development Decision at Milestone B is made when the program is ready to enter the Engineering and Manufacturing Development (EMD) phase. To enter EMD, all sources

of risk must be adequately mitigated to include technology, engineering, integration, manufacturing, and sustainment.

Within the EMD phase, the objective is developed, built, and tested to verify that all operational and derived requirements are met before production. Developmental Test and Evaluation (DT&E) is conducted to evaluate the sub-system's ability to perform and achieve KPPs and KSAs. Operational Test and Evaluation (OT&E) events evaluate the system's performance and should be conducted in conjunction with DT&E events when feasible. Some high-cost programs like spacecraft and ships do not produce prototypes during EMD for testing. All testing should be conducted on the product that will go into operations.

When the product is not developed and manufactured in-house, the DoD enters contract to produce the product during the EMD phase. Most of the details of the Milestone B decision would be included in the Request for Proposal (RFP) Release Decision Point that occurred during TMRR. The EMD phase ends when a design is stable and testing proves it meets the requirements of the CDD.

The decision to approve a program at Milestone C enters the program into the Production and Deployment (P&D) phase. Much of the criteria for approval were specified during Milestone B and defined in the Milestone B Acquisition Decision Memorandum (ADM). P&D starts with low-rate initial production (LRIP) before expanding into full-rate production (FRP) following positive results from OT&E, initial manufacturing, and limited deployment of the product. The OT&E of a produced article should be conducted in a realistic environment of its intended use. Once started, FRP continues until operational capacity is reached. Operation and Support (O&S) phase

begins after the decision to start production. Since this thesis examines the procedures prior to O&S, it will not go into details regarding sustainment or disposal (Department, 2020b). This process is mapped in Figure 14.

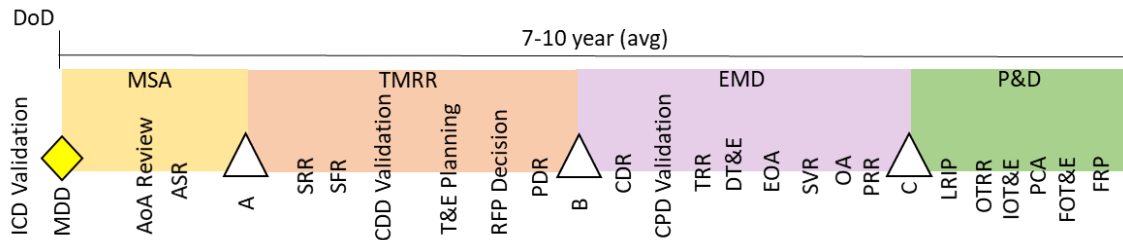


Figure 14. DoD Life-Cycle Model

This all-inclusive life-cycle was designed to be tailored. As shown, it is most appropriate for a very expensive and high-risk program which is not the case at CSRA. To tailor this model, the Initial Capabilities Document (ICD) Validation is waived prior to the Materiel Development Decision (MDD). The MDD itself is tailored to represent CSRA's decision to accept the responsibility of a new CubeSat project. Since it is very likely that CSRA will be working with a sponsoring agency, the agency should provide the capability requirements they expect to be resolved through CSRA's work. The Alternative Systems Review (ASR) can be combined with the Analysis of Alternatives (AoA) Review as it is a very similar topic. The functional baseline can be reviewed during the System Requirements Review (SRR) so the System Functional Review (SFR) can be waived. The Capability Development Document (CDD) Validation is waived as the CDD can be validated during the Preliminary Design Review (PDR). The Test and Evaluation Planning event does not need to occur if all testing information is properly documented in the Test and Evaluation Master Plan (TEMP).

The Request for Proposal (RFP) Decision, Production Readiness Review (PRR), Low-Rate Initial Production (LRIP) Decision Review, Physical Configuration Audit (PCA), and Full-Rate Production (FRP) Decision Review are dropped since there are no contracting efforts. The Early Operational Assessment (EOA) is captured as part of the Developmental Test and Evaluation (DT&E) and the Operational Assessment (OA) occurs as part of the Operational Test & Evaluation (OT&E). The Capabilities Production Document (CPD) Validation is waived as the CPD can be validated during the Critical Design Review (CDR). Initial OT&E (IOT&E) and Follow-on OT&E (FOT&E) are only required for programs on the Director, Operational Test and Evaluation (DOT&E) oversight list. Finally, the timeline was adjusted to use the DoD's Accelerated Acquisition Model which combines Milestones A and B to allow the project to start production and testing much earlier. These tailoring efforts are mapped in Figure 15 to provide a visual representation of the changes made.

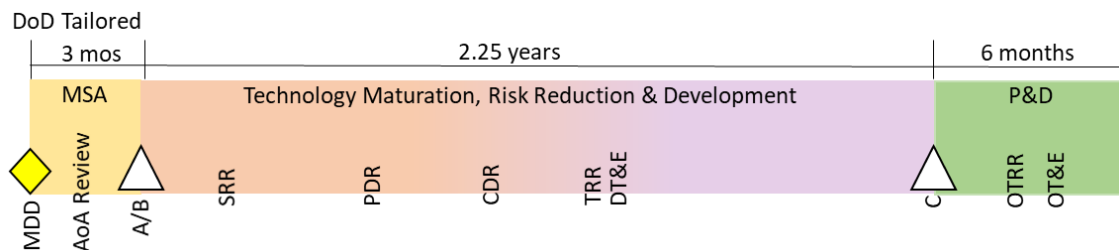


Figure 15. DoD Tailored Life-Cycle

Like the DoD life-cycle, NASA's project management includes four project life-cycle phases that occur within the higher-level Formulation and Implementation phases. Many activities also occur during a pre-formulation cycle called Concept Studies. This is the initial research and legwork that needs to be performed before a project concept emerges such as feasibility studies, the analysis of alternatives (AoA), and risk

assessments that will likely affect cost and schedule. These activities lead to the Mission Concept Review (MCR) and key decision point (KDP) A. If a project is evaluated as feasible and meets NASA objectives, KDP A is approved and the project officially starts in Formulation.

Formulation consists of Concept & Technology Development and Preliminary Design & Technology Completion. Activities focus on identifying and defining project requirements, assessing technology requirements and availability, creating mission and system designs, establishing performance metrics, developing acquisition plans, and conducting trade studies for risks, schedule, and cost. The final life-cycle review (LCR) in Formulation is the PDR. If the design and technology have matured to an acceptable level, KDP C may be approved which starts the Implementation cycle.

Implementation encompasses Final Design & Fabrication; System Assembly, Integration & Test, Launch & Checkout; and Operations & Sustainment. During this time, the system design is finalized, and fabrication occurs. Following component testing, the system is fully assembled, integrated, and tested. After the full system verification and KDP E, the system will be launched, and operations begin (NASA, 2014d). Figure 16 maps this untailored life-cycle.

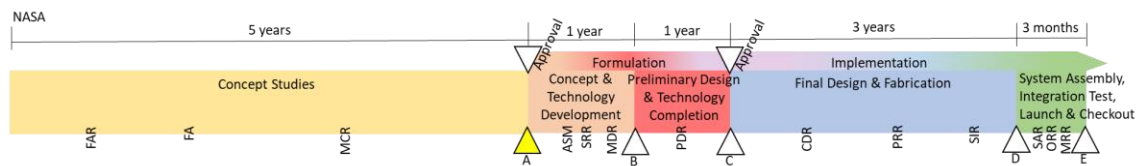


Figure 16. NASA Life-Cycle Model

Although NASA's life-cycle is not as extensive as the DoD model, there is still plenty of room for tailoring as is expected by NASA. To start, KDP A is equivalent to the

MDD as it is the decision point to enter the acquisition process. As was done with the DoD model, the work done prior to KPD A is waived because it should be completed by the sponsor before CSRA decides to proceed with the project. The Acquisition Strategy Meeting (ASM) is held above the project level and does not need to be captured here. The Mission Definition Review (MDR) can be combined with the System Requirements Review (SRR). Because all work is being performed in-house versus contracting out, the Production Readiness Review (PRR), Product Transition process, and System Acceptance Review (SAR) are not applicable. Lastly, the timeline was adjusted to fit CSRA's plan.

Although NASA's phases and processes are titled differently than the DoD's, they accomplish the same purpose. Both organizations have the same readiness reviews, meaning both acquisition models are practically the same. The similarities can be seen after mapping the tailored approach taken against NASA's life-cycle in Figure 17.

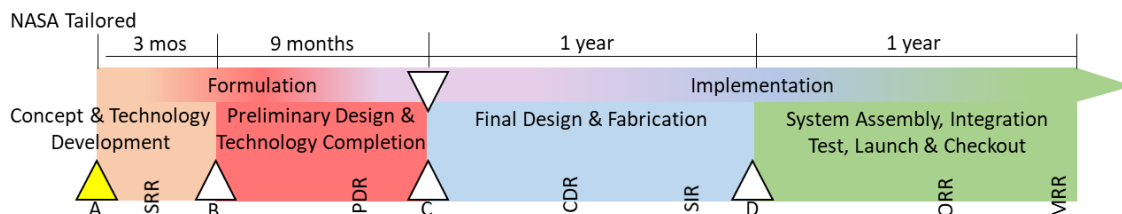


Figure 17. NASA Tailored Life-Cycle

As mentioned in Chapter II, the Air Force framework is built on the DoD process. Since the DoD regulations are a higher priority, the USAF regulations cannot discount any events or reviews but can make additions. The primary addition is that the risk management plan and should-cost report will be reviewed at all major readiness reviews. Additionally, all tailoring must be documented in the Acquisition Strategy (AS) or

Acquisition Decision Memorandum (ADM), which will be re-evaluated after each readiness review to ensure the tailored model is still the most appropriate pathway (Department, 2020f). Figure 18 provides a visual model of this process.

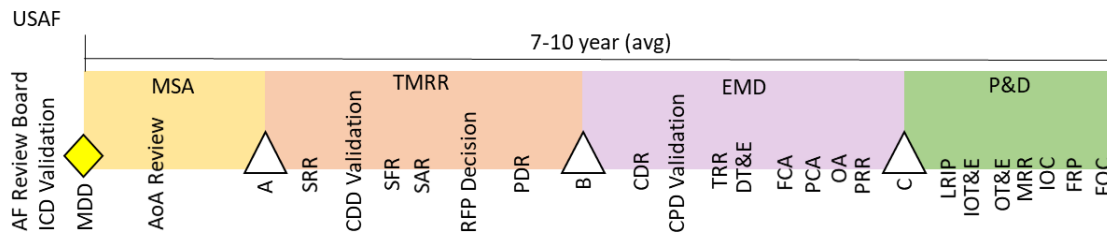


Figure 18. USAF Life-Cycle Model

The USAF life-cycle model was tailored very similarly to the DoD model. The Review Board and Initial Capabilities Document (ICD) Validation were waived prior to the Materiel Development Decision (MDD) since the sponsoring agency should provide the capability requirements that they expect to be resolved through CSRA's work. The system functions and architecture that would be reviewed during the System Functional Review (SFR) and System Requirements and Architecture Review (SRAR) can be reviewed during the System Requirements Review (SRR). The Request for Proposal (RFP) Decision is waived because no contract will be awarded for this in-house development. The OA was dropped because all developmental and operational testing will be systematically conducted during the Developmental Test & Evaluation (DT&E) events and the Operational Test & Evaluation (OT&E) events. The Functional Configuration Audit (FCA) is waived with the requirements verified against the allocated baseline during DT&E. There are not any commercially produced CubeSats so the Physical Configuration Audit (PCA), Production Readiness Review (PRR), Low-Rate Initial Production (LRIP), Manufacturing Readiness Review, Initial Operating Capability

(IOC), and Full-Rate Production (FRP) Decision were waived. With these events/reviews waived or combined, Figure 19 is similar to the DoD tailored model.

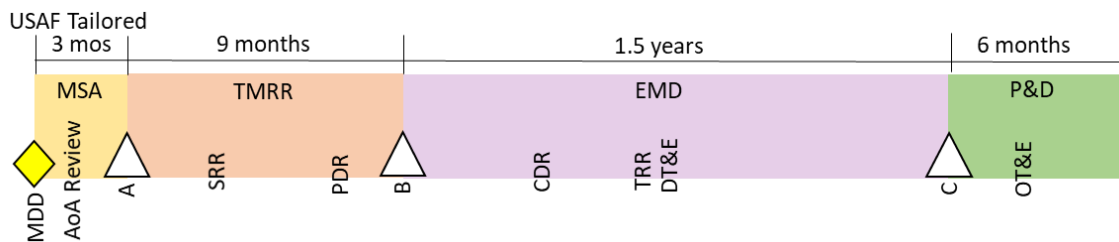


Figure 19. USAF Tailored Life-Cycle

In addition to the standard USAF life-cycle, there is a quicker approach through the Middle Tier of Acquisition (MTA) option. The Air Force guidance to rapid acquisition activities does not enforce any additional requirements but encourages use of a four-phase model. Phase Alpha addresses the balance between risk and reward. Program managers are encouraged to design without considering limitations of budget or schedule. Once the design is complete, then it should be slowly scaled down to meet the restraints of the schedule and budget. It is more acceptable to stumble when attempting to overachieve during a rapid prototype.

Once ready to field the prototype, the Beta phase is entered. During Beta, performance is improved until it can operate in an operationally relevant demonstration. During this time, efforts are made for initial production. The milestone decision, termed the Beta Decision, moves the program into the Gamma phase for modernization and follow-on production. The program becomes an official Program of Record following the Beta Decision. Following an increase to the production of the current system configuration, the Gamma Decision is made based on balancing user needs, upgrade options, and pricing. The Delta phase is the same as Operations and Sustainment of the

major acquisition development model (Roper, 2018a). The AF MTA life-cycle, depicted in Figure 20, looks much different than the normal USAF life-cycle.

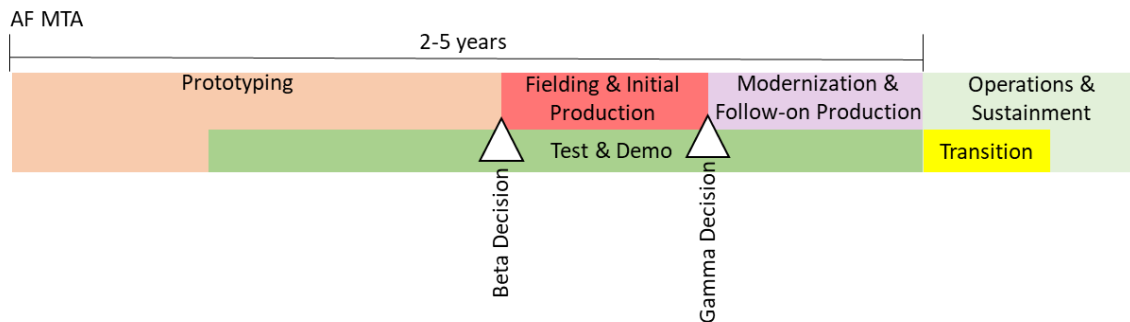


Figure 20. AF MTA Life-Cycle Model

The base model does not offer much to be tailored but CSRA is not starting with an already designed satellite, so the first phase was adjusted to include development before prototyping. Additionally, CSRA is only constructing one CubeSat per project so the other phases were changed to reflect the single product. The transition phase was also removed because this finished CubeSat is not being given to troops in the field; it will be operated in-house. Figure 21 reflects this minor tailoring.

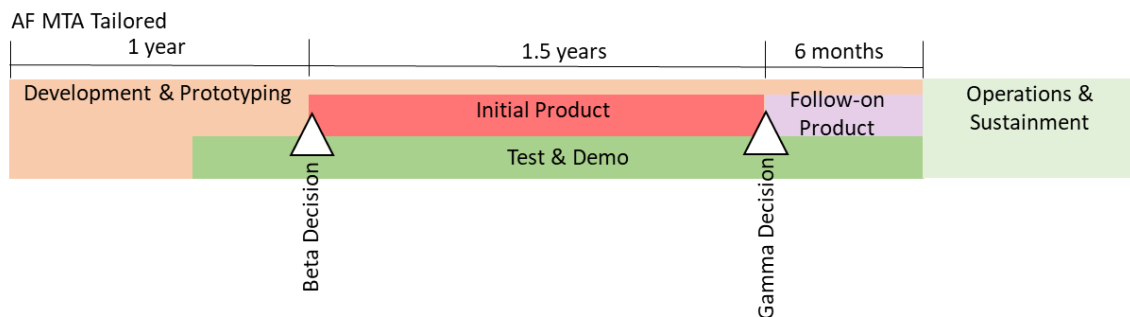


Figure 21. AF MTA Tailored Life-Cycle

This tailored approach could be implemented within CSRA, but it lacks details. Having only a few readiness reviews is beneficial but too few can prove disadvantageous.

Having readiness reviews on the schedules provides a tangible means of measuring progress with comparison to the project timeline.

With all the life-cycles mapped and tailored, they can now be compared to each other. The four untailored complex life-cycles range from two years to over ten years. The timelines of the above models are to scale in their own right but not with each other. Figure 22 shows how each life-cycle and phase compare to each other.

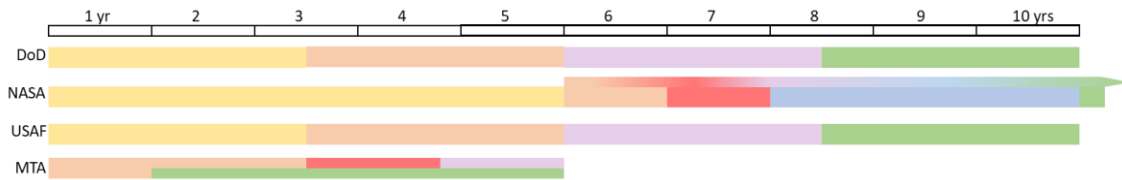


Figure 22. Complex Life-Cycle Timelines

The above complex VMS life-cycles reflect that there are some event and review similarities between the models. To evaluate these events and reviews more closely, they were individually listed by model and organized to identify the parallels and uniqueness. Table 8 itemizes the events and reviews side by side and reveals the frequency of use among the four models.

Table 8. Complex Events by Organization

| Org   | DoD                                        | NASA                               | USAF                                 | AF MTA         | frequency |
|-------|--------------------------------------------|------------------------------------|--------------------------------------|----------------|-----------|
| Event |                                            |                                    | AF Review Board                      |                | 1         |
|       | ICD Validation                             |                                    | ICD Validation                       |                | 2         |
|       |                                            | MCR                                |                                      |                | 1         |
|       | MDD                                        | KDP A                              | MDD                                  |                | 3         |
|       | AoA Review                                 |                                    | AoA Review                           |                | 2         |
|       |                                            | ASM                                |                                      |                | 1         |
|       | ASR                                        |                                    |                                      |                | 1         |
|       |                                            | MDR                                |                                      |                | 1         |
|       | Milestone A Decision Review                | KDP B                              | Milestone A                          |                | 3         |
|       | SRR                                        | SRR                                | SRR                                  |                | 3         |
|       | SFR                                        |                                    | SFR                                  |                | 2         |
|       | CDD Validation                             |                                    | CDD Validation                       |                | 2         |
|       |                                            |                                    | SRAR                                 |                | 1         |
|       | Test & Evaluation Planning                 |                                    |                                      |                | 1         |
|       | RFP Release Decision                       |                                    | RFP Decision                         |                | 2         |
|       | PDR                                        | PDR                                | PDR                                  |                | 3         |
|       | Milestone B Decision Review                | KDP C                              | Milestone B                          | Beta Decision  | 4         |
|       | CDR                                        | CDR                                | CDR                                  |                | 3         |
|       | CPD Validation                             |                                    | CPD Validation                       |                | 2         |
|       | Test Readiness Review (TRR)                |                                    | TRR                                  |                | 2         |
|       | DT&E                                       |                                    | DT&E                                 |                | 2         |
|       | EOA                                        |                                    |                                      |                | 1         |
|       | System Verification Review (SVR)           |                                    | Verification & Validation (V&V)      |                | 2         |
|       |                                            |                                    | Functional Configuration Audit (FCA) |                | 1         |
|       | OA                                         |                                    | OA                                   |                | 2         |
|       | PRR                                        | PRR                                | PRR                                  |                | 3         |
|       |                                            | System Integration Review (SIR)    |                                      |                | 1         |
|       | Milestone C Decision Review                | KDP D                              | Milestone C                          | Gamma Decision | 4         |
|       | LRIP Decision Review                       |                                    | LRIP                                 |                | 2         |
|       | Operational Test Readiness Review (OTRR)   |                                    |                                      |                | 1         |
|       | IOT&E                                      |                                    | IOT&E                                |                | 2         |
|       | OT&E                                       |                                    | OT&E                                 |                | 2         |
|       | PCA                                        | SAR                                | PCA                                  |                | 3         |
|       | FOT&E                                      |                                    |                                      |                | 1         |
|       |                                            | Operational Readiness Review (ORR) |                                      |                | 1         |
|       |                                            |                                    | Manufacturing Readiness Review       |                | 1         |
|       |                                            |                                    | Initial Operating Capability (IOC)   |                | 1         |
|       | Full-Rate Production (FRP) Decision Review |                                    | FRP Decision                         |                | 2         |
|       |                                            | Mission Readiness Review (MRR)     |                                      |                | 1         |
|       |                                            |                                    | Full Operational Capability (FOC)    |                | 1         |

To assess the necessity of these events and reviews when examining them all as a single life-cycle, the 40 line items need to be examined more closely. Table 9 removes the repeats and provides descriptions of each. Examining the descriptions provides insight into events and reviews that can be combined or waived.

Table 9. All Complex Events

| Event                       | Org  | Reference     | Description                                                                                                                                                                                                       |
|-----------------------------|------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| AF Review Board             | AF   | AFI 63-101    | forums chaired by the SAE, or as delegated, for conducting major decision reviews                                                                                                                                 |
| ICD Validation              | DoD  | JCIDS         | stakeholders validate operational attributes and capability requirements best address the needs of the force                                                                                                      |
| MCR                         | NASA | 7123.1C       | to evaluate the feasibility of the proposed mission concept(s) and its fulfillment of the program's needs and objectives                                                                                          |
| MDD                         | DoD  | DoDI 5000.02T | entry point into the acquisition process                                                                                                                                                                          |
| AoA Review                  | DoD  | DoDI 5000.02T | Assess how well the recommended alternative satisfies requirements in the most cost-effective manner                                                                                                              |
| ASM                         | NASA | 7120.5E       | strategic planning and procurement forum where senior Agency management reviews major acquisitions in programs and projects                                                                                       |
| ASR                         | DoD  | DAG           | evaluate whether there is sufficient understanding of the technical maturity, feasibility, and risk of the preferred materiel solution                                                                            |
| MDR                         | NASA | NPR 7123.1C   | to evaluate the credibility and responsiveness of the proposed mission/system architecture to the program requirements and constraints                                                                            |
| Milestone A Decision Review | AF   | AFI 63-101    | investment decision to pursue specific product or design concepts, and to commit the resources required to mature technology and/or reduce any risks                                                              |
| SRR                         | AF   | SMC SE        | technical review to ensure the system requirements are captured and stakeholders are ready to proceed with the initial system design                                                                              |
| SFR                         | DoD  | DAG           | to evaluate whether the functional baseline satisfies the end-user requirements and capability needs and whether functional requirements and verification methods support achievement of performance requirements |
| CDD Validation              | DoD  | DoDI 5000.02T | validate that requirements are technically achievable, affordable, testable and address the priorities of the stakeholders                                                                                        |
| SRAR                        | AF   | SMC SE        | Review and Approval of the Software Architecture and Functional Requirements Baseline                                                                                                                             |
| Test & Evaluation Planning  | DoD  | DoDI 5000.02T | develop integrated test program summary and master schedule of all major test events or test phases                                                                                                               |
| RFP Release Decision        | DoD  | DoDI 5000.02T | to ensure, prior to the release of the solicitation for EMD, that an executable and affordable program has been planned to use a sound business and technical approach                                            |
| PDR                         | DoD  | DoDI 5000.02T | decision to commit the resources needed to conduct development leading to production and fielding of the product.                                                                                                 |
| Milestone B Decision Review | AF   | AFI 63-101    | decision to commit the resources needed to conduct development leading to production and fielding of the product.                                                                                                 |
| CDR                         | DoD  | DoDI 5000.02T | assesses design maturity, design build-to documentation, and remaining risks and establishes the initial product baseline; decision point to begin prototype build                                                |
| CPD Validation              | DoD  | JCIDS         | assess how the capability solution, its performance attributes (KPPs, KSAs, and APAs), and other supporting data, address the validated capability requirements                                                   |
| TRR                         | DoD  | DoDI 5000.02T | assess test objectives, test methods and procedures, test scope, safety, and whether test resources have been properly identified and coordinated                                                                 |
| DT&E                        | DoD  | DoDI 5000.02T | to manage and mitigate risks during development and verify that products are compliant with operational requirements                                                                                              |
| EOA                         | DoD  | DAG           | to evaluate a program's progress early in the process towards developing an operationally effective, suitable, and survivable system                                                                              |
| SVR                         | DoD  | DAG           | technical assessment point at which the actual system performance is verified to meet the requirements in the system performance specification and is documented in the functional baseline                       |
| FCA                         | AF   | SMC SE        | formal examination of functional characteristics to verify that the system has achieved the requirements in its allocated baseline                                                                                |
| OA                          | DoD  | DAG           | test event that is conducted before initial production units are available and which incorporates substantial operational realism                                                                                 |
| PRR                         | DoD  | DAG           | determines whether the system design is ready for production, and whether the developer has accomplished adequate production planning for entering LRIP and FRP                                                   |
| SIR                         | NASA | NPR 7123.1C   | to evaluate the readiness of the project and associated supporting infrastructure to begin system integration and evaluate whether the remaining project development can be completed within available resources  |
| Milestone C Decision Review | DoD  | DoDI 5000.02T | decision that the project is stable and will meet stated and derived requirements based on acceptable performance                                                                                                 |

|                                |      |               |                                                                                                                                                                                                |
|--------------------------------|------|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| LRIP Decision Review           | DoD  | DoDI 5000.02T | establishes the initial production base for the system or capability increment                                                                                                                 |
| OTRR                           | DoD  | DAG           | review of DT&E results, an assessment of the system's progress against the KPPs, key system attributes, and critical technical parameters in the TEMP                                          |
| IOT&E                          | DoD  | DoDI 5000.02T | independent, dedicated phase of OT&E before full-rate production or full deployment that provides objective test results free from potential conflicts of interest or bias                     |
| OT&E                           | DoD  | DoDI 5000.02T | to determine the operational effectiveness, operational suitability, and survivability (including cybersecurity) or lethality of a system when operated under realistic operational conditions |
| PCA                            | DoD  | DAG           | to examine the "as-built" configuration of the system or a configuration item against its technical documentation to establish or verify its product baseline                                  |
| FOT&E                          | DoD  | DAG           | to complete unfinished IOT&E activity and evaluate major technical changes made to the system to correct identified deficiencies in the IOT&E                                                  |
| ORR                            | NASA | NPR 7123.1C   | ensures that all system and support hardware, software, personnel, procedures, supporting capabilities, and user documentation are operationally ready                                         |
| Manufacturing Readiness Review | AF   | SMC SE        | confirm readiness for Production, Training, Deployment, Ops, and Support                                                                                                                       |
| IOC                            | AF   | AFPAM         | the initial number of systems identified in the contract have been delivered to start operations                                                                                               |
| FRP Decision Review            | DoD  | DoDI 5000.02T | assess the results of initial OT&E, initial manufacturing, and limited deployment, and determine whether or not to produce the full amount                                                     |
| MRR                            | NASA | NPR 7123.1C   | examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful launch                                                                    |
| FOC                            | AF   | AFPAM         | the full number of systems identified in the contract have been delivered                                                                                                                      |

By waiving unnecessary events and combining others where possible, the list is reduced to one that looks similar to a combination of the tailored DoD and NASA models. The list identifying why events were waived and where events were combined is found in Appendix A due to its size. In addition to tailoring the events and reviews, the phases and timeline were modified for CSRA usage in Figure 23.

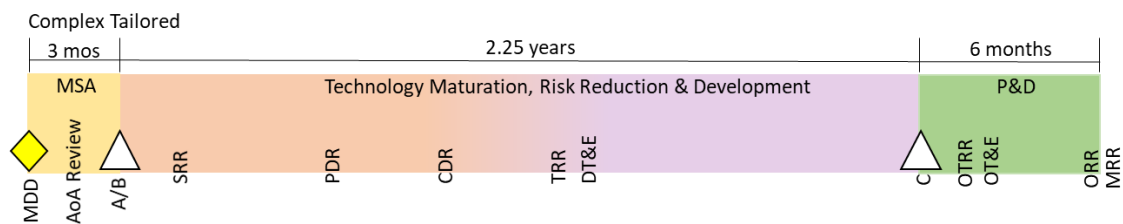


Figure 23. Complex Tailored Life-Cycle

Next, the simple life-cycles were examined the same way using the same methods. At the USAFA, cadets are expected to hold several of the DoD reviews and briefs, including the Alternative Systems Review (ASR), Preliminary Design Review (PDR), Critical Design Review (CDR), and Final Readiness Review (FRR). No parts

could be ordered or fabricated until the PDR was held and all open action items had been closed. Similarly, subsystem integration is not authorized until cadets complete the CDR. Following subsystem integration, the system is tested to confirm operational performance and lastly field testing. The FRR confirms that all the system requirements have been met and the satellite is ready to launch.

Unlike any of the life-cycles that have been already reviewed, the USAFA cadets do not just complete one satellite build. They start with an Engineering Model (EM) that is used to confirm all components fit and are compatible with each other. During the EM build, cadets hold the first CDR when they reach the appropriate level of design and the FRR when complete. Following a successful EM FRR, a Qualification Model (QM) is assembled. The QM is built like a functional satellite but is used for all the required testing. Testing is conducted above the limits required for the final satellite to be flown in order to find the true limitations. During the QM's lifespan, cadets hold another CDR and FRR. Finally, the Flight Model (FM) is constructed as the satellite to be launched. It must still pass all required qualification testing that the QM went through. Again, with the FM, a CDR and FRR are accomplished (Siegenthaler, 2004). Because the total build is several years, this process of three different builds gives cadets the opportunity to get hands on experience with at least one satellite (Blacksun, 2012). This unique life-cycle is mapped in Figure 24.

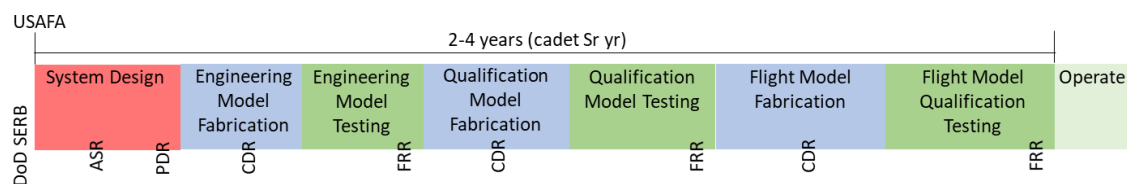


Figure 24. USAFA Life-Cycle Model

In tailoring the USAFA life-cycle, the multiple builds were dropped and the timeline was adjusted. The DoD SERB, ASR, PDR, CDR, and FRR are value-added events so all were kept in the tailored model as portrayed in Figure 25. Furthermore, the DoD SERB was moved to occur only after the project was accepted and started. The timeline was also adjusted to allow for considerable testing.

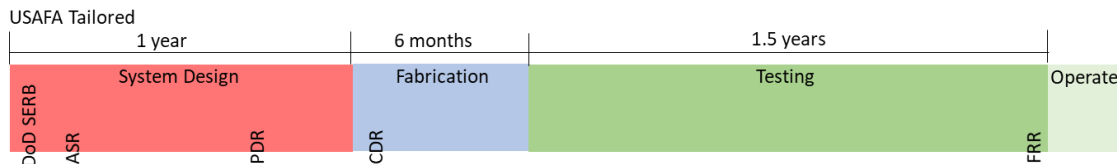


Figure 25. USAFA Tailored Life-Cycle

The cadets at the USNA complete their small satellite build in much less time than the USAFA. Even though the USNA cadets attempt to have a functioning CubeSat within a single year, they hold five reviews to include the System Concept Review (SCR), System Requirements Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), and Mission Readiness Review (MRR). The CDR must be completed by the end of the cadets' first semester of the capstone so the second semester can focus on the fabrication and testing. If all goes well, cadets should be ready for the MRR by the end of the second semester. This simple life-cycle is mapped in Figure 26.

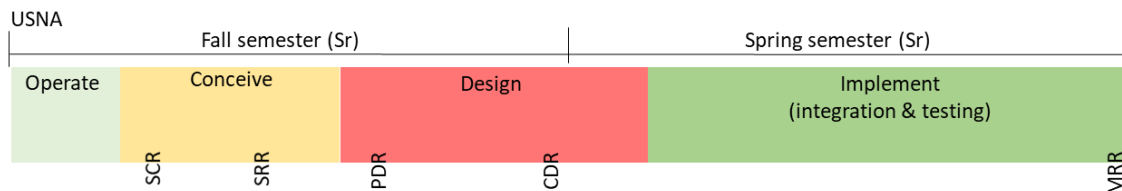


Figure 26. USNA Life-Cycle Model

All five reviews are value-added so none were removed from the tailored model. The CSRA staff and students are regularly operating the satellites already in orbit so the

operating phase in the beginning was removed. Furthermore, the timeline was adjusted in Figure 27 since CSRA is not trying to complete each CubeSat in a year. Within the three years, most of the life-cycle was devoted to integration and testing per the advice of many other universities as mentioned in Chapter II.

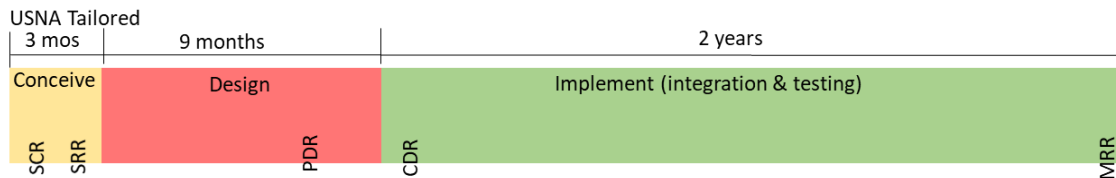


Figure 27. USNA Tailored Life-Cycle

At MIT, the coursework is designed in a manner that entrenches students into project management methods to execute on schedule within resource constraints, effectively manage risks, and meet mission objectives. Students must document their designs, hold major design reviews, and regularly interface with their customers and reviewers. Students conduct a System Requirements Review (SRR) and Conceptual Design Review (CoDR) in preparation to present their completed CubeSat designs that fulfill mission requirements in a Preliminary Design Review (PDR) at the end of the first semester. Since the next two semesters focus on hands-on lab work, the students conduct bench reviews near the end of each. The Critical Design Review (CDR) and Acceptance Review (AR) demonstrate the lab experiments and present the students' results and analysis. Throughout the courses, students submit several written deliverables on mission requirements, CubeSat design, tradeoffs, budget, test plans, and test results (Smith, 2011). The MIT model is presented in Figure 28.

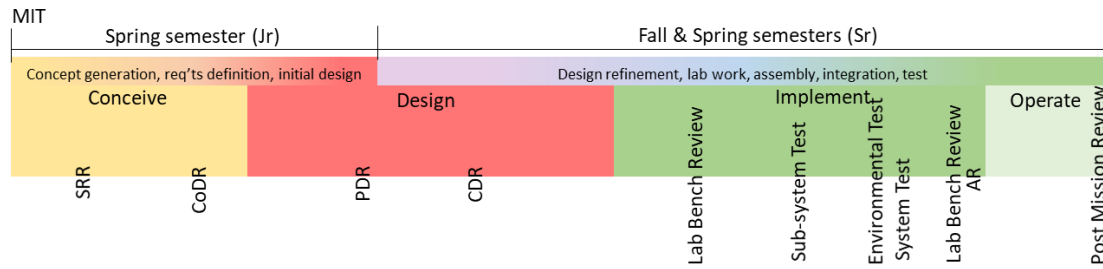


Figure 28. MIT Life-Cycle Model

The tailored model removed the CoDR and the end of semester Lab Bench Reviews. Although the CSRA CubeSats are discussed and used as examples in the academia, the classes are not directly tied to the development schedule. Figure 29 also reveals that the timeline was adjusted to reflect the three-year objective. Because the USNA used MIT's CDIO model, the tailored life-cycles have the same timelines for the three phases of development.

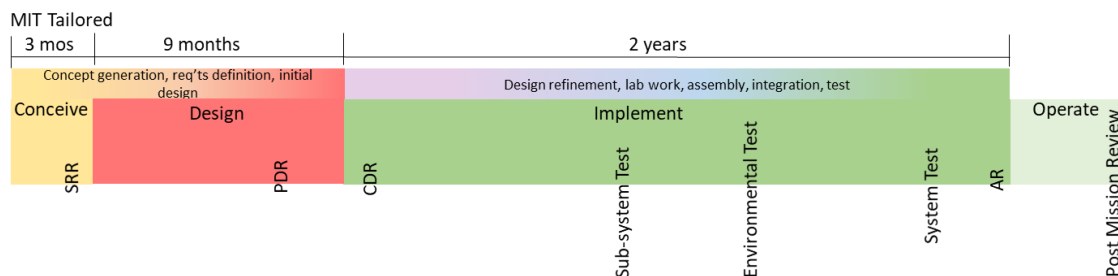


Figure 29. MIT Tailored Life-Cycle

The SmallSats produced at NPS are not completed in one year so students do not experience the full life-cycle. In addition to hosting a Mission Requirements Review, PDR, CDR, two post-test reviews, ORR, and FRR, students hold quarterly reviews to provide status updates. These updates provide briefing experience to students who are not present for the official reviews. The Mission Requirements Review acts as a control gate

between analysis and design, and the CDR is the control gate between design and fabricate, integrate, and test. Figure 30 is the untailored NPS life-cycle.

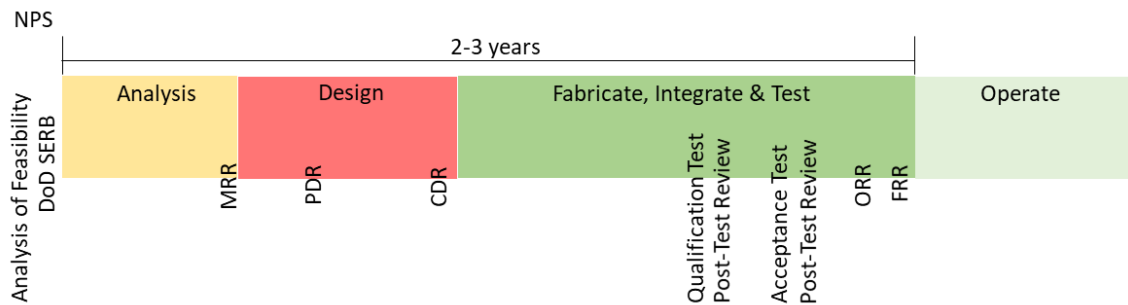


Figure 30. NPS Life-Cycle Model

As with all the other tailored models, the events prior to the start of the life-cycle were modified. The Analysis of Feasibility was waived as this should be completed by the sponsor with information provided to CSRA upon adoption of the project. The DoD SERB was moved to occur only after the project was accepted and started. The rest of the events and reviews were saved except for the post-test review following the acceptance test. This review can be combined with the ORR because if the test results are not to standards, the ORR should not be held. The tailored NPS life-cycle is portrayed in Figure 31.

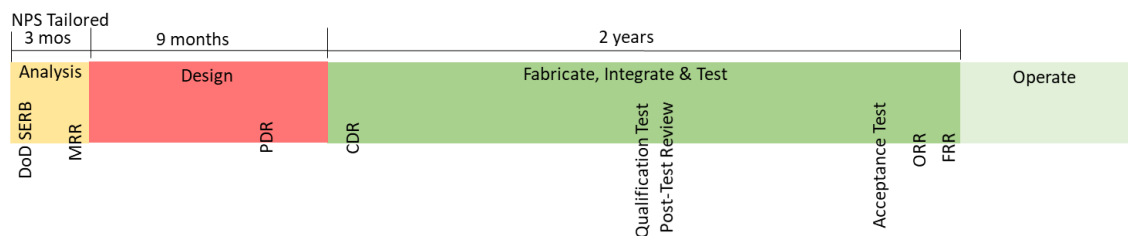


Figure 31. NPS Tailored Life-Cycle

The only information obtained for Aalborg University was that the students take two to four years on average to progress through the four cycles of design, prototype,

build, and test. Since Aalborg is one of the two overseas universities with data acquired in this research, the information is still worth reporting. These phases are mapped in Figure 32.



Figure 32. Aalborg University Life-Cycle Model

Without much to tailor, only the timeline was adjusted in Figure 33. The tailored timeline provides ample time for the developers to test the sub-systems and integrated systems.

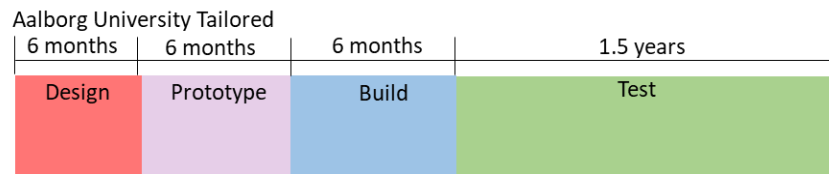


Figure 33. Aalborg University Tailored Life-Cycle

Information for another overseas CubeSat developing university was found for the Luleå University of Technology. The students that developed SE01, a 2U CubeSat, followed the University's standard processes consisting of multiple overlapping phases. The design phase concludes with a CDR (Nieto-Peroy, 2019). With all the overlapping phases, it was easier to map the life-cycle than to explain it. All the phases and few events are documented in Figure 34.

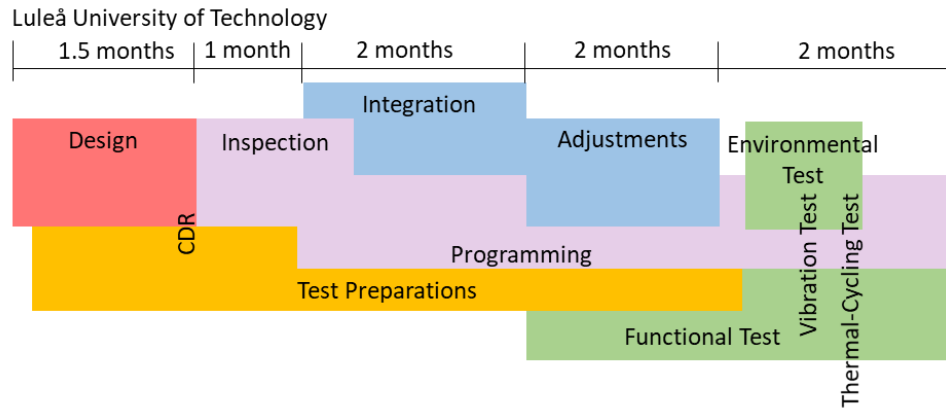


Figure 34. Luleå University Life-Cycle Model

Many of the modeled phases overlapped in purpose and time so they were combined when appropriate. The few events that were recorded are important so they were kept as shown in Figure 35. The test phase was only scheduled for one year because it is portrayed as strictly testing instead of integration and testing. Testing can/may also occur during the integration/adjustment period so plenty of time is still being allocated to this important aspect.

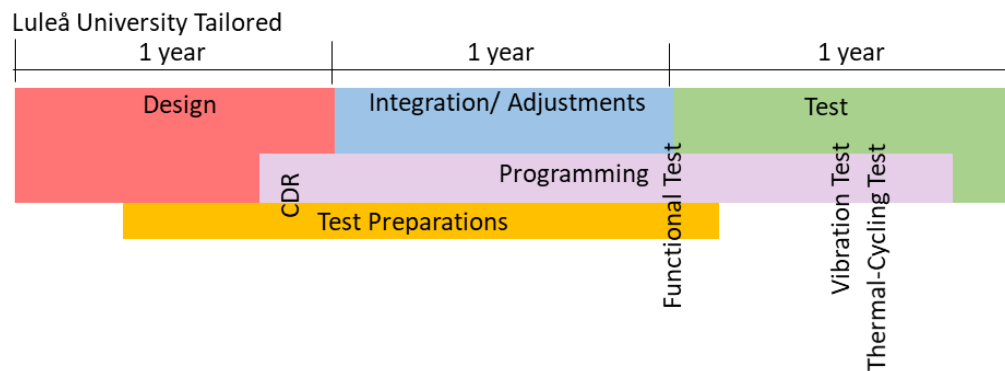


Figure 35. Luleå University Tailored Life-Cycle

While the information from some of the universities was vague, the CubeSat 101 is descriptive. Concept development is built around the CubeSat mission. If the mission is sponsored, the sponsor will already have a concept and will provide requirements to

design to. If not sponsored, the purpose of the CubeSat development can be almost anything. As others noted though, it is key to keep the objective at an obtainable level. If the sponsor did not specify mission criteria, they may require some type of merit or feasibility review to judge if the mission can be executed as planned. This review can produce needed insight from outside subject matter experts and in time provides stakeholder assurance that the developer can produce a mission successful CubeSat.

Once all stakeholders are confident that a CubeSat can be designed to accomplish the mission, it is time to start researching other designs to determine what will work, might work, and will not work. Many CubeSats have already been developed so reviewing their designs is the suggested start of designing a new satellite. Research will also need to take place to select which components will work best for the system. Many COTS parts are available, but they may not meet the specific mission needs or may not fall within the project's budget constraints. Building components in-house can keep costs low while also enhancing student's educational experience. The CubeSat 101 suggests keeping the design as simple as possible and reviewing limitations as specified in the *CubeSat Design Specification* (CDS) published by Cal Poly. The CubeSat design is a very critical step so ample time should be scheduled to ensure all aspects are considered.

Whether the CubeSat's mission is part of the CubeSat Launch Initiative (CSLI) or a sponsored program or completely independent, there is a need to be manifested on a rocket launch. Once a launch vehicle (LV) provider is determined, mission coordination needs to start. Coordination includes managing integration schedules, deliverable documents, and mission-specific CubeSat-to-dispenser Interface Control Document (ICD) requirement verification between the LV provider and CubeSat developer. The LV

provider will provide information on the CubeSat dispenser that will be used so the satellite can be designed to correctly interface. The ICD is the official rulebook that must be complied with for the LV provider to accept the CubeSat for launch.

Deliverables required by the ICD are created and submitted throughout the CubeSat development. Some standard deliverables are: Orbital Debris Assessment Report (ODAR), transmitter surveys, materials list, mass properties report, battery report, dimensional verifications, electrical report, venting analysis, testing procedures and reports, compliance letter, and safety package inputs. All required deliverables will be detailed in the ICD.

Radio signals are key to communication between the orbiting CubeSat and the ground station. To legally transmit these radio frequency signals, a radio license must be obtained per Federal law. Obtaining licenses is a lengthy process so it is important to understand the regulatory rules and constraints to ensure the application contains all necessary information before it is submitted. This should occur before finalizing the system design and operation plans because alterations may be needed. Radio licenses for transmission to or from U.S. Government operated satellites are handled by the National Telecommunications and Information Administration (NTIA). The CubeSat team will work directly with the appropriate Federal agency Spectrum Office who works with the NTIA to obtain RF authorization.

If any necessary hardware for the satellite cannot be acquired as COTS, these components need to be fabricated in-house. This can increase learning opportunities for students and keep cost down, but it can also cause schedule delays. The schedule needs to include plenty of margin when planning for fabrication.

During CubeSat subsystem assembly, system integration, and testing, developers should maintain detailed records of all phases and take as many pictures as possible. A very common problem with student turnover is the immediate loss of knowledge and expertise. Thorough documentation helps new students pick up where the graduating students left off.

Developmental testing is accomplished to confirm all parts of the CubeSat work as planned. These tests are done in-house to the degree that meets the design requirements that were initially specified. They can be performed as often as the developer deems necessary. Subsystem functions should be tested prior to interfacing and components should be added incrementally, testing along the way. The test reports should be overly detailed but will stay in-house. Verification testing proves to the LV provider that the CubeSat is as safe and sturdy as specified in the ICD. The ICD will layout the specific tests to be performed and require the test results for the verification. This typically includes vibration, shock, thermal vacuum, acoustic environment, and Day-in-the-Life (DITL) testing. Once verification testing is successfully complete, the CubeSat is to be left as is.

After the CubeSat is fully assembled and testing complete, a Mission Readiness Review (MRR) will be delivered to CSLI or any sponsor to show that the CubeSat satisfies all the ICD requirements. All the necessary deliverables should have been submitted by this point so the MRR is a summary of the data previously submitted. Before the satellite is put on a rocket, the CubeSat must be integrated with the CubeSat dispenser and tested to confirm no issues. After all testing is completed, the LV provider team typically has physical control of the integrated CubeSat dispenser and the developer

will no longer have access to it. At some point following this integration, the dispenser is integrated with the launch vehicle. The LV integration normally occurs between two weeks and four months prior to the scheduled launch. Finally, all parties wait for launch and then CubeSat operations begin (Chin, 2017). The life-cycle displayed in Figure 36 is based on the notional timeline listed but development can be completed at any pace.

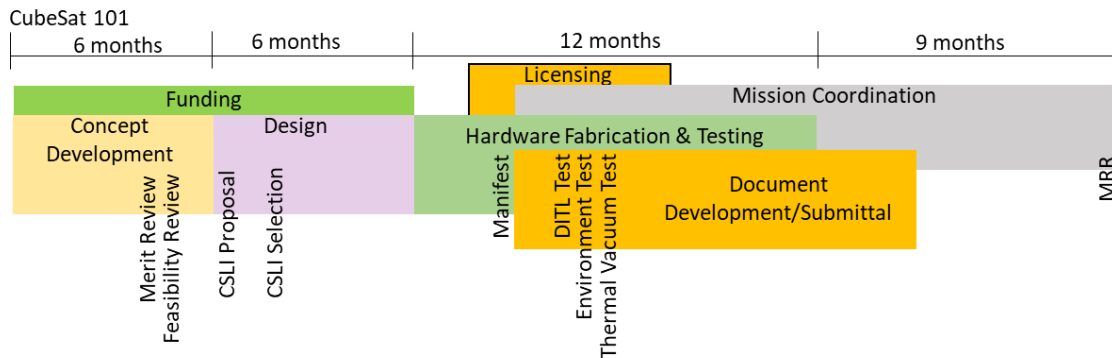


Figure 36. CubeSat 101 Life-Cycle Model

The tailored model removes the CSLI Proposal and Selection events because this process does not apply to CSRA. The Funding phase was removed because CSRA works with the sponsor to determine resource allocations before agreeing to start a project. The Hardware Fabrication and Testing phase was expanded based on the recommendations of numerous subject matter experts (SME) and other universities suggesting the importance of testing. This final tailored life-cycle is revealed in Figure 37.

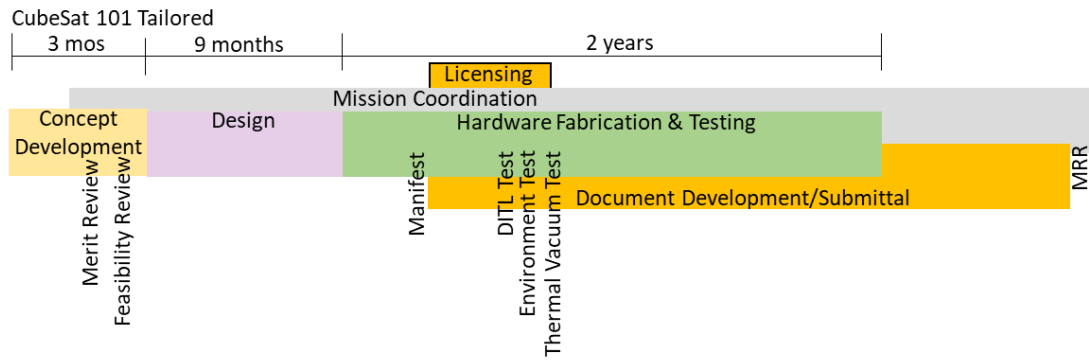


Figure 37. CubeSat 101 Tailored Life-Cycle

With all the simple life-cycles mapped and tailored, they can now be compared to each other. The seven untailored life-cycles range from nine months to four years. The timelines of the above models are to scale in their own right but not with each other. Figure 38 shows how each life-cycle and phase compare to each other. It also includes the full period for MSU and U-M without phases because only the average completion time was identified.

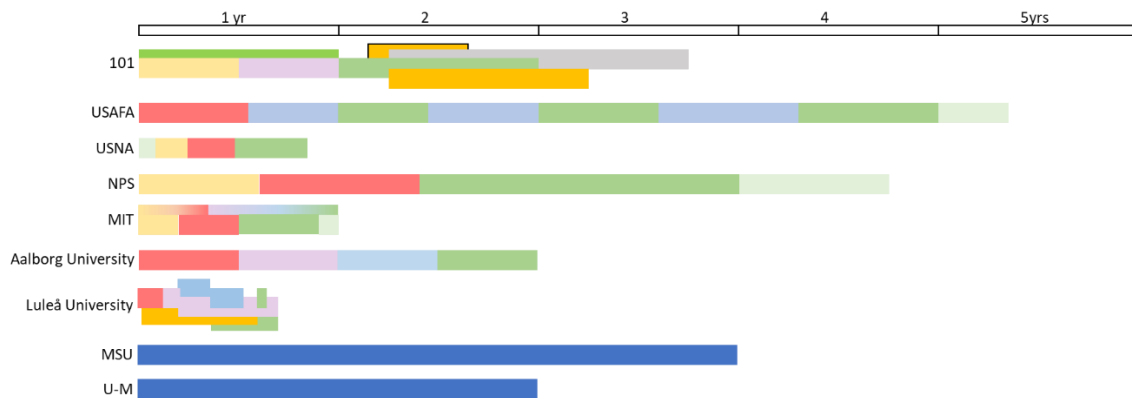


Figure 38. Simple Life-Cycle Timelines

The above simple VMS life-cycles reflect that there are some event and review similarities between the models. To compare these events and reviews more closely, they were individually listed by model and organized to identify the parallels. Table 10

itemizes the events and reviews side by side and reveals the frequency of use among the ten universities analyzed and the CubeSat 101.

Table 10. Simple Events by Organization

| frequency                 | 1             | 2                       | 2        | 1   | 1   | 3                           | 1             | 1 | 4                        | 1                                | 1              |
|---------------------------|---------------|-------------------------|----------|-----|-----|-----------------------------|---------------|---|--------------------------|----------------------------------|----------------|
| <b>CubeSat 101</b>        | Merit Review  | Feasibility Review      |          |     |     |                             | CSLI Proposal |   |                          |                                  |                |
| <b>Luleå University</b>   |               |                         |          |     |     |                             |               |   |                          |                                  |                |
| <b>MSU</b>                |               |                         |          |     |     |                             |               |   | Weekly all-hands meeting |                                  |                |
| <b>Aalborg University</b> |               |                         |          |     |     |                             |               |   | Weekly Standup           |                                  |                |
| <b>U-M</b>                |               |                         |          |     |     |                             |               |   | Weekly Standup           |                                  |                |
| <b>NPS</b>                |               | Analysis of Feasibility | DoD SERB |     |     | Mission Requirements Review |               |   |                          |                                  |                |
| <b>MIT</b>                |               |                         |          |     |     | SRR                         | CoDR          |   |                          | End-of-Semester Lab Bench Review |                |
| <b>USCGA</b>              |               |                         |          |     |     |                             |               |   | Weekly Update            |                                  | Capstone Brief |
| <b>USMA</b>               |               |                         |          |     |     |                             |               |   |                          |                                  |                |
| <b>USNA</b>               |               |                         |          | SCR |     | SRR                         |               |   |                          |                                  |                |
| <b>USAFSA</b>             |               |                         | DoD SERB |     | ASR |                             |               |   |                          |                                  |                |
| <b>Org</b>                | <b>Events</b> |                         |          |     |     |                             |               |   |                          |                                  |                |

|                |     |     |                  |                |              |                    |                  |                              |                             |                        |                 |                  |     |
|----------------|-----|-----|------------------|----------------|--------------|--------------------|------------------|------------------------------|-----------------------------|------------------------|-----------------|------------------|-----|
| 1              | 5   | 6   | 1                | 1              | 2            | 3                  | 1                | 1                            | 3                           | 2                      | 2               | 1                | 2   |
| CSLI Selection |     |     | Mission Manifest |                | DITL Testing |                    |                  |                              | Dynamic Environment Testing | Thermal Vacuum Testing |                 |                  |     |
|                |     | CDR |                  |                |              |                    |                  |                              | Vibration Test              | Thermal-Cycle Test     |                 |                  |     |
|                |     |     |                  | Ground testing | DITL Testing | Subsystem Testing  |                  | Hardware-in-the-Loop Testing |                             |                        |                 |                  |     |
|                |     |     |                  |                |              |                    |                  |                              |                             |                        |                 |                  |     |
|                |     |     |                  |                |              |                    |                  |                              |                             |                        |                 |                  |     |
|                | PDR | CDR |                  |                |              | Qualification Test | Post Test Review |                              |                             |                        | Acceptance Test | Post Test Review | ORR |
|                | PDR | CDR |                  |                |              | Sub-system Test    |                  |                              | Environmental Test          |                        | System Test     |                  | AR  |
|                |     |     |                  |                |              |                    |                  |                              |                             |                        |                 |                  |     |
|                | PDR | CDR |                  |                |              |                    |                  |                              |                             |                        |                 |                  |     |
|                | PDR | CDR |                  |                |              |                    |                  |                              |                             |                        |                 |                  |     |
|                | PDR | CDR |                  |                |              |                    |                  |                              |                             |                        |                 |                  |     |

|  |     |     |  |  |                     |     |  |  |  |  |     |   |
|--|-----|-----|--|--|---------------------|-----|--|--|--|--|-----|---|
|  | FRR | MRR |  |  |                     | FRR |  |  |  |  | MRR | 4 |
|  |     |     |  |  | Post Mission Review |     |  |  |  |  |     | 1 |

To assess the necessity of these events and reviews when examining them all as a single life-cycle, the 27 line items need to be examined more closely. Table 11 removes the repeats and provides descriptions to each. Examining the descriptions provides insight into events and reviews that can be combined or waived.

Table 11. All Simple Events

| Event                            | Org    | Description                                                                                                                                                                        |
|----------------------------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Merit Review                     | CS-101 | assess the goals and objectives of the mission to determine the quality of its investigation in regard to science, education, and/or technology                                    |
| Analysis of Feasibility          | NPS    | to determine the viability of a concept                                                                                                                                            |
| DoD SERB                         | USAF   | evaluate, approve, and prioritize a list of candidate experiments for spaceflight consideration                                                                                    |
| SCR                              | USNA   | to ensure the concept is a viable approach for meeting the system requirements                                                                                                     |
| ASR                              | USAF   | evaluate whether there is sufficient understanding of the technical maturity, feasibility, and risk of the preferred materiel solution                                             |
| SRR/MRR                          | USNA   | technical review to ensure the system requirements are captured and stakeholders are ready to proceed with the initial system design                                               |
| CSLI Proposal                    | CS-101 | response to NASA posting any Announcement of Opportunity                                                                                                                           |
| CoDR                             | MIT    | conceptualizing, analyzing, and defining project plans and requirements                                                                                                            |
| Weekly Update                    | USCGA  | held among the primary participants to manage the project                                                                                                                          |
| End-of-semester Lab Bench Review | MIT    | students demonstrate their laboratory experiments, present analysis and results, and field questions from the teaching staff                                                       |
| Capstone Brief                   | USCGA  | detailed summary of all work performed during student's capstone project                                                                                                           |
| CSLI Selection                   | CS-101 | proposal approval confirming that NASA will support CubeSat launch                                                                                                                 |
| PDR                              | USAF   | assesses the maturity of the preliminary design supported by the results of requirements trades, prototyping, and critical technology demonstrations; establish allocated baseline |
| CDR                              | USAF   | assesses design maturity, design build-to documentation, and remaining risks and establishes the initial product baseline; decision point to begin prototype build                 |
| Mission Manifest                 | CS-101 | matched with a launch that will work for your mission parameters                                                                                                                   |
| Ground testing                   | MSU    | confirm satellite communication with ground station performs as expected                                                                                                           |
| DITL Testing                     | MSU    | shows the CubeSat's electronics and flight software work as expected                                                                                                               |
| Sub-system Test                  | MIT    | testing individual sub-systems before integration to verify they perform as required                                                                                               |
| Post Test Review                 | NPS    | determine sub-system effectiveness based on test results and take appropriate actions                                                                                              |
| Hardware-in-the-Loop Testing     | MSU    | hardware tested in simulated scenarios                                                                                                                                             |
| Environmental Test               | MIT    | show the CubeSat will survive the vibration and shock that it will experience during launch                                                                                        |
| Thermal Vacuum Testing           | CS-101 | required on almost all missions, primarily to allow the CubeSat's materials to outgas any possible contaminants before the actual launch                                           |
| System Test                      | MIT    | testing individual sub-systems before integration to verify they perform as required                                                                                               |
| Post Test Review                 | NPS    | determine system effectiveness based on test results and take appropriate actions                                                                                                  |
| ORR                              | NPS    | ensures that all system and support hardware, software, personnel, procedures, supporting capabilities, and user documentation are operationally ready                             |
| FRR                              | USAF   | examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful launch                                                        |
| Post Mission Review              | MIT    | report the outcomes of the vehicle performance                                                                                                                                     |

By waiving unnecessary events and combining others where possible, the list becomes the USNA model with the addition of DoD SERB, sub-system test, system test, and post mission review. The list identifying why events were waived and where events were combined is found in Appendix B due to its size. In addition to tailoring the events and reviews, the phases and timeline were modified for CSRA usage in Figure 39.

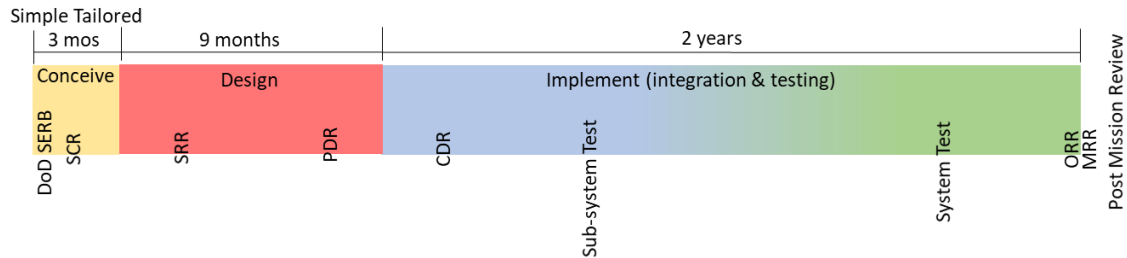


Figure 39. Simple Tailored Life-Cycle

When comparing the tailored complex model to the tailored simple model, they are very similar even though they were created by reviewing different agencies. Figure 40 shows how similar the models are.

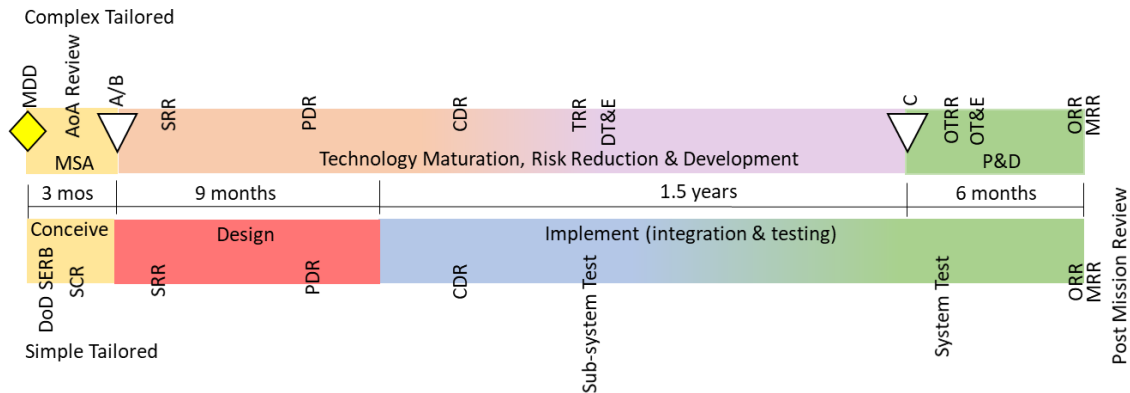


Figure 40. Comparing Tailored Models

The two models are similar because while the simple and complex organizations hold different reviews and events, the critical ones are present in both. The other “fluff” can be either waived or combined. Either could work but since they were created within

the limitations of the initial models, they are not fully customized. Figure 41 contains many of the same phases and reviews but has been further tailored with extra attention given to the recommendations of other successful CubeSat developers.

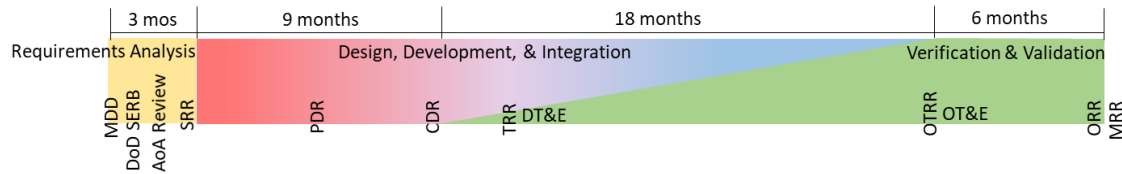


Figure 41. Final Life-Cycle

The Materiel Development Decision (MDD) is CSRA’s decision to accepting the responsibility of a new CubeSat and starts the Requirements Analysis phase. As soon as CSRA decides to undertake a project, arrangements need to be made for the still undeveloped CubeSat to be approved for launch during a DoD SERB. After completing research into the capability requirements provided by the sponsor, an Analysis of Alternatives (AoA) Review is held to discuss possible recommendations and decide on the approach. The Systems Requirements Review (SRR) is conducted once all capability and functional requirements have been captured and satisfy the stakeholders’ needs. This review will also act as a milestone because the project will not proceed until stakeholders agree that system requirements have been accurately captured and other specific criteria have been met. With SRR approval, the project enters the Design, Development, and Integration (DD&I) phase. Next, the Preliminary Design Review (PDR) is held when an initial design that meets all capability and functionality requirements has been developed.

Following more design, development, and integration of subsystems, the Critical Design Review (CDR) is held to assess design maturity. After the CDR, DD&I blends with the Verification and Validation (V&V) phase. The two phases overlap because

verification can be confirmed through Developmental Testing and Evaluation (DT&E) while the final design is still in development. Prior to any testing, a Test Readiness Review (TRR) must be held to ensure the planned tests will be conducted safely and will conclude with results showing how requirements are met. Similar to the SRR, the TRR serves as the required milestone before testing occurs.

The Operational Test Readiness Review (OTRR) serves as the final milestone and is held prior to any Operational Testing and Evaluation (OT&E) to ensure planned tests will be executed in a safe manner and that the tests will accurately validate that the system does what it was developed for in an operationally relevant environment. Following the completion of the OT&E events is the Operational Readiness Review (ORR) to confirm the system is fully operational and required deliverables for the launch vehicle provider (LVP) are complete. The CubeSat may not be integrated with the launch vehicle for a lengthy period so a Mission Readiness Review (MRR) will be held immediately prior to this occurring. The MRR is to confirm the CubeSat is still fully operational, has a full battery charge, and all associated equipment is available to be taken to the integration site.

The model holds reviews when it is important to get input from the stakeholders and requires the rest of the communication to occur offline between the specific parties involved. By combining the milestone decisions with the SRR, TRR, and OTRR, the project can focus more on the work than building charts and planning for extra meetings. Starting DT&E early allows the team to start testing components shortly after a preliminary design is approved which provides more time to identify and mitigate issues

or risks. The entrance/exit criteria that must occur at the milestone will be detailed later in this chapter.

## Tailoring Deliverables

The life-cycle is only one part of a developmental framework. Another major contributor to the framework is the documentation that is required to be completed and maintained. Just like the life-cycle, these too can be tailored, combined, or waived except for statutory deliverables. Statutory deliverables are mandated by law so they must be accomplished.

Before we can tailor the deliverables, we need to examine the full list from each organization. The lists of required documentation were sorted for assessment by organization as described in Chapter III. Also mentioned in Chapter III, the agencies were arranged by the level of complexity, referred to as complex and simple. First, all the complex deliverables were examined starting with the DoD in Table 12.

Table 12. DoD Full Deliverables

| Deliverable                         | Guidance      | Reference                   | Description                                                                                                                                                                                        | Stat | Reg |
|-------------------------------------|---------------|-----------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|
| AoA Study Guidance                  | DoDI 5000.02T | DoDI 5000.02T para 6d(1)(b) | regulatory guidance to guide the AoA; informs preparation of AoA Study Plan; prepared by DCAPE                                                                                                     |      | x   |
| AoA Study Plan                      | DoDI 5000.02T | DoDI 5000.02T para 6d(1)(b) | regulatory guidance to guide the AoA; prepared by lead DoD Component                                                                                                                               |      | x   |
| Defense Intelligence Threat Library | DoDI 5000.02T | DIA Directive 5000.200      | maintains projections of technology and adversary capability trends over the next 20 years                                                                                                         |      | x   |
| ICD                                 | DoDI 5000.02T | CJCSI 3170.01               | specifies one or more capability requirements and associated capability gaps which represent unacceptable operational risk if left unmitigated                                                     |      | x   |
| Affordability Analysis              | DoDI 5000.02T | DoDI 5000.02T Enc 8, Sec 3  | to promote responsible and sustainable investment decisions while avoiding starting or continuing programs that cannot be produced and supported within reasonable expectations for future budgets |      | x   |

|                                                       |               |                                 |                                                                                                                                                                                                                                                                                     |   |   |
|-------------------------------------------------------|---------------|---------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|
| Integrated Master Plan (IMP)                          | DAG           |                                 | event-driven government document that provides a framework against which all work is measured; consists of program events, significant accomplishments, and accomplishment criteria; should encompass all Integrated Product Team (IPT) and Work Breakdown Structure (WBS) elements |   |   |
| Acquisition Strategy (AS)                             | DoDI 5000.02T | DoDI 5000.02T Enc 2, para 6a    | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives                                                                |   | x |
| AoA                                                   | DoDI 5000.02T | 40 U.S.C 11312                  | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement                                                     |   | x |
| System Engineering Plan (SEP)                         | DoDI 5000.02T | DoDI 5000.02T Enc 3, Sec 2      | management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                                                              |   | x |
| Life-Cycle Sustainment Plan (LCSP)                    | DoDI 5000.02T | DoDI 5000.02 Enc 6, Sec 3       | describe sustainment influences on system design and the technical, business, and management activities to develop, implement, and deliver a product support package                                                                                                                |   | x |
| Integrated Master Schedule (IMS)                      | DAG           |                                 | integrated, networked model containing all the detailed discrete tasks necessary to realize the IMP accomplishment criteria                                                                                                                                                         |   |   |
| Technology Targeting Risk Assessment                  | DoDI 5000.02T | DIA Directive 5000.200          | country-by-country assessment conducted by the DoD entities within the DISE that quantify risks to critical program information (CPI) and related enabling technologies for weapons systems, and advanced technologies or programs                                                  |   | x |
| Program Protection Plan (PPP)                         | DoDI 5000.02T | DoDI 5000.02T Enc 3, para 13a   | to manage the risks to critical program information and mission-critical functions and components associated with the program                                                                                                                                                       |   | x |
| CDD                                                   | DoDI 5000.02T | JCIDS Manual                    | specifies capability requirements, in terms of developmental performance attributes (KPPs, KSAs, and APAs), and other related information necessary to support development of one or more increments of a materiel capability solution                                              |   | x |
| System Requirements Document (SRD)                    | DAG           | JCIDS Enclosure D               | defines the performance of the preferred materiel solution; system performance specification has sufficiently conservative requirements to allow for design trade space                                                                                                             |   |   |
| Concept of Operations (CONOPS)/Mission Profile (MP)   | DoDI 5000.02T | JCIDS Manual                    | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                      |   | x |
| Validated on-line Life-Cycle Threat (VOLT) Report     | DoDI 5000.02T | DIA Directive 5000.200          | includes threat modules and is written to articulate the relevance of each module to a specific acquisition program or planned capability                                                                                                                                           |   | x |
| Should Cost Target                                    | DoDI 5000.02T | DoDI 5000.02T para 6d(3)(b)1    | to proactively target cost reduction and drive productivity improvement into programs                                                                                                                                                                                               |   | x |
| Core Logistics Determination *                        | DoDI 5000.02T | DoDI 5000.02T Enc 6, para 3d(2) | applicability of core depot-level maintenance and repair capability requirements                                                                                                                                                                                                    | x |   |
| Item Unique Identification (IUID) Implementation Plan | DoDI 5000.02T | DoDI 8320.04                    | to identify and track applicable major end items, configuration-controlled items, and government-furnished property                                                                                                                                                                 |   | x |
| Test & Evaluation Master Plan (TEMP)                  | DoDI 5000.02T | DoDI 5000.02T Enc 4 & 5         | primary planning and management tool for the integrated test program                                                                                                                                                                                                                |   | x |

|                                                                                                                                   |               |                              |                                                                                                                                                                                                                                                                                    |   |   |
|-----------------------------------------------------------------------------------------------------------------------------------|---------------|------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|
| Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)/ National Environmental Policy Act (NEPA) Compliance * | DoDI 5000.02T | 42 U.S.C 4321-4347           | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system | x |   |
| Bandwidth Requirements Review                                                                                                     | DoDI 5000.02T | Sec 1047, Public Law 110-417 | a formal review process to ensure that the bandwidth requirements needed to support such program are or will be met                                                                                                                                                                |   | x |
| Information Support Plan (ISP)                                                                                                    | DoDI 5000.02T | DoDI 8330.01                 | describes IT and information needs, dependencies, and interfaces for programs; focuses on efficient and effective exchange of information that, if not properly managed, could limit or restrict the operation of the program                                                      |   | x |
| Spectrum Supportability Risk Assessment (SSRA)                                                                                    | DoDI 5000.02T | DoDI 4650.01                 | written determinations that the electromagnetic spectrum necessary to support the operation of the system during its expected life-cycle is or will be available in accordance with DoD Instruction 4650.01                                                                        |   | x |
| Information Technology (IT) and National Security System (NSS) Interoperability Certification                                     | DoDI 5000.02T | DoDI 8330.01                 | Joint Interoperability Test Command (JITC) certifies interoperability of IT with joint, multinational, and/or interagency interoperability requirements                                                                                                                            |   | x |
| RFP                                                                                                                               | DoDI 5000.02T | FAR                          | include specifications and statement of work                                                                                                                                                                                                                                       |   | x |
| Frequency Allocation Application *                                                                                                | DoDI 5000.02T | 47 U.S.C. 305                | required for all systems/equipment that use electromagnetic spectrum operating in U.S.                                                                                                                                                                                             | x |   |
| Clinger-Cohen Act (CCA) Compliance *                                                                                              | DoDI 5000.02T | Title 40 USC, Subtitle III   | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu or table 11 of DoDI 5000.02                                                      | x |   |
| Cybersecurity Strategy (CSS)                                                                                                      | DoDI 5000.02T | DoDI 8500.01                 | plan that provides an overview of the cybersecurity requirements for the system and describes the security controls in place or planned for meeting those requirements.                                                                                                            |   | x |
| Waveform Assessment Application                                                                                                   | DoDI 5000.02T | DoDI 4630.09                 | Application to the DoD CIO for approval of the development or modification of waveforms                                                                                                                                                                                            |   | x |
| Acquisition Program Baseline (APB)                                                                                                | DoDI 5000.02T | DoDD 5000.01                 | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                            |   | x |
| Capability Production Document (CPD)                                                                                              | DoDI 5000.02T | JCIDS Manual                 | specifies capability requirements, in terms of production performance parameters (KPPs, KSAs, and APAs), and other related information necessary to support production of a single increment of a materiel capability solution                                                     |   | x |
| Operational Test Plan (OTP)                                                                                                       | DoDI 5000.02T | DoDI 5000.02T Enc 5, para 3e | documents the test design, supporting methodology, and analytic details required for the specific operational test                                                                                                                                                                 |   | x |
| DT&E Assessment                                                                                                                   | DAG           |                              | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                                                                                   |   |   |
| Director, OT&E (DOT&E) Report of IOT&E                                                                                            | DoDI 5000.02T | 10 U.S.C 2399                | determine a system's operational effectiveness and operational suitability prior to FRP                                                                                                                                                                                            |   | x |
| Operational Test Agency (OTA) Report of OT&E Results                                                                              | DoDI 5000.02T | DoDI 5000.02T Enc 5          | all records, reports, and data from every OT&E and LFT&E event                                                                                                                                                                                                                     |   | x |
| Live Fire Test & Evaluation (LFT&E) Report                                                                                        | DoDI 5000.02T | 10 U.S.C. 2366               |                                                                                                                                                                                                                                                                                    |   | x |

|                                    |               |                 |                                                                           |   |   |
|------------------------------------|---------------|-----------------|---------------------------------------------------------------------------|---|---|
| DoD Component LFT&E Report         | DoDI 5000.02T | 10 U.S.C 2399   |                                                                           |   | x |
| ADM                                | DoDI 5000.02T | DoDI 5000.02T   | documents MDA decisions after each review                                 |   | x |
| Post Implementation Review (PIR) * | DoDI 5000.02T | 40 U.S.C. 11313 | to compare actual program results with established performance objectives | x |   |

All these documents do not need to be completed or on file at CSRA, so the list was tailored. Table 13 reflects the deliverables that were kept but not the reasoning for why some were tailored or waived. Appendix C contains the full list of deliverables with justification why events were waived and where events were combined. Much of the justification for each list of deliverables will be in an appendix because the list is too long to fit within the narrative.

Table 13. DoD Tailored Deliverables

| Deliverable                        | Reference                     | Description                                                                                                                                                                                                                                                                        | Stat | Reg |
|------------------------------------|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|
| ICD                                | CJCSI 3170.01                 | specifies one or more capability requirements and associated capability gaps which represent unacceptable operational risk if left unmitigated                                                                                                                                     |      | x   |
| Affordability Analysis             | DoDI 5000.02T Enc 8, Sec 3    | to promote responsible and sustainable investment decisions while avoiding starting or continuing programs that cannot be produced and supported within reasonable expectations for future budgets                                                                                 |      | x   |
| AS                                 | DoDI 5000.02T Enc 2, para 6a  | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives                                                               |      | x   |
| AoA                                | 40 U.S.C 11312                | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement                                                    |      | x   |
| SEP                                | DoDI 5000.02T Enc 3, Sec 2    | management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                                                             |      | x   |
| PPP                                | DoDI 5000.02T Enc 3, para 13a | to manage the risks to critical program information and mission-critical functions and components associated with the program                                                                                                                                                      |      | x   |
| CDD                                | JCIDS Manual                  | specifies capability requirements, in terms of developmental performance attributes (KPPs, KSAs, and APAs), and other related information necessary to support development of one or more increments of a materiel capability solution                                             |      | x   |
| CONOPS/MP                          | JCIDS Manual                  | contains operational tasks, events, durations, frequency, operating conditions and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                      |      | x   |
| TEMP                               | DoDI 5000.02T Enc 4 & 5       | primary planning and management tool for the integrated test program                                                                                                                                                                                                               |      | x   |
| PESHE/NEPA Compliance *            | 42 U.S.C 4321-4347            | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system | x    |     |
| SSRA                               | DoDI 4650.01                  | written determinations that the electromagnetic spectrum necessary to support the operation of the system during its expected life-cycle is or will be available in accordance with DoD Instruction 4650.01                                                                        |      | x   |
| Frequency Allocation Application * | 47 U.S.C. 305                 | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                                       | x    |     |
| CCA Compliance *                   | Title 40 USC, Subtitle III    | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu or table 11 of DoDI 5000.02                                                      | x    |     |
| APB                                | DoDD 5000.01                  | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                            |      | x   |
| CPD                                | JCIDS Manual                  | specifies capability requirements, in terms of production performance parameters (KPPs, KSAs, and APAs), and other related information necessary to support production of a single increment of a materiel capability solution                                                     |      | x   |
| DT&E Assessment                    |                               | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                                                                                   |      |     |
| OTA Report of OT&E Results         | DoDI 5000.02T Enc 5           | all records, reports, and data from every OT&E and LFT&E event                                                                                                                                                                                                                     |      | x   |
| ADM                                | DoDI 5000.02T                 | documents MDA decisions after each review                                                                                                                                                                                                                                          |      | x   |
| PIR *                              | 40 U.S.C. 11313               | to compare actual program results with established performance objectives                                                                                                                                                                                                          | x    |     |

Similar to how NASA had the most events and reviews in their life-cycle process, NASA also had the most documentation requirements. The NASA regulations do not

specify which documents are statutory, but it can be implied that it would be the same as those of the DoD. The full list of 72 deliverables is exhibited in Table 14.

Table 14. NASA Full Deliverables

| <b>Deliverable</b>                                              | <b>Guidance</b> | <b>Reference</b> | <b>Description</b>                                                                                                                                                                                                                                                       |
|-----------------------------------------------------------------|-----------------|------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Stakeholder Identification and Expectations definition Baseline | 7123.1C         | 5.2.2.2.a(1)     | captures the stakeholder expectations identified as needs, goals, and objectives                                                                                                                                                                                         |
| Formulation Authorization Document (FAD)                        | 7120.5E         |                  | describes the purpose of the project, including a clear traceability from the goals and objectives in the Mission Directorate strategies and/ or Program Plan                                                                                                            |
| Formulation Agreement (FA)                                      | 7120.5E         |                  | establishes technical and acquisition work that needs to be conducted during Formulation and defines the schedule and funding requirements during Phase A and Phase B for that work                                                                                      |
| Concept definition Baseline                                     | 7123.1C         | 5.2.2.2.a(2)     | presents feasible ways of accomplishing the stakeholder expectations                                                                                                                                                                                                     |
| Concept Documentation                                           | 7120.5E         |                  | captures and communicates a feasible concept that meets the goals and objectives of the mission, including results of analyses of alternative concepts, the concept of operations, preliminary risks, and potential descopes                                             |
| Program Plan                                                    | 7120.5E         |                  | defines the goals and objectives of the program, the environment within which the program operates, and the Management Agreement commitments of the program, including identifying the high-level requirements on both the program and each constituent project          |
| Technology Readiness Assessment (TRA)                           | 7120.5E         |                  | Identify the specific new technologies that are part of this project; their criticality to the project's objectives, goals, and success criteria; and the current status of each planned technology development, including TRL and associated risks                      |
| Engineering Development Assessment                              | 7120.5E         |                  | Identify major engineering development risks and any engineering prototyping or software model development that needs to be accomplished during phases A and B to reduce development risk                                                                                |
| Heritage Assessment Documentation                               | 7120.5E         |                  | Identify the major heritage hardware and software assumptions and associated risks and the activities and reviews planned to validate those assumptions                                                                                                                  |
| Measure of Effectiveness (MOE) definition Baseline              | 7123.1C         | 5.2.2.2.a(3)     | capture the stakeholders' view of what would be considered the successful achievement of each expectation                                                                                                                                                                |
| Technology Development Plan                                     | 7120.5E         | NPD 7500.2       | describes the technology assessment, development, management, and acquisition strategies needed to achieve the project's mission objectives                                                                                                                              |
| ASM minutes                                                     | 7120.5E         |                  | decision-making forum where senior Agency management reviews and approves project acquisition strategies                                                                                                                                                                 |
| Safety & Mission Assurance (SMA) Plan                           | 7120.5E         | NPD 8730.5       | addresses life-cycle SMA functions and activities, including SMA roles, responsibilities, and relationships                                                                                                                                                              |
| Risk Management Plan                                            | 7120.5E         | NPR 8000.4       | Summarizes how the program or project will implement the NASA risk management process                                                                                                                                                                                    |
| Acquisition Plan                                                | 7120.5E         | 4.3.4.2.2        | documents an integrated acquisition strategy that enables the program to meet its mission objectives and provides the best value to NASA                                                                                                                                 |
| System Engineering Management Plan (SEMP)                       | 7123.1C         | NPR 7123.1       | Describes the overall approach for systems engineering including the system design and product realization processes as well as the technical management processes                                                                                                       |
| Review Plan                                                     | 7120.5E         | 4.3.4.3          | Summarizes the project's approach for conducting a series of reviews including internal reviews and program life- cycle reviews                                                                                                                                          |
| Configuration Management Plan                                   | 7120.5E         | SP 6105          | Describes the organization, tools, methods, and procedures for configuration identification, configuration control, traceability, and accounting/ auditing                                                                                                               |
| Human Rating Certification Package                              | 7120.5E         | NPR 8705.2       | Focuses on the integration of the human into the system, pre- venting catastrophic events during the mission, and protecting the health and safety of humans involved in or exposed to space activities, specifically the public, crew, passengers, and ground personnel |

|                                                          |         |              |                                                                                                                                                                                                                                                              |
|----------------------------------------------------------|---------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Requirements Baseline                                    | 7123.1C | 5.2.2.2.b(2) | agreed upon need, capability, capacity, or demand for personnel, equipment, facilities, or other resources or services                                                                                                                                       |
| System & Subsystem Requirements                          | 7120.5E |              | Document the project's proposed milestones for flow down of requirements to the project, system, and subsystem levels on the project schedule, and provide rationale for any differences from requirements in product maturities                             |
| Architecture definition Baseline                         | 7123.1C | 5.2.2.2.c(2) | decomposition of the defined functional and performance requirements by functions, time, and behaviors                                                                                                                                                       |
| Mission Architecture                                     | 7120.5E |              | credible and responsive to program requirements and constraints on the project, including resources                                                                                                                                                          |
| Spacecraft Architecture                                  | 7120.5E |              | how the major project components will be integrated and are intended to operate together and with heritage systems, as applicable, to achieve project goals and objectives                                                                                   |
| Technical Performance Measures (TPM) definition Baseline | 7123.1C | 5.2.2.2.c(1) | the important key driving requirements, key performance parameters, leading or lagging indicators, or other measures to track efforts                                                                                                                        |
| Technical, Schedule, & Cost Control Plan                 | 7120.5E | 4.5.3.2.2    | Describes how the program or project plans to control program or project requirements, technical design, schedule, and cost to achieve its high-level requirements                                                                                           |
| Information Technology Plan                              | 7120.5E | NPR 2830.1   | Describes how the program or project will acquire and use information technology including IT security requirements                                                                                                                                          |
| Software Management Plan                                 | 7120.5E | NPR 7150.C   | how the project will develop and/or manage the acquisition of software required to achieve project and mission objectives                                                                                                                                    |
| Environmental Management Plan                            | 7120.5E | NPR 8580.1   | Describes the program's NEPA strategy at all affected Centers, including decisions regarding programmatic NEPA documents                                                                                                                                     |
| Nuclear Safety Launch Approval Plan                      | 7120.5E | NPR 8715.3   | Describes potential risks associated with a planned launch of radioactive materials into space, on launch vehicles and spacecraft, and during flight                                                                                                         |
| Partnership Agreements                                   | 7120.5E |              | documents roles and contributed items and plans for getting commitments for contributions and finalizing open inter-agency agreements, domestic partnerships, and foreign contributions                                                                      |
| NEPA Compliance Documentation                            | 7120.5E | NPR 8580.1   | Environmental Checklist and Record of Environmental Consideration (REC), Environmental Assessment (EA), and Environmental Impact Statement (EIS)                                                                                                             |
| Allocation of Requirements Baseline                      | 7123.1C | 5.2.2.2.c(3) | shows how the requirements are allocated to the architecture elements of the next lower level of the product hierarchy                                                                                                                                       |
| Operations Concept                                       | 7120.5E |              | describe how the flight system and ground system work together across mission phases for launch, cruise, critical activities, science observations, and the end of the mission to achieve the mission                                                        |
| Preliminary Design Solution definition                   | 7123.1C | 5.2.2.2.d(1) | translates the outputs of the logical decomposition process into a design solution definition that is in a form consistent with the product life-cycle phase and product layer location in the system structure and that will satisfy phase success criteria |
| Project Baselines                                        | 7120.5E |              | set of requirements, cost, schedule, and technical content that forms the foundation for project execution and reporting                                                                                                                                     |
| Project Plan                                             | 7120.5E |              | defines the scope of the project, the implementation approach, the environment within which the project operates, and the baseline commitments of the project                                                                                                |
| Initial trend of required leading indicators             | 7123.1C | 5.2.2.2.c(4) | document presenting trends for the leading indicators that have been identified by the Agency as required for each program/project                                                                                                                           |
| Staffing Requirements & Plans                            | 7120.5E |              | All elements of personnel management including, identifying, recruiting, selecting, managing, and evaluating the team members to achieve a coherent, efficient, and effective team                                                                           |
| Infrastructure Requirements & Plans                      | 7120.5E |              | include the acquisition, renovation, and/or use of real property/facilities, aircraft, personal property, and information technology                                                                                                                         |
| Cost & Schedule Baseline                                 | 7123.1C |              | baselined estimated life-cycle costs and schedule                                                                                                                                                                                                            |
| Baseline Integrated Master Schedule                      | 7120.5E |              | a summary of its IMS, including all critical milestones, major events, life-cycle reviews, and KDPs throughout the project life-cycle                                                                                                                        |
| Cost Estimate                                            | 7120.5E |              | includes all costs, including all Unallocated Future Expenses (UFE) and funded schedule margins for development through prime mission operations to disposal, excluding extended operations                                                                  |
| Joint Cost & Schedule Confidence Level                   | 7120.5E |              | to measure the likelihood of completing all remaining work at or below the budgeted levels and on or before the planned completion of the development phase                                                                                                  |

|                                                                     |         |              |                                                                                                                                                                                                                                                                                                                  |
|---------------------------------------------------------------------|---------|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| External Cost & Schedule Commitments                                | 7120.5E |              | includes applicable model inputs, rationale/justification for analogies, and details supporting bottom-up cost and schedule estimates                                                                                                                                                                            |
| Cost Analysis Data Requirement (CADRe)                              | 7120.5E |              | describes the programmatic, technical, and life-cycle cost and cost and schedule risk information of a project                                                                                                                                                                                                   |
| Design Solution definition Baseline                                 | 7123.1C | 5.2.2.2.e(1) | final design that meets the requirements with adequate margins                                                                                                                                                                                                                                                   |
| Design Documentation                                                | 7120.5E |              | series of documents that captures and communicates to others the specific technical aspects of a design                                                                                                                                                                                                          |
| Interface definition Baseline                                       | 7123.1C |              | controls system product development efforts when the efforts are divided between Government programs, contractors, and/or geographically diverse technical teams                                                                                                                                                 |
| Implementation Plans Baseline                                       | 7123.1C |              | identifies how components will be acquired (make or buy) with associated costs and schedules                                                                                                                                                                                                                     |
| Integration Plans Baseline                                          | 7123.1C | 5.2.2.2.f(1) | describe how the products will be integrated including procedures, environment, and configuration of the items                                                                                                                                                                                                   |
| Integrated Logistics Support Plan                                   | 7120.5E | NPD 7500.1B  | Describes how the program or project will implement a maintenance and support concept, enhancing supportability, supply support, maintenance planning, packaging, handling and transportation, training, manpower, required facilities, and logistics information systems for the life of the program or project |
| Human Systems Integration Plan                                      | 7120.5E | NPR 7123.1B  | interdisciplinary and comprehensive management and technical process that focuses on the integration of human considerations into the system acquisition and development processes to enhance human system design, reduce life-cycle ownership cost, and optimize total system performance                       |
| Security Plan                                                       | 7120.5E | NPD 1600.2   | describes the project's plans for ensuring security and technology protection                                                                                                                                                                                                                                    |
| PPP                                                                 | 7120.5E | 4.3.6.3      | based on the program Threat Summary, which documents the threat environment the project is most likely to encounter as it reaches operational capability and recommends potential countermeasures                                                                                                                |
| V&V Plans Baseline                                                  | 7123.1C |              | finalized planning and management tool for the integrated test program                                                                                                                                                                                                                                           |
| Technology Transfer Control Plan                                    | 7120.5E | NPR 2190.1   | Describes how the program or project will implement the export control requirements                                                                                                                                                                                                                              |
| Knowledge Management Plan                                           | 7120.5E | NPD 7120.4   | Describes the program's approach to creating the knowledge management strategy and processes, examining the lessons learned database for relevant lessons, and creating the plan for how the program continuously captures and documents lessons learned throughout the program life-cycle                       |
| Planetary Protection Plan                                           | 7120.5E | NPR 8020.12  | the control of terrestrial microbial contamination associated with space vehicles intended to land, orbit, fly by, or otherwise encounter extraterrestrial solar system bodies                                                                                                                                   |
| Communications Plan                                                 | 7120.5E | 4.3.4.2.2    | Describe plans to implement a diverse, broad, and integrated set of efforts and activities to communicate with and engage target audiences, the public, and other stakeholders in understanding the project, its objectives, elements, and benefits                                                              |
| Safety Data Packages                                                | 7120.5E | NPR 8715.3   | data and information to support each section of the SMA Plan for each major milestone review to include the Safety and Mission Success Review                                                                                                                                                                    |
| Preliminary V&V Results                                             | 7123.1C | 5.2.2.2.f(2) | results of lower-level subsystem testing accomplished before assembly                                                                                                                                                                                                                                            |
| Expendable Launch Vehicle (ELV) Payload Safety Process Deliverables | 7120.5E | NPR 8715.7   | payload design, fabrication, testing, vehicle integration, launch processing, launch, and planned recovery                                                                                                                                                                                                       |
| Range Safety Risk Management Process Documentation                  | 7120.5E | NPR 8715.5   | focus on the protection of the public, workforce, and property during range flight operations                                                                                                                                                                                                                    |
| Operations Handbook                                                 | 7120.5E |              | provides information essential to the operation of the spacecraft                                                                                                                                                                                                                                                |
| Mission Operations Plan                                             | 7120.5E | 4.4.1.3      | Discusses how the project will implement the associated facilities, hardware, software, and procedures required to complete the mission                                                                                                                                                                          |
| Science Data Management Plan                                        | 7120.5E | 4.3.6.3      | describes how the project will manage the scientific data generated and captured by the operational mission                                                                                                                                                                                                      |
| Mishap Preparedness & Contingency Plan (MPCP)                       | 7120.5E | NPR 8621.1   | address coordination and cooperation actions to be taken by all parties                                                                                                                                                                                                                                          |

|                                    |         |              |                                                                                                                                                                                                                               |
|------------------------------------|---------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ODAR                               | 7120.5E | NPR 8715.6   | for planned breakups, reentry of major components that potentially could reach the surface, the planned orbital lifetime, and the use of tethers                                                                              |
| End of Mission Plans               | 7120.5E | NPR 8715.6   | describes the project management approach and the mission overview; spacecraft description; assessment of spacecraft debris released during and after passivation; assessment of spacecraft potential for on-orbit collisions |
| V&V Report                         | 7123.1C | 5.2.2.2.h(2) | results of all systems testing                                                                                                                                                                                                |
| Final Certification for Flight/Use | 7123.1C | 5.2.2.2.h(3) | certifies to stakeholders that product is ready to put into the operational phase                                                                                                                                             |

These 72 can be tailored down to 16. This is accomplished by waiving documents that are not applicable and combining those that can be done so logically. The 16 documents to be completed are presented in Table 15 while the full list with justification is in Appendix D.

Table 15. NASA Tailored Deliverables

| Deliverable                         | Reference    | Description                                                                                                                                                                                                                                                                                |
|-------------------------------------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Concept definition Baseline         | 5.2.2.2.a(2) | presents feasible ways of accomplishing the stakeholder expectations                                                                                                                                                                                                                       |
| SMA Plan                            | NPD 8730.5   | addresses life-cycle SMA functions and activities, including SMA roles, responsibilities, and relationships                                                                                                                                                                                |
| Acquisition Plan                    | 4.3.4.2.2    | documents an integrated acquisition strategy that enables the program to meet its mission objectives and provides the best value to NASA                                                                                                                                                   |
| SEMP                                | NPR 7123.1   | Describes the overall approach for systems engineering including the system design and product realization processes as well as the technical management processes                                                                                                                         |
| Requirements Baseline               | 5.2.2.2.b(2) | agreed upon need, capability, capacity, or demand for personnel, equipment, facilities, or other resources or services                                                                                                                                                                     |
| NEPA Compliance Documentation       | NPR 8580.1   | Environmental Checklist and Record of Environmental Consideration (REC), Environmental Assessment (EA), and Environmental Impact Statement (EIS)                                                                                                                                           |
| Operations Concept                  |              | describes how the flight system and ground system work together across mission phases for launch, cruise, critical activities, science observations, and the end of the mission to achieve the mission                                                                                     |
| Project Baselines                   |              | set of requirements, cost, schedule, and technical content that forms the foundation for project execution and reporting                                                                                                                                                                   |
| Project Plan                        |              | defines the scope of the project, the implementation approach, the environment within which the project operates, and the baseline commitments of the project                                                                                                                              |
| Design Solution definition Baseline | 5.2.2.2.e(1) | final design that meets the requirements with adequate margins                                                                                                                                                                                                                             |
| V&V Plans Baseline                  |              | finalized planning and management tool for the integrated test program                                                                                                                                                                                                                     |
| Knowledge Management Plan           | NPD 7120.4   | Describes the program's approach to creating the knowledge management strategy and processes, examining the lessons learned database for relevant lessons, and creating the plan for how the program continuously captures and documents lessons learned throughout the program life-cycle |
| Safety Data Packages                | NPR 8715.3   | data and information to support each section of the SMA Plan for each major milestone review to include the Safety and Mission Success Review                                                                                                                                              |
| Preliminary V&V Results             | 5.2.2.2.f(2) | results of lower-level subsystem testing accomplished before assembly                                                                                                                                                                                                                      |
| Operations Handbook                 |              | provides information essential to the operation of the spacecraft                                                                                                                                                                                                                          |

The list of USAF deliverables is very similar to the DoD list. All the USAF required documents are listed in Table 16.

Table 16. USAF Full Deliverables

| Deliverable                                   | Guidance | Reference                     | Description                                                                                                                                                                                                                                                                         | Stat | Reg |
|-----------------------------------------------|----------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|
| AoA Study Guidance                            | AFI      | DoDI 5000.02T para 6d(1)(b)   | regulatory guidance to guide the AoA; informs preparation of AoA Study Plan; prepared by DCAPE                                                                                                                                                                                      |      | x   |
| AoA Study Plan                                | AFI      | DoDI 5000.02T para 6d(1)(b)   | regulatory guidance to guide the AoA; prepared by lead DoD Component                                                                                                                                                                                                                |      | x   |
| ICD                                           | SMC SE   | CJCSI 3170.01                 | documents the capability gap, gap analyses and associated risks, and the derived operational capability requirement(s)                                                                                                                                                              |      | x   |
| Affordability Analysis                        | AFI      | DoDI 5000.02T Enc 8, Sec 3    | to promote responsible and sustainable investment decisions while avoiding starting or continuing programs that cannot be produced and supported within reasonable expectations for future budgets                                                                                  |      | x   |
| WBS                                           | SMC SE   |                               | a means of organizing system development activities based on system and product decompositions; defines the total system of hardware, software, services, data, and facilities, and relates these elements to each other and to the end products                                    |      |     |
| Cost Analysis Requirements Description (CARD) | SMC SE   |                               | basis of cost estimates for complex projects; contains a technical, programmatic, and a schedule that are used as the basis for deriving a cost estimate                                                                                                                            |      |     |
| IMP                                           | SMC SE   |                               | event-driven government document that provides a framework against which all work is measured; consists of program events, significant accomplishments, and accomplishment criteria; should encompass all Integrated Product Team (IPT) and Work Breakdown Structure (WBS) elements |      |     |
| AS                                            | AFI      | DoDI 5000.02T Enc 2, para 6a  | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives                                                                |      | x   |
| AoA Report                                    | SMC SE   | 40 U.S.C 11312                | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement                                                     |      | x   |
| SEP                                           | SMC SE   | DoDI 5000.02T Enc 3, Sec 2    | process-oriented document/management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                                    |      | x   |
| LCSP                                          | AFI      | DoDI 5000.02 Enc 6, Sec 3     | describe sustainment influences on system design and the technical, business, and management activities to develop, implement, and deliver a product support package                                                                                                                |      | x   |
| Requirements Baseline                         | SMC SE   |                               | documented performance, functional, architectural, dependability, and constraints specifications                                                                                                                                                                                    |      |     |
| IMS                                           | SMC SE   |                               | integrated, networked model containing all the detailed discrete tasks necessary to realize the IMP accomplishment criteria                                                                                                                                                         |      |     |
| TRA                                           | AFPAM    |                               | tool for identifying triggers that may become risks and providing inputs with regard to how well these items are managed over time                                                                                                                                                  |      |     |
| PPP                                           | AFI      | DoDI 5000.02T Enc 3, para 13a | to manage the risks to critical program information and mission-critical functions and components associated with the program                                                                                                                                                       |      | x   |
| SRD                                           | SMC SE   | JCIDS Enclosure D             | defines the performance of the preferred materiel solution; system performance specification has sufficiently conservative requirements to allow for design trade space                                                                                                             |      |     |

|                                                |        |                            |                                                                                                                                                                                                                                                                                       |   |   |
|------------------------------------------------|--------|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|
| CDD                                            | SMC SE | JCIDS Manual               | provides authoritative, measurable, and testable operational performance attributes, including producibility and supportability, necessary for the acquisition community to design the proposed system(s), including key performance parameters (KPP) and Key System Attributes (KSA) |   | x |
| CONOPS                                         | AFPAM  | JCIDS Manual               | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                        |   | x |
| VOLT Report                                    | AFI    | DIA Directive 5000.200     | includes threat modules and is written to articulate the relevance of each module to a specific acquisition program or planned capability                                                                                                                                             |   | x |
| Mission Data Plan                              | AFI    |                            | to capture and address intelligence mission data production shortfalls identified by the intelligence community                                                                                                                                                                       |   |   |
| Functional Architecture Baseline               | SMC SE |                            | decomposes and allocates requirements into sub functions to the point that they can be unambiguously related to subsystems and lower system elements or products that make up the design                                                                                              |   |   |
| Allocated Baseline                             | SMC SE |                            | allocating the system technical requirements and constraints to the elements of the physical hierarchy                                                                                                                                                                                |   |   |
| Item Unique Identification Implementation Plan | AFI    | DoDI 8320.04               | to identify and track applicable major end items, configuration-controlled items, and government-furnished property                                                                                                                                                                   |   | x |
| TEMP                                           | AFI    | DoDI 5000.02T Enc 4 & 5    | primary planning and management tool for the integrated test program                                                                                                                                                                                                                  |   | x |
| PESHE/NEPA Compliance *                        | AFI    | 42 U.S.C 4321-4347         | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system    | x |   |
| ISP                                            | AFI    | DoDI 4630.8                | technical document required for all Information Technology and National Security Systems (IT/NSS) that exchange information of any type to other systems                                                                                                                              |   |   |
| Frequency Allocation Application *             | AFI    | 47 U.S.C. 305              | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                                          | x |   |
| CCA Compliance *                               | AFI    | Title 40 USC, Subtitle III | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu & table 11 of DoDI 5000.02                                                          | x |   |
| CSS                                            | AFI    | DoDI 8500.01               | plan that provides an overview of the cybersecurity requirements for the system and describes the security controls in place or planned for meeting those requirements.                                                                                                               |   |   |
| APB                                            | AFI    | DoDD 5000.01               | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                               |   | x |
| Design Baseline                                | SMC SE |                            | represents build-to system design and process specifications; provides the basis for manufacturing, buying, coding, and subsequent integration of the products that make up the system                                                                                                |   |   |
| CPD                                            | SMC SE | JCIDS Manual               | provides authoritative, testable capability requirements and performance attributes to include KPPs and KSAs to enter the P&D phase of an acquisition program                                                                                                                         |   | x |
| Product Baseline                               | SMC SE |                            | represents as-built system design and process specifications                                                                                                                                                                                                                          |   |   |
| ADM                                            | SMC SE | DoDI 5000.02T              | documents MDA decisions after each review                                                                                                                                                                                                                                             |   | x |
| Decision database                              | SMC SE |                            | a record of the basis for each decision that is made in developing and maintaining each baseline                                                                                                                                                                                      |   |   |
| PIR *                                          | AFI    | 40 U.S.C. 11313            | to compare actual program results with established performance objectives                                                                                                                                                                                                             | x |   |

Like the previous lists, not all of these deliverables are necessary. The USAF deliverables can be reduced by half by waiving documents that are not applicable and combining those that can be done so logically. The documents kept are presented in Table 17 while the full list with justification is in Appendix E.

Table 17. USAF Tailored Deliverables

| Deliverable                        | Reference                       | Description                                                                                                                                                                                                                                                                           | Stat | Reg |
|------------------------------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|
| ICD                                | CJCSI 3170.01                   | documents the capability gap, gap analyses and associated risks, and the derived operational capability requirement(s)                                                                                                                                                                |      | x   |
| CARD                               |                                 | basis of cost estimates for complex projects; contains a technical, programmatic, and a schedule that are used as the basis for deriving a cost estimate                                                                                                                              |      |     |
| AS                                 | DoDI 5000.02T<br>Enc 2, para 6a | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives                                                                  |      | x   |
| AoA Report                         | 40 U.S.C 11312                  | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement                                                       |      | x   |
| SEP                                | DoDI 5000.02T<br>Enc 3, Sec 2   | process-oriented document/management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                                      |      | x   |
| CDD                                | JCIDS Manual                    | provides authoritative, measurable, and testable operational performance attributes, including producibility and supportability, necessary for the acquisition community to design the proposed system(s), including key performance parameters (KPP) and Key System Attributes (KSA) |      | x   |
| CONOPS                             | JCIDS Manual                    | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                        |      | x   |
| TEMP                               | DoDI 5000.02T<br>Enc 4 & 5      | primary planning and management tool for the integrated test program                                                                                                                                                                                                                  |      | x   |
| PESHE/NEPA Compliance *            | 42 U.S.C 4321-4347              | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system    | x    |     |
| Frequency Allocation Application * | 47 U.S.C. 305                   | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                                          | x    |     |
| CCA Compliance *                   | Title 40 USC, Subtitle III      | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu or table 11 of DoDI 5000.02                                                         | x    |     |
| APB                                | DoDD 5000.01                    | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                               |      | x   |
| Design Baseline                    |                                 | represents build-to system design and process specifications; provides the basis for manufacturing, buying, coding, and subsequent integration of the products that make up the system                                                                                                |      |     |
| CPD                                | JCIDS Manual                    | provides authoritative, testable capability requirements and performance attributes to include KPPs and KSAs to enter the P&D phase of an acquisition program                                                                                                                         |      | x   |
| ADM                                | DoDI 5000.02T                   | documents MDA decisions after each review                                                                                                                                                                                                                                             |      | x   |
| PIR *                              | 40 U.S.C. 11313                 | to compare actual program results with established performance objectives                                                                                                                                                                                                             | x    |     |

Since the AF MTA life-cycle was very compressed, one can assume that the accompanying required documentation would be less than the others. Only seven deliverables are required specifically for this framework. These are listed in Table 18.

Table 18. AF MTA Full Deliverables

| <b>Deliverable</b>                                                                                  | <b>Reference</b>           | <b>Description</b>                                                                                                                                                                                                                                                                 |
|-----------------------------------------------------------------------------------------------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Acquisition Strategy Document (ASD)                                                                 |                            | lists required program documentation, decision points, metrics, guardrails, test plans, as well as timing and scope of decision reviews, and to establish cost, schedule, risk, and performance objectives                                                                         |
| IMS                                                                                                 |                            | integrated, networked model containing all the detailed discrete tasks necessary to realize the IMP accomplishment criteria                                                                                                                                                        |
| Concept Analysis                                                                                    |                            | a feasible concept that meets the goals and objectives of the mission                                                                                                                                                                                                              |
| CCA Compliance, Risk Management Framework, & Cybersecurity Strategy                                 | Title 40 USC, Subtitle III | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu & table 11 DoDI 5000.02                                                          |
| Environmental Safety Occupational Health Evaluation/NEPA/ Executive Order 12114 Compliance Schedule | 42 U.S.C 4321-4347         | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system |
| Frequency Allocation Application                                                                    | DoDD 5000.01               | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                            |
| Intelligence & Threat Information/Life-Cycle Mission Data Plan                                      |                            | to capture and address intelligence mission data production shortfalls identified by the intelligence community                                                                                                                                                                    |

Tailoring the list was quick since there was so few to review and they were documents that are also listed by the other agencies. Because this list is so small, the justifications to the tailored deliverables are provided in Table 19.

Table 19. AF MTA Tailored Deliverables

| Deliverable                                                                                         | Reference                  | Description                                                                                                                                                                                                                                                                        | Keep | Waive | Tailor | Justification  |
|-----------------------------------------------------------------------------------------------------|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|--------|----------------|
| ASD                                                                                                 |                            | lists required program documentation, decision points, metrics, guardrails, test plans, as well as timing and scope of decision reviews, and to establish cost, schedule, risk, and performance objectives                                                                         | x    |       | x      |                |
| IMS                                                                                                 |                            | integrated, networked model containing all the detailed discrete tasks necessary to realize the IMP accomplishment criteria                                                                                                                                                        |      | x     | x      | capture in ASD |
| Concept Analysis                                                                                    |                            | a feasible concept that meets the goals and objectives of the mission                                                                                                                                                                                                              |      | x     | x      | capture in ASD |
| CCA Compliance, Risk Management Framework, & Cybersecurity Strategy                                 | Title 40 USC, Subtitle III | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu or table 11 of DoDI 5000.02                                                      | x    |       |        | statutory      |
| Environmental Safety Occupational Health Evaluation/NEPA/ Executive Order 12114 Compliance Schedule | 42 U.S.C 4321-4347         | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system | x    |       |        | statutory      |
| Frequency Allocation Application                                                                    | DoDD 5000.01               | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                            | x    |       |        | needed for TM  |
| Intelligence & Threat Information/Life-Cycle Mission Data Plan                                      |                            | to capture and address intelligence mission data production shortfalls identified by the intelligence community                                                                                                                                                                    |      | x     |        | capture in ASD |

Many of the tailored deliverables were similar across the different lists. To obtain a picture of the full list of deliverables among the complex frameworks, they were individually listed by model and organized to identify the parallels. Table 20 lists the deliverables side by side and reveals the frequency of use between the four frameworks.

Table 20. Complex Deliverables by Organization

| Org         | DoD                                  | NASA                                                            | USAF                   | AF MTA           | Frequency |
|-------------|--------------------------------------|-----------------------------------------------------------------|------------------------|------------------|-----------|
| Deliverable |                                      | Stakeholder Identification and Expectations definition Baseline |                        |                  | 1         |
|             | AoA Study Guidance                   |                                                                 | AoA Study Guidance     |                  | 2         |
|             | AoA Study Plan                       |                                                                 | AoA Study Plan         |                  | 2         |
|             |                                      | FAD                                                             |                        |                  | 1         |
|             |                                      | FA                                                              |                        |                  | 1         |
|             | Defense Intelligence Threat Library  |                                                                 |                        |                  | 1         |
|             | ICD                                  | Concept definition Baseline                                     | ICD                    | Concept Analysis | 4         |
|             |                                      | Concept Documentation                                           |                        |                  | 1         |
|             | Affordability Analysis               | Cost Estimate                                                   | Affordability Analysis |                  | 3         |
|             |                                      | CADRe                                                           |                        |                  | 1         |
|             |                                      |                                                                 | WBS                    |                  | 1         |
|             |                                      | Cost & Schedule Baseline                                        | CARD                   |                  | 2         |
|             |                                      | Program Plan                                                    |                        |                  | 1         |
|             |                                      | TRA                                                             | TRA                    |                  | 2         |
|             |                                      | Engineering Development Assessment                              |                        |                  | 1         |
|             |                                      | Communications Plan                                             |                        |                  | 1         |
|             |                                      | Heritage Assessment Documentation                               |                        |                  | 1         |
|             |                                      | MOE definition Baseline                                         |                        |                  | 1         |
|             | IMP                                  |                                                                 | IMP                    |                  | 2         |
|             |                                      | Technology Development Plan                                     |                        |                  | 1         |
|             |                                      | SMA Plan                                                        |                        |                  | 1         |
|             |                                      | Risk Management Plan                                            |                        |                  | 1         |
|             |                                      | Acquisition Plan                                                |                        |                  | 1         |
|             | AS                                   |                                                                 | AS                     | ASD              | 3         |
|             |                                      | ASM minutes                                                     |                        |                  | 1         |
|             | AoA Report                           |                                                                 | AoA Report             |                  | 2         |
|             | SEP                                  | SEMP                                                            | SEP                    |                  | 3         |
|             |                                      | Review Plan                                                     |                        |                  | 1         |
|             | LCSP                                 |                                                                 | LCSP                   |                  | 2         |
|             |                                      | Configuration Management Plan                                   |                        |                  | 1         |
|             |                                      | Human Rating Certification Package                              |                        |                  | 1         |
|             |                                      | Requirements Baseline                                           | Requirements Baseline  |                  | 2         |
|             |                                      | Infrastructure Requirements & Plans                             |                        |                  | 1         |
|             | IMS                                  | Baseline Integrated Master Schedule                             | IMS                    | IMS              | 4         |
|             | Technology Targeting Risk Assessment |                                                                 |                        |                  | 1         |
|             |                                      | Software Management Plan                                        |                        |                  | 1         |
|             |                                      | Human Systems Integration Plan                                  |                        |                  | 1         |
|             |                                      | Security Plan                                                   |                        |                  | 1         |
|             | PPP                                  | PPP                                                             | PPP                    |                  | 3         |
|             | CDD                                  |                                                                 | CDD                    |                  | 2         |
|             | SRD                                  | System & Subsystem Requirements                                 | SRD                    |                  | 3         |
|             |                                      | TPM definition Baseline                                         |                        |                  | 1         |

|                                       |                                              |                                  |                                                                     |   |
|---------------------------------------|----------------------------------------------|----------------------------------|---------------------------------------------------------------------|---|
|                                       | Technical, Schedule, & Cost Control Plan     |                                  |                                                                     | 1 |
|                                       | Information Technology Plan                  |                                  |                                                                     | 1 |
|                                       |                                              | Functional Architecture Baseline |                                                                     | 1 |
|                                       | Architecture definition Baseline             |                                  |                                                                     | 1 |
|                                       | Mission Architecture                         |                                  |                                                                     | 1 |
|                                       | Spacecraft Architecture                      |                                  |                                                                     | 1 |
|                                       | Allocation of Requirements Baseline          | Allocated Baseline               |                                                                     | 2 |
|                                       | Initial trend of required leading indicators |                                  |                                                                     | 1 |
|                                       | Staffing Requirements & Plans                |                                  |                                                                     | 1 |
| CONOPS/MP                             | Operations Concept                           | CONOPS                           |                                                                     | 3 |
| VOLT Report                           |                                              | VOLT Report                      | Intelligence & Threat Information/Life-Cycle Mission Data Plan      | 3 |
| Should Cost Target                    |                                              |                                  |                                                                     | 1 |
|                                       | Preliminary Design Solution definition       |                                  |                                                                     | 1 |
|                                       | Interface definition Baseline                |                                  |                                                                     | 1 |
| Core Logistics Determination          | Integrated Logistics Support Plan            |                                  |                                                                     | 2 |
|                                       | Implementation Plans Baseline                |                                  |                                                                     | 1 |
| IUID Implementation Plan              |                                              | IUID Implementation Plan         |                                                                     | 2 |
|                                       | Integration Plans Baseline                   |                                  |                                                                     | 1 |
| TEMP                                  | V&V Plans Baseline                           | TEMP                             |                                                                     | 3 |
|                                       | Environmental Management Plan                |                                  |                                                                     | 1 |
|                                       | Nuclear Safety Launch Approval Plan          |                                  |                                                                     | 1 |
|                                       | Partnership Agreements                       |                                  |                                                                     | 1 |
| PESHE/NEPA Compliance                 | NEPA Compliance Documentation                | PESHE/NEPA Compliance            | PESHE/NEPA/Executive Order 12114 Compliance                         | 4 |
| Bandwidth Requirements Review         |                                              |                                  |                                                                     | 1 |
| ISP                                   |                                              | ISP                              |                                                                     | 2 |
| SSRA                                  |                                              |                                  |                                                                     | 1 |
| IT/NSS Interoperability Certification |                                              |                                  |                                                                     | 1 |
| RFP                                   |                                              |                                  |                                                                     | 1 |
| Frequency Allocation Application      |                                              | Frequency Allocation Application | Frequency Allocation Application                                    | 3 |
| CCA Compliance                        |                                              | CCA Compliance                   | CCA Compliance, Risk Management Framework, & Cybersecurity Strategy | 3 |
| CSS                                   |                                              | CSS                              |                                                                     | 2 |
| Waveform Assessment Application       |                                              |                                  |                                                                     | 1 |
| APB                                   | Project Baselines                            | APB                              |                                                                     | 3 |
|                                       | Project Plan                                 |                                  |                                                                     | 1 |
|                                       | Joint Cost & Schedule Confidence Level       |                                  |                                                                     | 1 |
|                                       | External Cost & Schedule Commitments         |                                  |                                                                     | 1 |
|                                       | Design Solution definition Baseline          | Design Baseline                  |                                                                     | 2 |
|                                       | Design Documentation                         |                                  |                                                                     | 1 |

|  |                            |                                                    |                   |   |
|--|----------------------------|----------------------------------------------------|-------------------|---|
|  | CPD                        |                                                    | CPD               | 2 |
|  |                            |                                                    | Product Baseline  | 1 |
|  |                            | Technology Transfer Control Plan                   |                   | 1 |
|  |                            | Range Safety Risk Management Process Documentation |                   | 1 |
|  |                            | Safety Data Packages                               |                   | 1 |
|  | OTP                        |                                                    |                   | 1 |
|  | DT&E Assessment            | Preliminary V&V Results                            |                   | 2 |
|  |                            | ELV Payload Safety Process Deliverables            |                   | 1 |
|  |                            | Operations Handbook                                |                   | 1 |
|  |                            | Mission Operations Plan                            |                   | 1 |
|  |                            | Science Data Management Plan                       | Mission Data Plan | 2 |
|  |                            | MPCP                                               |                   | 1 |
|  |                            | ODAR                                               |                   | 1 |
|  |                            | Planetary Protection Plan                          |                   | 1 |
|  | DOT&E Report of IOT&E      |                                                    |                   | 1 |
|  | OTA Report of OT&E Results | V&V Report                                         |                   | 2 |
|  | LFT&E Report               |                                                    |                   | 1 |
|  | DoD Component LFT&E Report |                                                    |                   | 1 |
|  |                            | End of Mission Plans                               |                   | 1 |
|  |                            | Final Certification for Flight/Use                 |                   | 1 |
|  | ADM                        |                                                    | ADM               | 2 |
|  |                            |                                                    | Decision database | 1 |
|  | PIR                        | Knowledge Management Plan                          | PIR               | 3 |

The descriptions of these 103 deliverables have already been detailed in Tables 12, 14, 16, and 18. By waiving unnecessary documentation and combining others where possible, the list becomes much more manageable as depicted in Table 21. The justification for why deliverables were waived or tailored is found in Appendix F.

Table 21. Tailored Complex Deliverables

| Required Deliverable                | Org  | Reference                     | Description                                                                                                                                                                                                                                                       |
|-------------------------------------|------|-------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| ICD                                 | DoD  | CJCSI 3170.01                 | specifies one or more capability requirements and associated capability gaps which represent unacceptable operational risk if left unmitigated                                                                                                                    |
| CADRe                               | NASA |                               | basis of cost estimates for complex projects; contains a technical, programmatic, and a schedule that are used as the basis for a cost estimate                                                                                                                   |
| AS                                  | DoD  | DoDI 5000.02T Enc 2, para 6a  | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives                                              |
| AoA                                 | DoD  | 40 U.S.C 11312                | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement                                   |
| SEP                                 | DoD  | DoDI 5000.02T Enc 3, Sec 2    | management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                                            |
| PPP                                 | DoD  | DoDI 5000.02T Enc 3, para 13a | to manage the risks to critical program information and mission-critical functions and components associated with the program                                                                                                                                     |
| CDD)                                | DoD  | JCIDS Manual                  | specifies capability requirements, in terms of developmental performance attributes (KPPs, KSAs, and APAs), and other related information necessary to support development of one or more increments of a materiel capability solution                            |
| CONOPS/MP                           | DoD  | JCIDS Manual                  | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                    |
| TEMP                                | DoD  | DoDI 5000.02T Enc 4 & 5       | primary planning and management tool for the integrated test program                                                                                                                                                                                              |
| PESHE/NEPA Compliance *             | DoD  | 42 U.S.C 4321-4347            | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known/projected system-related activities that may trigger compliance requirements including testing, fielding, and support |
| SSRA                                | DoD  | DoDI 4650.01                  | written determinations that the electromagnetic spectrum necessary to support the operation of the system during its expected life-cycle is or will be available in accordance with DoD Instruction 4650.01                                                       |
| Frequency Allocation Application *  | DoD  | 47 U.S.C. 305                 | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                      |
| APB                                 | DoD  | DoDD 5000.01                  | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                           |
| Design Solution definition Baseline | NASA |                               | represents build-to system design and process specifications; provides the basis for manufacturing, buying, coding, and subsequent integration of the products that make up the system                                                                            |
| CPD                                 | DoD  | JCIDS Manual                  | specifies capability requirements, in terms of production performance parameters (KPPs, KSAs, and APAs), and other related information necessary to support production of a single increment of a materiel capability solution                                    |
| DT&E Assessment                     | DoD  |                               | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                                                                  |
| Operations Handbook                 | NASA | NPR 7120.5E                   | provides information essential to the operation of the spacecraft                                                                                                                                                                                                 |
| OTA Report of OT&E Results          | DoD  | DoDI 5000.02T Enc 5           | all records, reports, and data from every OT&E and LFT&E event                                                                                                                                                                                                    |
| ADM                                 | DoD  | DoDI 5000.02T                 | documents MDA decisions after each review                                                                                                                                                                                                                         |
| PIR *                               | DoD  | 40 U.S.C. 11313               | to compare actual program results with established objectives                                                                                                                                                                                                     |

Now that the complex level deliverables have been reviewed, we will assess how the simple ones compare. For starters, the amount of required documentation was

exceedingly less. So much less that not all the organizations' lists are independently assessed. Instead, Table 22 shows all the deliverables organized to capture the repeats.

Table 22. Simple Deliverables by Organization

| frequency        | 1                 | 1                       | 1                      | 1                     | 1                                     | 1                      | 1                    | 1                      | 1 | 2               | 2                     | 1                 |
|------------------|-------------------|-------------------------|------------------------|-----------------------|---------------------------------------|------------------------|----------------------|------------------------|---|-----------------|-----------------------|-------------------|
| USCGA            |                   |                         |                        |                       |                                       |                        |                      |                        |   |                 |                       |                   |
| Luleå University |                   |                         |                        |                       |                                       |                        |                      |                        |   |                 |                       |                   |
| MSU              |                   |                         |                        |                       |                                       |                        |                      |                        |   |                 |                       |                   |
| U-M              |                   |                         | End-of-Semester Report |                       |                                       |                        |                      | Tech Memo              |   |                 |                       |                   |
| NPS              |                   | Statement of Work (SOW) |                        |                       |                                       | Mission Assurance Plan | Risk Management Plan |                        |   | Master Schedule |                       |                   |
| MIT              | Student Portfolio |                         |                        | Requirements Analysis |                                       |                        |                      | Figures of Merit (FOM) |   |                 | Design Document       | Conceptual Design |
| USNA             |                   |                         |                        |                       | SysML Block Definition Diagrams (BDD) |                        |                      |                        |   | Schedule        | Computer Aided Design |                   |
| CubeSat 101      |                   |                         |                        |                       |                                       |                        |                      |                        |   |                 |                       |                   |
| Org              | Deliverable       |                         |                        |                       |                                       |                        |                      |                        |   |                 |                       |                   |





|                                             |                                       |                               |  |  |  |  |   |
|---------------------------------------------|---------------------------------------|-------------------------------|--|--|--|--|---|
| Dynamic<br>Environment<br>Testing<br>Report |                                       |                               |  |  |  |  | 1 |
|                                             | Full<br>Functional<br>Test<br>Results | Test<br>Results               |  |  |  |  | 2 |
|                                             | CubeSat<br>Acceptance<br>Checklist    |                               |  |  |  |  | 1 |
|                                             | Compliance<br>Letter                  |                               |  |  |  |  | 1 |
|                                             |                                       | Lessons<br>Learned<br>Reports |  |  |  |  | 1 |

To analyze the necessity of these documents, the duplicates were removed and the descriptions of the 47 line items were reviewed. Table 23 provides said details.

Table 23. All Simple Deliverables

| Deliverable                        | Org  | Reference  | Description                                                                                                                                                                             |
|------------------------------------|------|------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Student Portfolio                  | MIT  |            | the individual work of each student as a contribution to the project                                                                                                                    |
| SOW                                | NPS  |            | document broad responsibilities, deliverables, and the work activities required in a given project                                                                                      |
| End-of-Semester Report             | U-M  |            | to capture the major concepts, plans and progress for the lab                                                                                                                           |
| Requirements Analysis              | MIT  |            | assesses potential materiel solutions that could satisfy capability requirements                                                                                                        |
| SysML BDD                          | USNA |            | defines relationships between parts of the structures and shared components; includes Requirements Verification Matrix                                                                  |
| Mission Assurance Plan             | NPS  | NPD 8730.5 | addresses life-cycle Safety & Mission Assurance (SMA) functions and activities, including SMA roles, responsibilities, and relationships                                                |
| Risk Management Plan               | NPS  | NPR 8000.4 | Summarizes how the program or project will implement the NASA risk management process                                                                                                   |
| FOM                                | MIT  |            | capture the stakeholders' view of what would be considered the successful achievement of each expectation                                                                               |
| Tech Memo                          | U-M  |            | documents major milestones                                                                                                                                                              |
| Master Schedule                    | NPS  |            | integrated, networked model containing all critical milestones, major events, life-cycle reviews, and KDPs throughout the project life-cycle                                            |
| Design Document                    | MIT  |            | captures the organization, requirements, trades, design, budgets, and test results of the project                                                                                       |
| Conceptual Design                  | MIT  |            | presents feasible ways of accomplishing the stakeholder expectations                                                                                                                    |
| Preliminary Design                 | MIT  |            | initial design solution to meet requirements                                                                                                                                            |
| Requirements Verification Matrix   | USNA |            | to ensure that all requirements defined for a system are tested in the test protocols                                                                                                   |
| SEMP                               | NPS  |            | a foundation for the implementation of the engineering effort by identifying the deliverables during each phase and defining the quality assurance plan and methodology for the project |
| Master Product Breakdown Structure | NPS  |            | detailed information defining the satellite system, mission operations system, and ground support system and related subsystems                                                         |
| CARD                               | NPS  |            | delineates the design, construction, performance, and verification requirements; defines all tests, analyses, inspections, and certification methods                                    |

|                                       |        |                  |                                                                                                                                                                                                                                                                                                                 |
|---------------------------------------|--------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| CONOPS                                | USNA   |                  | operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                                                           |
| Environmental Management Plan         | NPS    | NPR 8580.1       | Describes the program's NEPA strategy at all affected Centers, including decisions regarding programmatic NEPA documents                                                                                                                                                                                        |
| Software Management Plan              | NPS    | NPR 7150.C       | how the project will develop and/or manage the acquisition of software required to achieve project and mission objectives                                                                                                                                                                                       |
| Logistics Plan                        | NPS    | NPD 7500.1B      | Describes how the program will implement a maintenance and support concept, enhancing supportability, supply support, maintenance planning, packaging, handling and transportation, training, manpower, required facilities, and logistics information systems for the life                                     |
| ICD                                   | USNA   |                  | a record of all interface information; provides the details and describes the interfaces between subsystems or to a system or subsystem                                                                                                                                                                         |
| PMP                                   | NPS    |                  | defining document for the program's mission and objectives; describes the technical approach that will be used by the development team                                                                                                                                                                          |
| Critical Design                       | MIT    |                  | final design that meets the requirements with adequate margins                                                                                                                                                                                                                                                  |
| Dimensional Verifications             | CS-101 |                  | shows adherence to the dimensional requirements specified in the CubeSat-to-dispenser ICD                                                                                                                                                                                                                       |
| Radio Frequency License               | CS-101 | 47 CFR Part 97   | must obtain appropriate license in order to transmit signals                                                                                                                                                                                                                                                    |
| Remote Sensing License                | CS-101 |                  | must obtain appropriate license in order to take pictures or videos of Earth                                                                                                                                                                                                                                    |
| Data Budget                           | USNA   |                  | calculation of data being generated and stored, and memory allocation                                                                                                                                                                                                                                           |
| Transmitter Surveys                   | CS-101 |                  | series of questions about the CubeSat's communication system used to help the LV provider perform EMI/EMC analysis to verify that the CubeSat meets RF inhibit requirements                                                                                                                                     |
| Mass Properties Report                | CS-101 |                  | identifies the CubeSat's total mass, center of gravity, moments of inertia (MOIs), and products of inertia (POI) relative to each axis                                                                                                                                                                          |
| Materials List                        | CS-101 |                  | usually a Word document identifying every material used on the CubeSat along with its mass (or expected mass), its location on the CubeSat, and its out-gassing properties including Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVMC)                                                  |
| Battery Report                        | CS-101 |                  | verify that proper battery circuit protection is in place                                                                                                                                                                                                                                                       |
| Electrical Report                     | CS-101 | CDS para 3.3     | to verify electrical requirements listed in CubeSat-to-dispenser ICD                                                                                                                                                                                                                                            |
| Thermal Vacuum Bakeout Testing Report | CS-101 |                  | to allow the CubeSat's materials to outgas any possible contaminants before the actual launch                                                                                                                                                                                                                   |
| Venting Analysis                      | CS-101 |                  | identify the vent and non-vent volumes, and the venting area locations on the CubeSat                                                                                                                                                                                                                           |
| MSPSP                                 | CS-101 |                  | covers all the hazards that the CubeSat could pose to the LV, the dispenser, other CubeSats, and personnel handling or in proximity                                                                                                                                                                             |
| ODAR                                  | CS-101 | 47 CFR 25.114(d) | assures all interested parties that CubeSat will not pose an unacceptable hazard to other orbiting spacecraft, will deorbit in a reasonable amount of time, and that no unacceptably large piece of the CubeSat is going to survive reentry when it deorbits and burns up in the atmosphere                     |
| Security Plan                         | NPS    | NPD 1600.2       | describes the project's plans for security and technology protection                                                                                                                                                                                                                                            |
| Testing Procedures & Reports          | CS-101 |                  | states which requirements are being verified and the specific evidence in the report that verifies each requirement                                                                                                                                                                                             |
| Data Management Plan                  | NPS    | NPR 7120.5E      | describes how the project will manage the scientific data generated and captured by the operational mission                                                                                                                                                                                                     |
| Mission Operations Plan               | NPS    | NPR 7120.5E      | Discusses how the project will implement the associated facilities, hardware, software, and procedures required to complete the mission                                                                                                                                                                         |
| DITL Testing Report                   | CS-101 |                  | will show that the CubeSat's timers and inhibit design function correctly, adhering to the appropriate mission ICD requirements                                                                                                                                                                                 |
| Dynamic Environment Testing Report    | CS-101 |                  | show that the CubeSat will survive the vibrations and shocks that it will experience during launch                                                                                                                                                                                                              |
| Test Results                          | MIT    |                  | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                                                                                                                |
| CubeSat Acceptance Checklist          | CS-101 |                  | confirms CubeSat adheres to dimensional requirements specified in the CubeSat-to-dispenser ICD                                                                                                                                                                                                                  |
| Compliance Letter                     | CS-101 |                  | statement from the CubeSat developer guaranteeing that the CubeSat is compliant with the entire CubeSat-to-dispenser Interface Control Document (ICoD), and that no prohibited components are aboard; includes mass properties, materials list, battery report, electrical report, CubeSat acceptance checklist |
| Lessons Learned Reports               | MIT    |                  | reflects on all issues encountered during development and offers solutions to avoid in the future                                                                                                                                                                                                               |

Not all of the documents were applicable to CSRA so the unnecessary documentation was waived and others were combined where possible. Table 24 reflects the deliverables that were kept. The list justifying why events were waived and where events were combined is found in Appendix G.

Table 24. Tailored Simple Deliverables

| Deliverable                   | Org    | Description                                                                                                                                                                                                                                                                        |
|-------------------------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| SOW                           | NPS    | document broad responsibilities, deliverables, and the work activities required in each project                                                                                                                                                                                    |
| SysML BDD                     | USNA   | defines relationships between parts of the structures and shared components; includes Requirements Verification Matrix                                                                                                                                                             |
| Mission Assurance Plan        | NPS    | addresses life-cycle SMA functions and activities, including SMA roles, responsibilities, and relationships                                                                                                                                                                        |
| SEMP                          | NPS    | a foundation for the implementation of the engineering effort by identifying the deliverables during each phase and defining the quality assurance plan and methodology for the project                                                                                            |
| CONOPS                        | USNA   | operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and phase of mission                                                                                       |
| Environmental Management Plan | NPS    | Describes the program's NEPA strategy at all affected Centers, including decisions regarding programmatic NEPA documents                                                                                                                                                           |
| ICD                           | USNA   | a record of all interface information; provides the details and describe the interface or interfaces between subsystems or to a system or subsystem                                                                                                                                |
| PMP                           | NPS    | defining document for the program's mission and objectives and describes the technical approach that will be used by the development team                                                                                                                                          |
| Critical Design               | MIT    | final design that meets the requirements with adequate margins                                                                                                                                                                                                                     |
| Radio Frequency License       | CS-101 | must obtain appropriate license in order to transmit signals                                                                                                                                                                                                                       |
| Remote Sensing License        | CS-101 | must obtain appropriate license in order to take pictures or videos of Earth                                                                                                                                                                                                       |
| Testing Procedures & Reports  | CS-101 | states which requirements are being verified and the specific evidence in the report that verifies each requirement                                                                                                                                                                |
| Test Results                  | MIT    | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                                                                                   |
| Compliance Letter             | CS-101 | statement from the CubeSat developer guaranteeing that the CubeSat is compliant with the entire CubeSat-to-dispenser ICoD, and that no prohibited components are aboard; includes mass properties, materials list, battery report, electrical report, CubeSat acceptance checklist |
| Lessons Learned Reports       | MIT    | reflects on all issues encountered during development and offers solutions to avoid in the future                                                                                                                                                                                  |

Several of the deliverables from the tailored complex list and tailored simple list were similar. To compare these similarities and the documents that were unique to each list more closely, both Table 21 and Table 24 were combined to create Table 25.

Table 25. Final Deliverables

| Deliverable                         | S/C/B | Org    | Reference                     | Description                                                                                                                                                                                                                                                                | Stat |
|-------------------------------------|-------|--------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|
| SOW                                 | S     | NPS    |                               | document broad responsibilities, deliverables, and the work activities required in a given project                                                                                                                                                                         |      |
| ICD                                 | C     | DoD    | CJCSI 3170.01                 | specifies one or more capability requirements and associated capability gaps which represent unacceptable operational risk if left unmitigated                                                                                                                             |      |
| SysML BDD                           | S     | USNA   |                               | captures the requirements & design; defines relationships between parts of the structures and shared components; includes Requirements Verification Matrix; used to build to Design Solution definition Baseline; incorporates Interface                                   |      |
| CADRe                               | C     | NASA   |                               | basis of cost estimates for complex projects; contains a technical, programmatic, and a schedule that are used as the basis for deriving a cost estimate                                                                                                                   |      |
| AS                                  | B     | DoD    | DoDI 5000.02T Enc 2, para 6a  | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives                                                       |      |
| AoA Report                          | C     | DoD    | 40 U.S.C 11312                | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement                                            |      |
| SEP                                 | B     | DoD    | DoDI 5000.02T Enc 3, Sec 2    | management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                                                     |      |
| PPP                                 | C     | DoD    | DoDI 5000.02T Enc 3, para 13a | addresses life-cycle Safety & Mission Assurance (SMA) functions and activities, including SMA roles, responsibilities, and relationships; and manage the risks to critical program information and mission-critical functions and components associated with the program   |      |
| CDD                                 | C     | DoD    | JCIDS Manual                  | specifies capability requirements, in terms of developmental performance attributes (KPPs, KSAs, and APAs), and other related information necessary to support development of one or more increments of a materiel capability solution                                     |      |
| CONOPS/MP                           | B     | DoD    | JCIDS Manual                  | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission; contains Core Logistics Determination *                    |      |
| TEMP                                | B     | DoD    | DoDI 5000.02T Enc 4 & 5       | primary planning and management tool for the integrated test program                                                                                                                                                                                                       |      |
| PESHE/NEPA Compliance *             | B     | DoD    | 42 U.S.C 4321-4347            | includes identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that trigger compliance requirements including testing, fielding, and support of the system | x    |
| SSRA                                | C     | DoD    | DoDI 4650.01                  | written determinations that the electromagnetic spectrum necessary to support the operation of the system during its expected life-cycle is or will be available in accordance with DoD Instruction 4650.01                                                                |      |
| Frequency Allocation Application *  | B     | DoD    | 47 U.S.C. 305                 | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                               | x    |
| Remote Sensing License              | S     | CS-101 |                               | must obtain appropriate license in order to take pictures or videos of Earth                                                                                                                                                                                               |      |
| APB                                 | C     | DoD    | DoDD 5000.01                  | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                    |      |
| Design Solution definition Baseline | B     | NASA   |                               | represents build-to system design and process specifications; provides the basis for manufacturing, buying, coding, and subsequent integration of the products that make up the system                                                                                     |      |

|                     |   |        |                     |                                                                                                                                                                                                                                                                             |   |
|---------------------|---|--------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| CPD                 | C | DoD    | JCIDS Manual        | specifies capability requirements, in terms of production performance parameters (KPPs, KSAs, and APAs), and other related information necessary to support production of a single increment of a materiel capability solution                                              |   |
| DT&E Assessment     | C | DoD    |                     | Analysis of system & sub-system progress in meeting performance metrics, technical risk, software maturity                                                                                                                                                                  |   |
| Operations Handbook | C | NASA   | NPR 7120.5E         | provides information essential to the vehicle operation                                                                                                                                                                                                                     |   |
| OT&E Results        | B | DoD    | DoDI 5000.02T Enc 5 | all records, reports, and data from every OT&E and LFT&E event                                                                                                                                                                                                              |   |
| Compliance Letter   | S | CS-101 |                     | statement from the CubeSat developer guaranteeing that the CubeSat is compliant with the CubeSat-to-dispenser ICoD, and that no prohibited components are aboard; includes mass properties, materials list, battery report, electrical report, CubeSat acceptance checklist |   |
| ADM                 | C | DoD    | DoDI 5000.02T       | documents MDA decisions after each review                                                                                                                                                                                                                                   |   |
| PIR *               | B | DoD    | 40 U.S.C. 11313     | to compare actual program results with established performance objectives                                                                                                                                                                                                   | x |

Within the “S/C/B” column, “S” represents deliverables only from the simple list, “C” is for deliverables only on the complex list, and “B” is when deliverables were captured by both lists. After evaluating the usefulness of these 24 required documents, none were waived. The list with justifications is found in Appendix H.

### Life-Cycle Phase Entrance/Exit Criteria

The entrance/exit criteria for each phase were addressed in the Life-Cycle section but details were not provided yet. This research did not assess the criteria specified by each organization or at each milestone/key decision point because all criteria would change as the life-cycles and deliverables were tailored. This would change all the criteria thus the decision was made to wait until a tailored life-cycle and list of deliverables was completed.

As previously mentioned, no reviews were scheduled to act solely as a Milestone Review. Successful completion of the SRR moves the project into DD&I. An effective TRR enters the project into V&V. And finally, the OTRR is equivalent to MS-C, allowing the start of operational testing. The entrance/exit criteria were developed around these reviews.

Most of the tailored deliverables were adopted from the DoD list which were detailed in DoDI 5000.02T. This instruction specified when these documents should be completed within the ACAT III life-cycle. Additionally, NPR 7123.1C and the *SMC Systems Engineering Primer and Handbook* were used to identify the appropriate criteria to be addressed. These three publications were the primary means of identifying when the deliverables are due and TRLs must be met. Entrance/exit criteria must be reviewed and completed by the Materiel Development Decision (MDD), System Requirements Review (SRR), Test Readiness Review (TRR), Operational Test Readiness Review (OTRR), and Operational Readiness Review (ORR).

The purpose of the entrance/exit criteria is not to have the deliverables completed for the review, but to ensure the deliverables that should have already been completed, are completed. The tailored entrance/exit criteria applicable to the previously tailored life-cycle and deliverables are as follows:

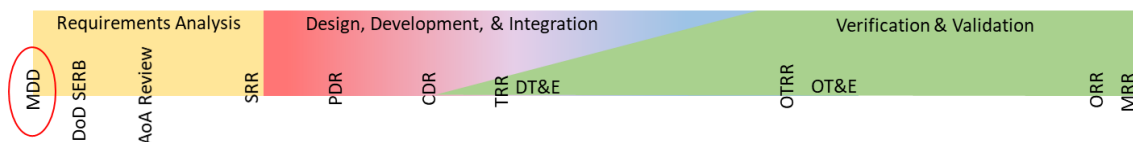


Figure 42. Requirements Analysis Entrance

@ MDD- entering Requirements Analysis

- Statement of Work (SOW)
- Initial Capabilities Document (ICD)
- Cost Analysis Data Requirement (CADRe)
  - Define cost estimates and goals
- Acquisition Decision Memorandum (ADM)

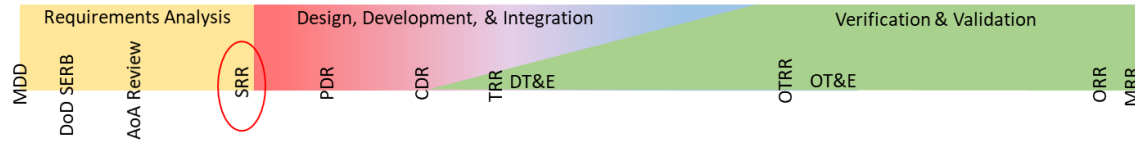


Figure 43. Requirements Analysis Exit

@ SRR- exiting Requirements Analysis; entering Design, Development, & Integration

(DD&I)

- Acquisition Strategy (AS)
- Update CADRe
  - Analyze affordability goals
  - Address cost risk
- System Engineering Plan (SEP)
- Analysis of Alternatives (AoA) report
- Program Protection Plan (PPP)
  - Identify & assess major risks
- Concept of Operations (CONOPS)
- System Modeling Language (SysML) Block Definition Diagrams
  - Define external interfaces
  - Allocate all technical requirements
- Frequency Allocation Application \*
  - Submitted if applicable
- Remote Sensing License
  - Submitted if applicable
- Draft Acquisition Program Baseline (APB)
  - Define schedule
- Draft Capability Development Document (CDD)
  - Identify key performance parameters (KPP)/key system attributes (KSA)
  - Define project requirements
- Draft Test & Evaluation Master Plan (TEMP)
- Confirm tailored model is still appropriate for program based on current status
- ADM

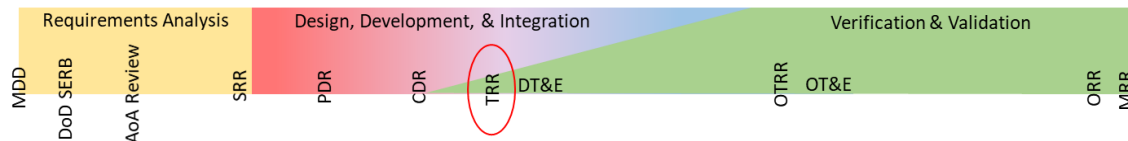


Figure 44. DD&I Exit

@ TRR- exiting DD&I; entering Verification & Validation (V&V)

- Updated AS
- CDD
  - Refine KPPs/KSAs
- Updated CADRe
  - Analyze binding affordability cap
  - Address cost risk
- Updated SEP
- Updated AoA
  - Technical trade-off studies completed
- Updated PPP
  - Performance risk are identified w/ effective plan to address
- Updated CONOPS
- Design Solution Definition Baseline
  - Meets acceptable level of risk
- APB
  - Address schedule risk
- TEMP
  - Comprehensive approach
- Spectrum Supportability Risk Assessment (SSRA)
- Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)/  
National Environmental Policy Act (NEPA) Compliance \*
- Test Readiness Level (TRL) 6
- Confirm tailored model is still appropriate for program based on current status
- ADM

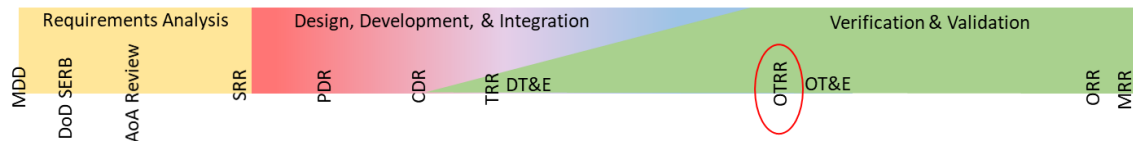


Figure 45. OT&E Entrance

@ OTRR- begin OT&E

- Updated AS
- Capability Production Document (CPD)
- Update CADRe
  - Analyze binding affordability cap
  - Address cost risk
- Updated SEP
- Updated AoA
- Updated PPP
  - Performance risk completely understood and managed
- Updated CONOPS
- Final Design Solution
  - Meets requirements w/in adequate margins
- Updated APB
  - Address schedule risk
- Developmental Test & Evaluation (DT&E) Assessment
  - Acceptable performance
- Operations Handbook
- TRL 7
- ADM

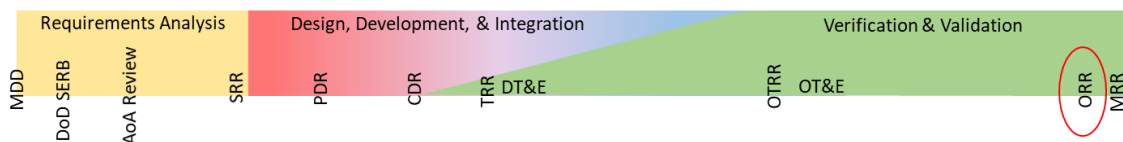


Figure 46. V&V Exit

@ ORR- exiting V&V

- Compliance Letter
  - Satellite meets all required criteria and is ready for mission
- Post Implementation Review (PIR) \*
- Operational Test & Evaluation (OT&E) Results

- Acceptable performance
- ADM

Establishing entrance/exit criteria for the tailored life-cycle identifies when the tailored deliverables must be complete. The rejoining of the framework's three facets completes the framework designed for CSRA's CubeSat projects.

## **Investigative Questions Answered**

Chapter I introduces three investigative questions to guide the research efforts throughout this process:

1. What acquisition regulations or other guidance does CSRA need to comply with and what other procedures are applicable to CSRA's CubeSat development cycle?
2. What developmental reviews, timelines, and documentation exist within other universities and/or civilian organizations developing CubeSats that may be implemented in CSRA?
3. What entrance/exit criteria should be followed for each of the major program reviews for the CSRA CubeSat program?

The first question directed the research to the review of regulations, instructions, and guidance from the DoD, Air Force, and NASA as they are the most relevant to the topic. AFPAM 63-128 defines a program as a system tracked on the Air Force Acquisition Master List (AML). NPR 7120.5E defines a program as a strategic investment by a Mission Directorate or Mission Support Office. Centered on these two definitions, CSRA's CubeSat projects are not official acquisitions programs and as such are not required to follow any of the corresponding regulations.

Although the processes used by several universities with CubeSat programs were studied in Chapter II and assessed in Chapter IV, the framework that was found to be most useful was that of the DoD process. Many of the universities examined for this

research required their students to be the primary CubeSat developers and to have a finished satellite by the end of their associated courses. CSRA's projects are more complex, require much more effort, and take longer than these universities thus the same life-cycles are not applicable.

After tailoring a life-cycle from all the possible phases, events, and reviews identified across various organizations, the list of required deliverables was also tailored to support the CubeSat development process. The deliverables and additional criteria were tied to specific events and reviews of the life-cycle in Chapter IV as a tailored approach to the entrance/exit criteria.

## **Summary**

This chapter tailored the phases, events, and reviews of every organization that was reviewed in Chapter II. Each life-cycle was tailored with intent of being used for CSRA's CubeSat project. The processes used by universities and suggested by the CubeSat 101 do not contain the level of reviews appropriate for the complexity of the CubeSats being developed by CSRA. The DoD, Air Force, and NASA models all had the same theme around how a development process would work and any one of them would be appropriate for CSRA. But since CSRA is not limited by the DoD, Air Force, or NASA regulations, a further tailored life-cycle could be created that is completely CSRA specific. Once a life-cycle was established, the list of required deliverables was tailored to match. Finally, the entrance/exit criteria were established to direct timing of the deliverables and readiness levels.

## **V. Conclusions and Recommendations**

### **Chapter Overview**

This final chapter summarizes how the research concluded in a new framework for the development of CubeSats. If Center for Space Research and Assurance (CSRA) adopts the purposed framework, it could improve management oversight and reduce wasted efforts for each CubeSat project. The research did not fully examine timelines or budgetary limits therefore future research should be conducted to analyze these important attributes.

### **Conclusions of Research**

This research examined the necessity of following Department of Defense (DoD), National Aeronautics and Space Administration (NASA), or U.S. Air Force (USAF) established regulations and determining which process is best for developing CubeSats. DoD and USAF regulations are directed at major acquisition programs and the projects that comprise the program. The acquisition process is very detailed with events and reviews that occur within determined phases and requires documentation throughout the process. NASA instructions direct a similar process comprised of different events and documentation. All three organizations advocated the full process be tailored or reduced to only the events and reviews that would lead to a successful project.

The DoD, NASA, and USAF acquisition processes were tailored in a manner to best suit a university developing CubeSats. The tailored processes contain many similarities suggesting that the overall practices were created around the same knowledge of how to successfully manage a project. Either tailored approach would be effective for

developing CubeSats, but they may not be the most effective process. If the process could be defined without the regulatory bindings of the DoD, USAF, or NASA, it could be tailored further.

Research identified that CSRA's CubeSat projects are not considered acquisition programs by the any organization. This makes the earlier regulations more like guidance instead of firm requirements. Based on recommendations from CubeSat developers and DoD, USAF, and NASA guidance, a new framework was conceived. The life-cycle is depicted in Figure 39, the accompanying documentation in Table 15, followed by the entrance/exit criteria in Chapter IV. These three aspects form the new framework developed specifically for CSRA's CubeSat projects.

### **Significance of Research**

The purpose of this research was to define an acquisition framework that would be most beneficial to the development of CubeSats by AFIT's Center for Space Research and Assurance. The final model represented by Figure 41 and accompanying deliverables identified in Chapter IV attempt to do just that. If CSRA finds this developmental framework acceptable, the ideal situation would be that personnel are able to spend more effort on the development process than the administrative obligations. This could both improve the quality of the CubeSat and reduce time to completion. It also provides a means to measure completion with respect to the planned launch vehicle integration date. Knowing the status of a project is crucial to keeping it on track, and this framework offers standardized reference points by which to judge status.

Assuming the framework is successful, it may one day be presented at a SmallSat Conference and adopted by other universities. As said by Dr. Keys at TEDx Nashville regarding space exploration, “getting to the destination is great but what you learn along the way is extraordinarily important” (TEDx, 2011). The use of a successful process in the academia environment improves student learning, thereby resulting in greater contributions to advancing technologies and improving society. If CubeSat popularity expands further into the DoD sector with the realization of how they could be used for incremental upgrade testing or short-term missions, this framework is one that could be considered for regular use.

### **Recommendations for Action**

It is recommended that CSRA adopt the purposed developmental framework for future CubeSat projects as a way to shorten the project timeline. The life-cycle reduces unnecessary reviews and directs focus to the development processes that require the most effort. It is also recommended that CSRA consider implementing other suggested ways of improving a CubeSat project that were offered by other CubeSat developers. These suggestions include enforcing the appropriate documentation, planning for early integration, and conducting testing early and often.

### **Recommendations for Future Research**

This developmental framework was designed to provide a transparent and manageable process with limited reviews and deliverables to allow CSRA to focus on the development instead of the administrative work. With more efforts focused on development, CSRA should be able to produce a successful CubeSat within the desired

timeframe of three years. This framework was developed based on information from regulations and recommendations of other developers but does not have sufficient data to confirm it fits CSRA's timeline. Based on publications that were reviewed, this framework fits with the estimated timelines associated with phases of development, but these are just estimates and do not accurately represent the manpower and resources available at CSRA. Further research should be conducted to refine the timing of reviews, thus allowing them to coordinate with student's curriculum and fit CSRA's desired window.

To better determine what events, reviews, milestones, and deliverables are associated with successful CubeSat or small satellite missions, statistical analyses could be conducted in more data is gathered. By identifying which events and documents were completed for each satellite mission and comparing to the successes, one can obtain a more accurate picture of what is likely to work.

Finally, this research was completed with the assumption that budget would not be a limiting factor. Budget availability influences manpower and resource availability. Future research could examine the relationships between this framework and the CubeSats that have previously been developed to gather data useful for estimating the funding requirements associated with the new process. Along the same lines, future research could also determine if the budget to timeframe ratio is appropriate by investigating the earned value management of the process.

## **Summary**

The CSRA CubeSat project does not meet the definition of an acquisition program in AFI 63-101 or NPR 7120.5E. Because it is not an acquisition project, CSRA is not required to follow the DoD or Air Force regulations on program management and acquisition life-cycles. Even though the regulations are not mandatory, they were analyzed heavily to extract the acquisition processes they recommend. Additionally, the processes of other universities developing CubeSats were reviewed to assess usefulness. After tailoring each process to meet the needs of CSRA, it was determined that the DoD or NASA processes would work but could be improved upon. Another approach was taken by developing a fully customized framework including life-cycles, deliverables, and entrance/exit criteria.

## Appendix A. Complex Life-Cycle Tailored

| Event                                            | Org  | Reference     | Description                                                                                                                                                                                                       | Keep | Waive | Tailor | Justification                                                                      |
|--------------------------------------------------|------|---------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|--------|------------------------------------------------------------------------------------|
| AF Review Board                                  | AF   | AFI 63-101    | forums chaired by the SAE, or as delegated, for conducting major decision reviews                                                                                                                                 |      | x     |        | not needed for AFIT project                                                        |
| Initial Capabilities Document (ICD) Validation   | DoD  | JCIDS         | stakeholders validate operational attributes and capability requirements best address the needs of the force                                                                                                      |      | x     |        | capability requirements will come from sponsor                                     |
| Mission Concept Review (MCR)                     | NASA | 7123.1C       | to evaluate the feasibility of the proposed mission concept(s) and its fulfillment of the program's needs and objectives                                                                                          |      | x     |        | will occur during KDP A                                                            |
| Materiel Development Decision (MDD)              | DoD  | DoDI 5000.02T | entry point into the acquisition process                                                                                                                                                                          | 3    |       | x      | CSRA's decision to develop CubeSat                                                 |
| Analysis of Alternatives (AoA) Review            | DoD  | DoDI 5000.02T | Assess how well the recommended alternative satisfies requirements in the most cost-effective manner                                                                                                              | x    |       |        | opportunity to ensure all plausible avenues have been explored                     |
| Acquisition Strategy Meeting (ASM)               | NASA | 7120.5E       | strategic planning and procurement forum where senior Agency management reviews major acquisitions in programs and projects                                                                                       |      | x     |        | held at the Mission Directorate/Mission Support Office level                       |
| Alternative Systems Review (ASR)                 | DoD  | DAG           | evaluate whether there is sufficient understanding of the technical maturity, feasibility, and risk of the preferred materiel solution                                                                            |      | x     | x      | materiel solutions can be reviewed during AoA Review                               |
| Mission Definition Review (MDR)                  | NASA | NPR 7123.1C   | to evaluate the credibility and responsiveness of the proposed mission/system architecture to the program requirements and constraints                                                                            |      | x     | x      | combine in SRR                                                                     |
| Milestone A Decision Review                      | AF   | AFI 63-101    | investment decision to pursue specific product or design concepts, and to commit the resources required to mature technology and/or reduce any risks                                                              | 3    |       | x      |                                                                                    |
| System Requirements Review (SRR)                 | AF   | SMC SE        | technical review to ensure the system requirements are captured and stakeholders are ready to proceed with the initial system design                                                                              | 3    |       | x      | use review as major decision point                                                 |
| System Functional Review (SFR)                   | DoD  | DAG           | to evaluate whether the functional baseline satisfies the end-user requirements and capability needs and whether functional requirements and verification methods support achievement of performance requirements |      | x     | x      | functional requirements can be combined with system requirements; combine with SRR |
| Capability Development Document (CDD) Validation | DoD  | DoDI 5000.02T | validate that requirements are technically achievable, affordable, testable and address the priorities of the stakeholders                                                                                        |      | x     | x      | CDD to be reviewed during PDR                                                      |

|                                                    |     |               |                                                                                                                                                                                             |   |   |   |                                                                                           |
|----------------------------------------------------|-----|---------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-------------------------------------------------------------------------------------------|
| System Requirements and Architecture Review (SRAR) | AF  | SMC SE        | Review and Approval of the Software Architecture and Functional Requirements Baseline                                                                                                       |   | x | x | can be combined with SRR                                                                  |
| Test & Evaluation Planning                         | DoD | DoDI 5000.02T | develop integrated test program summary and master schedule of all major test events or test phases                                                                                         |   | x | x | all testing planning and procedures will be documented in the TEMP                        |
| Request for Proposal (RFP) Release Decision        | DoD | DoDI 5000.02T | to ensure, prior to the release of the solicitation for EMD, that an executable and affordable program has been planned using a sound business and technical approach                       |   | x |   | not contracting efforts                                                                   |
| Preliminary Design Review (PDR)                    | DoD | DoDI 5000.02T | decision to commit the resources needed to conduct development leading to production and fielding of the product.                                                                           | 3 |   | x | need to decide if the project can still be accomplished by CSRA and ready to move forward |
| Milestone B Decision Review                        | AF  | AFI 63-101    | decision to commit the resources needed to conduct development leading to production and fielding of the product.                                                                           | 4 |   | x | hold w/ MS-A like DoDI 5000.02T accelerated model                                         |
| Critical Design Review (CDR)                       | DoD | DoDI 5000.02T | assesses design maturity, design build-to documentation, and remaining risks and establishes the initial product baseline; decision point to begin prototype build                          | 3 |   |   | need to ensure plans meet requirements                                                    |
| Capabilities Production Document (CPD) Validation  | DoD | JCIDS         | assess how the capability solution, its performance attributes (KPPs, KSAs, and APAs), and other supporting data, address the validated capability requirements                             |   | x |   | will re-validate CDD if no changes                                                        |
| Test Readiness Review (TRR)                        | DoD | DoDI 5000.02T | assess test objectives, test methods and procedures, test scope, safety, and whether test resources have been properly identified and coordinated                                           | x |   |   | ensure proper tests will be accomplished safely                                           |
| Developmental Test & Evaluation (DT&E)             | DoD | DoDI 5000.02T | to manage and mitigate risks during development and verify that products are compliant with operational requirements                                                                        | x |   |   | ensure subsystems and components work as expected prior to integration                    |
| Early Operational Assessment (EOA)                 | DoD | DAG           | to evaluate a program's progress early in the process towards developing an operationally effective, suitable, and survivable system                                                        |   | x | x | will be conducted as DT&E                                                                 |
| System Verification Review (SVR)                   | DoD | DAG           | technical assessment point at which the actual system performance is verified to meet the requirements in the system performance specification and is documented in the functional baseline |   | x | x | system will be verified in OT&E                                                           |

|                                                    |      |               |                                                                                                                                                                                                                  |   |   |   |                                                                                           |
|----------------------------------------------------|------|---------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-------------------------------------------------------------------------------------------|
| Functional Configuration Audit (FCA)               | AF   | SMC SE        | formal examination of functional characteristics to verify that the system has achieved the requirements in its allocated baseline                                                                               |   | x | x | can be examined during DT&E                                                               |
| Operational Assessment (OA)                        | DoD  | DAG           | test event that is conducted before initial production units are available and which incorporates substantial operational realism                                                                                |   | x | x | will be conducted as OT&E                                                                 |
| Production Readiness Review (PRR)                  | DoD  | DAG           | determines whether the system design is ready for production, and whether the developer has accomplished adequate production planning for entering LRIP and FRP                                                  |   | 3 |   | only making one in-house                                                                  |
| System Integration Review (SIR)                    | NASA | NPR 7123.1C   | to evaluate the readiness of the project and associated supporting infrastructure to begin system integration and evaluate whether the remaining project development can be completed within available resources |   | x |   | ensures all sub-systems and components are on track                                       |
| Milestone C Decision Review                        | DoD  | DoDI 5000.02T | decision that project is stable and will meet stated and derived requirements based on acceptable performance                                                                                                    | 4 |   |   | need to decide if the project can still be accomplished by CSRA and ready to move forward |
| Low-Rate Initial Production (LRIP) Decision Review | DoD  | DoDI 5000.02T | establishes the initial production base for the system or capability increment                                                                                                                                   |   | x |   | only making one in-house                                                                  |
| Operational Test Readiness Review (OTRR)           | DoD  | DAG           | review of DT&E results, an assessment of the system's progress against the KPPs, key system attributes, and critical technical parameters in the TEMP                                                            | x |   | x | only required for programs under DOT&E oversight; still need TRR prior to OT&E            |
| Initial Operational Test & Evaluation (IOT&E)      | DoD  | DoDI 5000.02T | independent, dedicated phase of OT&E before full-rate production or full deployment that provides objective test results free from potential conflicts of interest or bias                                       |   | x |   | only required for DOT&E oversight list; all operational testing grouped as OT&E           |
| Operational Test & Evaluation (OT&E)               | DoD  | DoDI 5000.02T | to determine the operational effectiveness, operational suitability, and survivability (including cybersecurity) or lethality of a system when operated under realistic operational conditions                   | x |   |   | ensure system works as expected                                                           |
| Physical Configuration Audit (PCA)                 | DoD  | DAG           | to examine the "as-built" configuration of the system or a configuration item against its technical documentation to establish or verify its product baseline                                                    |   | 3 |   | only making one in-house                                                                  |

|                                            |      |               |                                                                                                                                                        |      |       |        |                                                                                 |
|--------------------------------------------|------|---------------|--------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|--------|---------------------------------------------------------------------------------|
| Follow-on OT&E (FOT&E)                     | DoD  | DAG           | to complete unfinished IOT&E activity and evaluate major technical changes made to the system to correct identified deficiencies in the IOT&E          |      | x     |        | only required for DOT&E oversight list; all operational testing grouped as OT&E |
| Operational Readiness Review (ORR)         | NASA | NPR 7123.1C   | ensures that all system and support hardware, software, personnel, procedures, supporting capabilities, and user documentation are operationally ready | x    |       | x      | need to confirm system meets all requirements                                   |
| Manufacturing Readiness Review             | AF   | SMC SE        | confirm readiness for Production, Training, Deployment, Ops, and Support                                                                               |      | x     |        | only making one in-house                                                        |
| Initial Operating Capability (IOC)         | AF   | AFPAM         | the initial amount of systems identified in the contract have been delivered to start operations                                                       |      | x     |        | only making one in-house                                                        |
| Full-Rate Production (FRP) Decision Review | DoD  | DoDI 5000.02T | assess the results of initial OT&E, initial manufacturing, and limited deployment, and determine whether or not to produce the full amount             |      | x     |        | only making one in-house                                                        |
| Mission Readiness Review (MRR)             | NASA | NPR 7123.1C   | examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful launch                            | x    |       |        | last chance to ensure system is ready to accomplish the mission                 |
| Full Operational Capability (FOC)          | AF   | AFPAM         | the full amount of systems identified in the contract have been delivered                                                                              |      | x     |        | only making one in-house                                                        |
| Event                                      | Org  | Reference     | Description                                                                                                                                            | Keep | Waive | Tailor | Justification                                                                   |

Each event or review has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another event/review. An indicator in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for events to be kept with some tailoring. An indicator in the Waive column only is completely. An indicator in the Waive column and Tailor column is for events to be waived by combining it into another event.

A number in any column represents the frequency the event appears among the four frameworks. Only frequencies of three or four were identified.

## Appendix B. Simple Life-Cycle Tailored

| Event                                                               | Org    | Description                                                                                                                                                                        | Keep | Waive | Tailor | Justification                                                                   |
|---------------------------------------------------------------------|--------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|--------|---------------------------------------------------------------------------------|
| Merit Review                                                        | CS-101 | assess the goals and objectives of the mission to determine the quality of its investigation in regard to science, education, and/or technology                                    |      | x     | x      | conduct during SCR                                                              |
| Analysis of Feasibility                                             | NPS    | to determine the viability of a concept                                                                                                                                            |      | x     | x      | conduct during SCR                                                              |
| DoD Space Experiments Review Board (SERB)                           | USAFA  | evaluate, approve, and prioritize a list of candidate experiments for spaceflight consideration                                                                                    | x    |       |        | need approval to be assigned launch vehicle                                     |
| System Concept Review (SCR)                                         | USNA   | to ensure the concept is a viable approach for meeting the system requirements                                                                                                     | x    |       | x      |                                                                                 |
| Alternative Systems Review (ASR)                                    | USAFA  | evaluate whether there is sufficient understanding of the technical maturity, feasibility, and risk of the preferred materiel solution                                             |      | x     | x      | can be evaluated during SRR                                                     |
| System Requirements Review (SRR)/ Mission Requirements Review (MRR) | USNA   | technical review to ensure the system requirements are captured and stakeholders are ready to proceed with the initial system design                                               | 3    |       |        | to capture requirements from top tier down                                      |
| CubeSat Launch Initiative (CSLI) Proposal                           | CS-101 | response to NASA posting any Announcement of Opportunity                                                                                                                           |      | x     |        | not applicable                                                                  |
| Conceptual Design Review (CoDR)                                     | MIT    | conceptualizing, analyzing, and defining project plans and requirements                                                                                                            |      | x     |        | wait until PDR                                                                  |
| Weekly Update                                                       | USCGA  | held among the primary participants to manage the project                                                                                                                          |      | 4     |        | too many updates                                                                |
| End-of-semester Lab Bench Review                                    | MIT    | students demonstrate their laboratory experiments, present analysis and results, and field questions from the teaching staff                                                       |      | x     |        |                                                                                 |
| Capstone Brief                                                      | USCGA  | detailed summary of all work performed during student's capstone project                                                                                                           |      | x     |        | not applicable                                                                  |
| CSLI Selection                                                      | CS-101 | proposal approval confirming that NASA will support CubeSat launch                                                                                                                 |      | x     |        | not applicable                                                                  |
| Preliminary Design Review (PDR)                                     | USAFA  | assesses the maturity of the preliminary design supported by the results of requirements trades, prototyping, and critical technology demonstrations; establish allocated baseline | 5    |       | x      | chance to review designs early and make changes before extensive work exhausted |
| Critical Design Review (CDR)                                        | USAFA  | assesses design maturity, design build-to documentation, and remaining risks and establishes the initial product baseline; decision point to begin prototype build                 | 6    |       |        | need to ensure plans meet requirements                                          |
| Mission Manifest                                                    | CS-101 | matched with a launch that will work for your mission parameters                                                                                                                   |      | x     |        | not a meeting or review                                                         |
| Ground testing                                                      | MSU    | confirm satellite communication with ground station performs as expected                                                                                                           |      | x     | x      | conduct during sub-systems test                                                 |
| Day-in-the-Life (DITL) Testing                                      | MSU    | shows the CubeSat's electronics and flight software work as expected                                                                                                               |      | x     | x      | conduct during systems test                                                     |
| Sub-system Test                                                     | MIT    | testing individual sub-systems before integration to verify they perform as required                                                                                               | 3    |       |        |                                                                                 |
| Post Test Review                                                    | NPS    | determine sub-system effectiveness based on test results and take appropriate actions to loop or proceed                                                                           |      | x     | x      | verified during ORR                                                             |

|                                    |        |                                                                                                                                                        |   |   |   |                                               |
|------------------------------------|--------|--------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-----------------------------------------------|
| Hardware in the loop testing       | MSU    | hardware tested in simulated scenarios                                                                                                                 |   | x | x | conduct during sub-systems test               |
| Environmental Test                 | MIT    | to show the CubeSat will survive the vibrations and shocks that it will experience during launch                                                       |   | 3 | x | conduct during sub-systems & systems test     |
| Thermal Vacuum Testing             | CS-101 | required on almost all missions, primarily to allow the CubeSat's materials to outgas any possible contaminants before the actual launch               |   | x | x | conduct during sub-systems & systems test     |
| System Test                        | MIT    | testing individual sub-systems before integration to verify they perform as required                                                                   | x |   |   |                                               |
| Post Test Review                   | NPS    | determine system effectiveness based on test results and take appropriate actions to loop or proceed                                                   |   | x | x | verified during ORR                           |
| Operational Readiness Review (ORR) | NPS    | ensures that all system and support hardware, software, personnel, procedures, supporting capabilities, and user documentation are operationally ready | x |   | x | need to confirm system meets all requirements |
| Flight Readiness Review (FRR)      | USAFA  | examines tests, demonstrations, analyses, and audits that determine the system's readiness for a safe and successful launch                            | 4 |   |   |                                               |
| Post Mission Review                | MIT    | report the outcomes of the vehicle performance                                                                                                         | x |   |   |                                               |

Each event or review has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another event/review. An indicator in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for events to be kept with some tailoring. An indicator in the Waive column only is completely waived. An indicator in the Waive column and Tailor column is for events to be waived by combining it into another event.

A number in any column represents the frequency the event appears among the 11 frameworks. Only frequencies of three or greater were identified.

## Appendix C. DoD Deliverables Tailored

| Deliverable                                   | Guidance      | Reference                    | Description                                                                                                                                                                                                                                                                         | Stat | Reg | K | W | T | Justification                                                                                                                                |
|-----------------------------------------------|---------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|---|---|---|----------------------------------------------------------------------------------------------------------------------------------------------|
| Analysis of Alternatives (AoA) Study Guidance | DoDI 5000.02T | DoDI 5000.02T para 6d(1)(b)  | regulatory guidance to guide the AoA; informs preparation of AoA Study Plan; prepared by DCAPE                                                                                                                                                                                      |      | x   |   | x |   | normally provided prior to program start; not necessary to develop guidance directed at self                                                 |
| AoA Study Plan                                | DoDI 5000.02T | DoDI 5000.02T para 6d(1)(b)  | regulatory guidance to guide the AoA; prepared by lead DoD Component                                                                                                                                                                                                                |      | x   |   | x |   | normally developed prior to program start in response to Study Guidance; no DCAPE to respond to                                              |
| Defense Intelligence Threat Library           | DoDI 5000.02T | DIA Directive 5000.200       | maintains projections of technology and adversary capability trends over the next 20 years                                                                                                                                                                                          |      | x   |   | x |   | part of VOLT which is not needed for ACAT III                                                                                                |
| Initial Capabilities Document (ICD)           | DoDI 5000.02T | CJCSI 3170.01                | specifies one or more capability requirements and associated capability gaps which represent unacceptable operational risk if left unmitigated                                                                                                                                      |      | x   | x |   | x | capability requirements are identified by sponsor or similar agency in some form of documentation (details may be included in CDD per JCIDS) |
| Affordability Analysis                        | DoDI 5000.02T | DoDI 5000.02T Enc 8, Sec 3   | to promote responsible and sustainable investment decisions while avoiding starting or continuing programs that cannot be produced and supported within reasonable expectations for future budgets                                                                                  |      | x   | x |   |   | need to anticipate the remaining cost of a project and regularly monitor spending habits to confirm the project stays on budget              |
| Integrated Master Plan (IMP)                  | DAG           |                              | event-driven government document that provides a framework against which all work is measured; consists of program events, significant accomplishments, and accomplishment criteria; should encompass all Integrated Product Team (IPT) and Work Breakdown Structure (WBS) elements |      |     |   | x | x | can be captured in AS                                                                                                                        |
| Acquisition Strategy (AS)                     | DoDI 5000.02T | DoDI 5000.02T Enc 2, para 6a | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives                                                                |      | x   | x |   | x | need detailed game plan in order to keep track of what needs to be done, what has been done, and everything in between                       |

|                                       |               |                               |                                                                                                                                                                                                                                        |  |   |   |   |   |                                                                                                                        |
|---------------------------------------|---------------|-------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|---|---|---|------------------------------------------------------------------------------------------------------------------------|
| AoA                                   | DoDI 5000.02T | 40 U.S.C 11312                | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement        |  | x | x |   | x | need to identify and document possible capability solutions                                                            |
| System Engineering Plan (SEP)         | DoDI 5000.02T | DoDI 5000.02T Enc 3, Sec 2    | management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                 |  | x | x |   |   | need detailed game plan on how work will be completed and tracked                                                      |
| Life-Cycle Sustainment Plan (LCSP)    | DoDI 5000.02T | DoDI 5000.02 Enc 6, Sec 3     | describe sustainment influences on system design and the technical, business, and management activities to develop, implement, and deliver a product support package                                                                   |  | x |   | x | x | very short life-cycle in comparison to other acquisition programs; integrate into CONOPS                               |
| Integrated Master Schedule (IMS)      | DAG           |                               | integrated, networked model containing all the detailed discrete tasks necessary to realize the IMP accomplishment criteria                                                                                                            |  |   |   | x | x | can be captured in AS                                                                                                  |
| Technology Targeting Risk Assessment  | DoDI 5000.02T | DIA Directive 5000.200        | country-by-country assessment conducted by the DoD entities within the DISE that quantify risks to critical program information (CPI) and related enabling technologies for weapons systems, and advanced technologies or programs     |  | x |   | x |   | only required for programs that identify critical program information (CPI) per DAG Ch 7-5.1.4                         |
| Program Protection Plan (PPP)         | DoDI 5000.02T | DoDI 5000.02T Enc 3, para 13a | to manage the risks to critical program information and mission-critical functions and components associated with the program                                                                                                          |  | x | x |   |   | cybersecurity plans required for IT due to signal send/receive capabilities; required to meet statutory CCA compliance |
| Capability Development Document (CDD) | DoDI 5000.02T | JCIDS Manual                  | specifies capability requirements, in terms of developmental performance attributes (KPPs, KSAs, and APAs), and other related information necessary to support development of one or more increments of a materiel capability solution |  | x | x |   | x | need to document performance requirements                                                                              |

|                                                                                                                                   |               |                                 |                                                                                                                                                                                                                                                                                    |   |   |   |   |                                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------|---------------|---------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---|-------------------------------------------------------------------------------------------------------------------------------|
| System Requirements Document (SRD)                                                                                                | DAG           | JCIDS Enclosure D               | defines the performance of the preferred materiel solution; system performance specification has sufficiently conservative requirements to allow for design trade space                                                                                                            |   |   | x | x | criteria will be documented in CDD                                                                                            |
| Concept of Operations (CONOPS)/Mission Profile (MP)                                                                               | DoDI 5000.02T | JCIDS Manual                    | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                     |   | x | x | x | need to document system and mission operations                                                                                |
| Validated on-line Life-Cycle Threat (VOLT) Report                                                                                 | DoDI 5000.02T | DIA Directive 5000.200          | includes threat modules and is written to articulate the relevance of each module to a specific acquisition program or planned capability                                                                                                                                          |   | x |   | x | not required for ACAT III; can use VOLT from similar type program/project per DAG Ch 7-5.1.1; MDA can waive per DoDI 5000.02T |
| Should Cost Target                                                                                                                | DoDI 5000.02T | DoDI 5000.02T para 6d(3)(b)1    | to proactively target cost reduction and drive productivity improvement into programs                                                                                                                                                                                              |   | x |   | x | to control and reduce costs; combine with affordability analysis                                                              |
| Core Logistics Determination *                                                                                                    | DoDI 5000.02T | DoDI 5000.02T Enc 6, para 3d(2) | applicability of core depot-level maintenance and repair capability requirements                                                                                                                                                                                                   | x |   |   | x | no maintenance or repair once launched; information documented in LCSP per DoDI 5000.02T; LCSP being integrated to CONOPS     |
| Item Unique Identification (IUID) Implementation Plan                                                                             | DoDI 5000.02T | DoDI 8320.04                    | to identify and track applicable major end items, configuration-controlled items, and government-furnished property                                                                                                                                                                |   | x |   | x | does not meet IUID qualifications per DoDI 8320.04 Enc 3                                                                      |
| Test & Evaluation Master Plan (TEMP)                                                                                              | DoDI 5000.02T | DoDI 5000.02T Enc 4 & 5         | primary planning and management tool for the integrated test program                                                                                                                                                                                                               |   | x | x |   | means of recording all test plans                                                                                             |
| Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)/ National Environmental Policy Act (NEPA) Compliance * | DoDI 5000.02T | 42 U.S.C 4321-4347              | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system | x |   | x |   | statutory                                                                                                                     |

|                                                                                               |               |                              |                                                                                                                                                                                                                               |   |   |   |   |   |                                                                                                                                                 |
|-----------------------------------------------------------------------------------------------|---------------|------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---|---|-------------------------------------------------------------------------------------------------------------------------------------------------|
| Bandwidth Requirements Review                                                                 | DoDI 5000.02T | Sec 1047, Public Law 110-417 | a formal review process to ensure that the bandwidth requirements needed to support such program are or will be met                                                                                                           |   | x |   | x | x | data documented in ISP to reviewed by appropriate agency; since waiving ISP, review will be based on data provided in the CDD per DoDI 5000.02T |
| Information Support Plan (ISP)                                                                | DoDI 5000.02T | DoDI 8330.01                 | describes IT and information needs, dependencies, and interfaces for programs; focuses on efficient and effective exchange of information that, if not properly managed, could limit or restrict the operation of the program |   | x |   | x | x | can provide IT supportability analysis in CONOPS per DoDI 8330.01                                                                               |
| Spectrum Supportability Risk Assessment (SSRA)                                                | DoDI 5000.02T | DoDI 4650.01                 | written determinations that the electromagnetic spectrum necessary to support the operation of the system during its expected life-cycle is or will be available in accordance with DoD Instruction 4650.01                   |   | x | x |   |   | to ensure no interference with other systems electromagnetic spectrum                                                                           |
| Information Technology (IT) and National Security System (NSS) Interoperability Certification | DoDI 5000.02T | DoDI 8330.01                 | Joint Interoperability Test Command (JITC) certifies interoperability of IT with joint, multinational, and/or interagency interoperability requirements                                                                       |   | x |   | x |   | may request waiver for DoD Component-unique IT per DoDI 8330.01                                                                                 |
| Request for Proposal (RFP)                                                                    | DoDI 5000.02T | FAR                          | include specifications and statement of work                                                                                                                                                                                  |   | x |   | x |   | not contracting with commercial agency                                                                                                          |
| Frequency Allocation Application *                                                            | DoDI 5000.02T | 47 U.S.C. 305                | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                  | x |   | x |   |   | to obtain transmission frequencies                                                                                                              |
| Clinger-Cohen Act (CCA) Compliance *                                                          | DoDI 5000.02T | Title 40 USC, Subtitle III   | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu or table 11 of DoDI 5000.02 | x |   | x |   | x | all requirements are met by completion of ICD, CDD, AoA, Acquisition Strategy, PPP per DoDI 5000.02T table 11                                   |
| Cybersecurity Strategy (CSS)                                                                  | DoDI 5000.02T | DoDI 8500.01                 | plan that provides an overview of the cybersecurity requirements for the system and describes the security controls in place or planned for meeting those requirements.                                                       |   | x |   | x | x | documented in appendix of PPP per DoDI 8500.01                                                                                                  |

|                                                                                      |               |                              |                                                                                                                                                                                                                                |  |   |   |   |                                                                                                                          |
|--------------------------------------------------------------------------------------|---------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|---|---|--------------------------------------------------------------------------------------------------------------------------|
| Waveform Assessment Application                                                      | DoDI 5000.02T | DoDI 4630.09                 | Application to the DoD CIO for approval of the development or modification of waveforms                                                                                                                                        |  | x |   | x | not required when using commercial communication services or COTS waveforms that have not been modified per DODI 4630.09 |
| Acquisition Program Baseline (APB)                                                   | DoDI 5000.02T | DoDD 5000.01                 | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                        |  | x | x |   | need documented baseline to track development                                                                            |
| Capability Production Document (CPD)                                                 | DoDI 5000.02T | JCIDS Manual                 | specifies capability requirements, in terms of production performance parameters (KPPs, KSAs, and APAs), and other related information necessary to support production of a single increment of a materiel capability solution |  | x | x | x | If there are no changes, a revalidated CDD may be submitted for the CPD required at MS C per DoDI 5000.02T               |
| Operational Test Plan (OTP)                                                          | DoDI 5000.02T | DoDI 5000.02T Enc 5, para 3e | documents the test design, supporting methodology, and analytic details required for the specific operational test                                                                                                             |  | x |   | x | info will be listed in TEMP                                                                                              |
| Developmental Test & Evaluation (DT&E) Assessment                                    | DAG           |                              | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                               |  |   | x |   | need to report results of DT&E                                                                                           |
| Director, OT&E (DOT&E) Report of Initial OT&E (IOT&E)                                | DoDI 5000.02T | 10 U.S.C 2399                | determine a system's operational effectiveness and operational suitability prior to FRP                                                                                                                                        |  | x |   | x | only for programs on DOT&E oversight list per DoDI 5000.02T                                                              |
| Operational Test Agency (OTA) Report of Operational Test & Evaluation (OT&E) Results | DoDI 5000.02T | DoDI 5000.02T Enc 5          | all records, reports, and data from every OT&E and LFT&E event                                                                                                                                                                 |  | x | x | x | AFIT is OTA so may be documented in any agreed upon manner                                                               |
| Live Fire Test & Evaluation (LFT&E) Report                                           | DoDI 5000.02T | 10 U.S.C. 2366               |                                                                                                                                                                                                                                |  | x |   | x | only for programs on DOT&E oversight list per DoDI 5000.02T                                                              |
| DoD Component LFT&E Report                                                           | DoDI 5000.02T | 10 U.S.C 2399                |                                                                                                                                                                                                                                |  | x |   | x | only for programs on LFT&E oversight list per DoDI 5000.02T                                                              |
| Acquisition Decision Memorandum (ADM)                                                | DoDI 5000.02T | DoDI 5000.02T                | documents MDA decisions after each review                                                                                                                                                                                      |  | x | x |   | need documentation of each decision                                                                                      |

|                                    |               |                 |                                                                           |   |  |   |  |  |                              |
|------------------------------------|---------------|-----------------|---------------------------------------------------------------------------|---|--|---|--|--|------------------------------|
| Post Implementation Review (PIR) * | DoDI 5000.02T | 40 U.S.C. 11313 | to compare actual program results with established performance objectives | x |  | x |  |  | to establish lessons learned |
|------------------------------------|---------------|-----------------|---------------------------------------------------------------------------|---|--|---|--|--|------------------------------|

Each deliverable has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another deliverable. An 'x' in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for deliverables to be kept with some tailoring. An indicator in the Waive column only is to completely waive. An indicator in the Waive column and Tailor column is for deliverables to be waived by combining it into another deliverable.

## Appendix D. NASA Deliverable Tailored

| Deliverable                                                     | Guidance | Reference    | Description                                                                                                                                                                                                                                                     | Keep | Waive | Tailor | Justification                                                                                                      |
|-----------------------------------------------------------------|----------|--------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-------|--------|--------------------------------------------------------------------------------------------------------------------|
| Stakeholder Identification and Expectations definition Baseline | 7123.1C  | 5.2.2.2.a(1) | captures the stakeholder expectations identified as needs, goals, and objectives                                                                                                                                                                                |      | x     | x      | captured in Concept definition Baseline                                                                            |
| Formulation Authorization Document (FAD)                        | 7120.5E  |              | describes the purpose of the project, including a clear traceability from the goals and objectives in the Mission Directorate strategies and/ or Program Plan                                                                                                   |      | x     |        | not required for small projects per <\$150M guidance                                                               |
| Formulation Agreement (FA)                                      | 7120.5E  |              | establishes technical and acquisition work that needs to be conducted during Formulation and defines the schedule and funding requirements during Phase A and Phase B for that work                                                                             |      | x     | x      | no agreement until CSRA agrees to development at KDP A; necessary info can be added in Concept definition Baseline |
| Concept definition Baseline                                     | 7123.1C  | 5.2.2.2.a(2) | presents feasible ways of accomplishing the stakeholder expectations                                                                                                                                                                                            | x    |       | x      |                                                                                                                    |
| Concept Documentation                                           | 7120.5E  |              | captures and communicates a feasible concept that meets the goals and objectives of the mission, including results of analyses of alternative concepts, the concept of operations, preliminary risks, and potential descopes                                    |      | x     | x      | combine with Concept definition Baseline                                                                           |
| Program Plan                                                    | 7120.5E  |              | defines the goals and objectives of the program, the environment within which the program operates, and the Management Agreement commitments of the program, including identifying the high-level requirements on both the program and each constituent project |      | x     |        | not required for small projects per <\$150M guidance                                                               |
| Technology Readiness Assessment (TRA)                           | 7120.5E  |              | Identify the specific new technologies that are part of this project; their criticality to the project's objectives, goals, and success criteria; and the current status of each planned technology development, including TRL and associated risks             |      | x     | x      | combine with Concept definition Baseline                                                                           |
| Engineering Development Assessment                              | 7120.5E  |              | Identify major engineering development risks and any engineering prototyping or software model development that needs to be accomplished during phases A and B to reduce development risk                                                                       |      | x     | x      | combine with Concept definition Baseline                                                                           |

|                                                    |         |              |                                                                                                                                                                                                                                                                         |   |   |   |                             |
|----------------------------------------------------|---------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-----------------------------|
| Heritage Assessment Documentation                  | 7120.5E |              | Identify the major heritage hardware and software assumptions and associated risks and the activities and reviews planned to validate those assumptions                                                                                                                 |   | x | x | capture in Acquisition Plan |
| Measure of Effectiveness (MOE) definition Baseline | 7123.1C | 5.2.2.2.a(3) | capture the stakeholders' view of what would be considered the successful achievement of each expectation                                                                                                                                                               |   | x | x | capture in Acquisition Plan |
| Technology Development Plan                        | 7120.5E | NPD 7500.2   | describes the technology assessment, development, management, and acquisition strategies needed to achieve the project's mission objectives                                                                                                                             |   | x | x | capture in Acquisition Plan |
| Acquisition Strategy Meeting (ASM) minutes         | 7120.5E |              | decision-making forum where senior Agency management reviews and approves project acquisition strategies                                                                                                                                                                |   | x |   | no ASM involved             |
| Safety & Mission Assurance (SMA) Plan              | 7120.5E | NPD 8730.5   | addresses life-cycle SMA functions and activities, including SMA roles, responsibilities, and relationships                                                                                                                                                             | x |   | x |                             |
| Risk Management Plan                               | 7120.5E | NPR 8000.4   | Summarizes how the program or project will implement the NASA risk management process                                                                                                                                                                                   |   | x | x | combine in SMA plan         |
| Acquisition Plan                                   | 7120.5E | 4.3.4.2.2    | documents an integrated acquisition strategy that enables the program to meet its mission objectives and provides the best value to NASA                                                                                                                                | x |   | x |                             |
| System Engineering Management Plan (SEMP)          | 7123.1C | NPR 7123.1   | Describes the overall approach for systems engineering including the system design and product realization processes as well as the technical management processes                                                                                                      | x |   | x |                             |
| Review Plan                                        | 7120.5E | 4.3.4.3      | Summarizes the project's approach for conducting a series of reviews including internal reviews and program life-cycle reviews                                                                                                                                          |   | x | x | capture in Acquisition Plan |
| Configuration Management Plan                      | 7120.5E | SP 6105      | Describes the organization, tools, methods, and procedures for configuration identification, configuration control, traceability, and accounting/ auditing                                                                                                              |   | x | x | capture in Acquisition Plan |
| Human Rating Certification Package                 | 7120.5E | NPR 8705.2   | Focuses on the integration of the human into the system, pre-venting catastrophic events during the mission, and protecting the health and safety of humans involved in or exposed to space activities, specifically the public, crew, passengers, and ground personnel |   | x |   | no human integration        |

|                                                          |         |              |                                                                                                                                                                                                                                  |   |   |   |                                  |
|----------------------------------------------------------|---------|--------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|----------------------------------|
| Requirements Baseline                                    | 7123.1C | 5.2.2.2.b(2) | agreed upon need, capability, capacity, or demand for personnel, equipment, facilities, or other resources or services                                                                                                           | x |   | x |                                  |
| System & Subsystem Requirements                          | 7120.5E |              | Document the project's proposed milestones for flow down of requirements to the project, system, and subsystem levels on the project schedule, and provide rationale for any differences from requirements in product maturities |   | x | x | capture in Requirements Baseline |
| Architecture definition Baseline                         | 7123.1C | 5.2.2.2.c(2) | decomposition of the defined functional and performance requirements by functions, time, and behaviors                                                                                                                           |   | x | x | capture in Requirements Baseline |
| Mission Architecture                                     | 7120.5E |              | credible and responsive to program requirements and constraints on the project, including resources                                                                                                                              |   | x | x | capture in Operations Concept    |
| Spacecraft Architecture                                  | 7120.5E |              | how the major project components will be integrated and are intended to operate together and with heritage systems, as applicable, to achieve project goals and objectives                                                       |   | x | x | capture in Acquisition Plan      |
| Technical Performance Measures (TPM) definition Baseline | 7123.1C | 5.2.2.2.c(1) | the important key driving requirements, key performance parameters, leading or lagging indicators, or other measures to track efforts                                                                                            |   | x | x | capture in Requirements Baseline |
| Technical, Schedule, & Cost Control Plan                 | 7120.5E | 4.5.3.2.2    | Describes how the program or project plans to control program or project requirements, technical design, schedule, and cost to achieve its high-level requirements                                                               |   | x | x | capture in Acquisition Plan      |
| Information Technology Plan                              | 7120.5E | NPR 2830.1   | Describes how the program or project will acquire and use information technology including IT security requirements                                                                                                              |   | x | x | capture in Acquisition Plan      |
| Software Management Plan                                 | 7120.5E | NPR 7150.C   | how the project will develop and/or manage the acquisition of software required to achieve project and mission objectives                                                                                                        |   | x | x | capture in Acquisition Plan      |
| Environmental Management Plan                            | 7120.5E | NPR 8580.1   | Describes the program's NEPA strategy at all affected Centers, including decisions regarding programmatic NEPA documents                                                                                                         |   | x | x | capture in Acquisition Plan      |
| Nuclear Safety Launch Approval Plan                      | 7120.5E | NPR 8715.3   | Describes potential risks associated with a planned launch of radioactive materials into space, on launch vehicles and spacecraft, and during flight                                                                             |   | x |   | no radioactive materials         |

|                                                                   |         |              |                                                                                                                                                                                                                                                              |   |   |   |                                                                   |
|-------------------------------------------------------------------|---------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-------------------------------------------------------------------|
| Partnership Agreements                                            | 7120.5E |              | documents roles and contributed items and plans for getting commitments for contributions and finalizing open inter-agency agreements, domestic partnerships, and foreign contributions                                                                      |   | x |   | all inhouse                                                       |
| National Environmental Policy Act (NEPA) Compliance Documentation | 7120.5E | NPR 8580.1   | Environmental Checklist and Record of Environmental Consideration (REC), Environmental Assessment (EA), and Environmental Impact Statement (EIS)                                                                                                             | x |   |   | statutory                                                         |
| Allocation of Requirements Baseline                               | 7123.1C | 5.2.2.2.c(3) | shows how the requirements are allocated to the architecture elements of the next lower level of the product hierarchy                                                                                                                                       |   | x | x | capture in Project Baseline                                       |
| Operations Concept                                                | 7120.5E |              | describe how the flight system and ground system work together across mission phases for launch, cruise, critical activities, science observations, and the end of the mission to achieve the mission                                                        | x |   | x |                                                                   |
| Preliminary Design Solution definition                            | 7123.1C | 5.2.2.2.d(1) | translates the outputs of the logical decomposition process into a design solution definition that is in a form consistent with the product life-cycle phase and product layer location in the system structure and that will satisfy phase success criteria |   | x | x | capture in Project Baseline                                       |
| Project Baselines                                                 | 7120.5E |              | set of requirements, cost, schedule, and technical content that forms the foundation for project execution and reporting                                                                                                                                     | x |   | x |                                                                   |
| Project Plan                                                      | 7120.5E |              | defines the scope of the project, the implementation approach, the environment within which the project operates, and the baseline commitments of the project                                                                                                | x |   | x |                                                                   |
| Initial trend of required leading indicators                      | 7123.1C | 5.2.2.2.c(4) | document presenting trends for the leading indicators that have been identified by the Agency as required for each program/project                                                                                                                           |   | x |   |                                                                   |
| Staffing Requirements & Plans                                     | 7120.5E |              | All elements of personnel management including, identifying, recruiting, selecting, managing, and evaluating the team members to achieve a coherent, efficient, and effective team                                                                           |   | x | x | capture in Project Plan                                           |
| Infrastructure Requirements & Plans                               | 7120.5E |              | include the acquisition, renovation, and/or use of real property/facilities, aircraft, personal property, and information technology                                                                                                                         |   | x |   | Deemed not necessary for Class D missions due to low dollar value |
| Cost & Schedule Baseline                                          | 7123.1C |              | baselined estimated life-cycle costs and schedule                                                                                                                                                                                                            |   | x | x | capture in Project Baseline                                       |

|                                        |         |              |                                                                                                                                                                                                                                                                                                                  |   |   |   |                                                     |
|----------------------------------------|---------|--------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-----------------------------------------------------|
| Baseline Integrated Master Schedule    | 7120.5E |              | a summary of its IMS, including all critical milestones, major events, life-cycle reviews, and KDPs throughout the project life-cycle                                                                                                                                                                            |   | x | x | capture in Project Baseline                         |
| Cost Estimate                          | 7120.5E |              | includes all costs, including all Unallocated Future Expenses (UFE) and funded schedule margins for development through prime mission operations to disposal, excluding extended operations                                                                                                                      |   | x | x | capture in Project Baseline                         |
| Joint Cost & Schedule Confidence Level | 7120.5E |              | to measure the likelihood of completing all remaining work at or below the budgeted levels and on or before the planned completion of the development phase                                                                                                                                                      |   | x | x | capture in Project Baseline                         |
| External Cost & Schedule Commitments   | 7120.5E |              | includes applicable model inputs, rationale/justification for analogies, and details supporting bottom-up cost and schedule estimates                                                                                                                                                                            |   | x |   | all inhouse                                         |
| Cost Analysis Data Requirement (CADRe) | 7120.5E |              | describes the programmatic, technical, and life-cycle cost and cost and schedule risk information of a project                                                                                                                                                                                                   |   | x |   | not mandatory for small Category 3/Class D projects |
| Design Solution definition Baseline    | 7123.1C | 5.2.2.2.e(1) | final design that meets the requirements with adequate margins                                                                                                                                                                                                                                                   | x |   |   | finalized design; present at CDR                    |
| Design Documentation                   | 7120.5E |              | series of documents that captures and communicates to others the specific technical aspects of a design                                                                                                                                                                                                          |   | x | x | capture in Project Baseline                         |
| Interface definition Baseline          | 7123.1C |              | controls system product development efforts when the efforts are divided between Government programs, contractors, and/or geographically diverse technical teams                                                                                                                                                 |   | x |   | all inhouse                                         |
| Implementation Plans Baseline          | 7123.1C |              | identifies how components will be acquired (make or buy) with associated costs and schedules                                                                                                                                                                                                                     |   | x | x | capture in Project Plan                             |
| Integration Plans Baseline             | 7123.1C | 5.2.2.2.f(1) | describe how the products will be integrated including procedures, environment, and configuration of the items                                                                                                                                                                                                   |   | x | x | capture in Project Plan                             |
| Integrated Logistics Support Plan      | 7120.5E | NPD 7500.1B  | Describes how the program or project will implement a maintenance and support concept, enhancing supportability, supply support, maintenance planning, packaging, handling and transportation, training, manpower, required facilities, and logistics information systems for the life of the program or project |   | x | x | capture in Project Plan                             |

|                                                |         |              |                                                                                                                                                                                                                                                                                            |   |   |   |                                                          |
|------------------------------------------------|---------|--------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|----------------------------------------------------------|
| Human Systems Integration Plan                 | 7120.5E | NPR 7123.1B  | interdisciplinary and comprehensive management and technical process that focuses on the integration of human considerations into the system acquisition and development processes to enhance human system design, reduce life-cycle ownership cost, and optimize total system performance |   | x |   | no human integration                                     |
| Security Plan                                  | 7120.5E | NPD 1600.2   | describes the project's plans for ensuring security and technology protection                                                                                                                                                                                                              |   | x | x | capture in Project Plan                                  |
| Project Protection Plan (PPP)                  | 7120.5E | 4.3.6.3      | based on the program Threat Summary, which documents the threat environment the project is most likely to encounter as it reaches operational capability and recommends potential countermeasures                                                                                          |   | x | x | capture in SEMP                                          |
| Verification & Validation (V&V) Plans Baseline | 7123.1C |              | finalized planning and management tool for the integrated test program                                                                                                                                                                                                                     | x |   | x |                                                          |
| Technology Transfer Control Plan               | 7120.5E | NPR 2190.1   | Describes how the program or project will implement the export control requirements                                                                                                                                                                                                        |   | x |   | no transfer; all inhouse                                 |
| Knowledge Management Plan                      | 7120.5E | NPD 7120.4   | Describes the program's approach to creating the knowledge management strategy and processes, examining the lessons learned database for relevant lessons, and creating the plan for how the program continuously captures and documents lessons learned throughout the program life-cycle | x |   |   | document lessons learned and key decisions               |
| Planetary Protection Plan                      | 7120.5E | NPR 8020.12  | the control of terrestrial microbial contamination associated with space vehicles intended to land, orbit, fly by, or otherwise encounter extraterrestrial solar system bodies                                                                                                             |   | x |   | not leaving LEO                                          |
| Communications Plan                            | 7120.5E | 4.3.4.2.2    | Describe plans to implement a diverse, broad, and integrated set of efforts and activities to communicate with and engage target audiences, the public, and other stakeholders in understanding the project, its objectives, elements, and benefits                                        |   | x | x | will be addressed in whatever document is used as the FA |
| Safety Data Packages                           | 7120.5E | NPR 8715.3   | data and information to support each section of the SMA Plan for each major milestone review to include the Safety and Mission Success Review                                                                                                                                              | x |   |   | represent risk mitigation at KDPs                        |
| Preliminary V&V Results                        | 7123.1C | 5.2.2.2.f(2) | results of lower-level subsystem testing accomplished before assembly                                                                                                                                                                                                                      | x |   | x | subsystems need to work before integrations              |

|                                                                     |         |              |                                                                                                                                                                                                                               |   |   |   |                                                                                               |
|---------------------------------------------------------------------|---------|--------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-----------------------------------------------------------------------------------------------|
| Expendable Launch Vehicle (ELV) Payload Safety Process Deliverables | 7120.5E | NPR 8715.7   | payload design, fabrication, testing, vehicle integration, launch processing, launch, and planned recovery                                                                                                                    |   | x | x | complete requirements specified by launch vehicle provider's interface control document (ICD) |
| Range Safety Risk Management Process Documentation                  | 7120.5E | NPR 8715.5   | focus on the protection of the public, workforce, and property during range flight operations                                                                                                                                 |   | x |   | does not apply to projects developing a payload that will that fly onboard a vehicle          |
| Operations Handbook                                                 | 7120.5E |              | provides information essential to the operation of the spacecraft                                                                                                                                                             | x |   |   |                                                                                               |
| Mission Operations Plan                                             | 7120.5E | 4.4.1.3      | Discusses how the project will implement the associated facilities, hardware, software, and procedures required to complete the mission                                                                                       |   | x | x | capture in Operations Concept                                                                 |
| Science Data Management Plan                                        | 7120.5E | 4.3.6.3      | describes how the project will manage the scientific data generated and captured by the operational mission                                                                                                                   |   | x | x | capture in Project Plan                                                                       |
| Mishap Preparedness & Contingency Plan (MPCP)                       | 7120.5E | NPR 8621.1   | address coordination and cooperation actions to be taken by all parties                                                                                                                                                       |   | x | x | capture in SMA Plan                                                                           |
| Orbital Debris Assessment Report (ODAR)                             | 7120.5E | NPR 8715.6   | for planned breakups, reentry of major components that potentially could reach the surface, the planned orbital lifetime, and the use of tethers                                                                              |   | x | x | capture in V&V Report                                                                         |
| End of Mission Plans                                                | 7120.5E | NPR 8715.6   | describes the project management approach and the mission overview; spacecraft description; assessment of spacecraft debris released during and after passivation; assessment of spacecraft potential for on-orbit collisions |   | x | x | capture in Project Plan                                                                       |
| V&V Report                                                          | 7123.1C | 5.2.2.2.h(2) | results of all systems testing                                                                                                                                                                                                | x |   | x |                                                                                               |
| Final Certification for Flight/Use                                  | 7123.1C | 5.2.2.2.h(3) | certifies to stakeholders that product is ready to put into the operational phase                                                                                                                                             |   | x | x | can be captured in V&V Report                                                                 |

Each deliverable has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another deliverable. An 'x' in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for deliverables to be kept with some tailoring. An indicator in the Waive column only is to completely waive. An indicator in the Waive column and Tailor column is for deliverables to be waived by combining it into another deliverable.

## Appendix E. USAF Deliverables Tailored

| Deliverable                                   | Guidance | Reference                   | Description                                                                                                                                                                                                                                                                         | Stat | Reg | K | W | T | Justification                                                                                                                                |
|-----------------------------------------------|----------|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|---|---|---|----------------------------------------------------------------------------------------------------------------------------------------------|
| Analysis of Alternatives (AoA) Study Guidance | AFI      | DoDI 5000.02T para 6d(1)(b) | regulatory guidance to guide the AoA; informs preparation of AoA Study Plan; prepared by DCAPE                                                                                                                                                                                      |      | x   |   | x |   | normally provided prior to program start; not necessary to develop guidance directed at self                                                 |
| AoA Study Plan                                | AFI      | DoDI 5000.02T para 6d(1)(b) | regulatory guidance to guide the AoA; prepared by lead DoD Component                                                                                                                                                                                                                |      | x   |   | x |   | normally developed prior to program start in response to Study Guidance; no DCAPE to respond to                                              |
| Initial Capabilities Document (ICD)           | SMC SE   | CJCSI 3170.01               | documents the capability gap, gap analyses and associated risks, and the derived operational capability requirement(s)                                                                                                                                                              |      | x   | x |   | x | capability requirements are identified by sponsor or similar agency in some form of documentation (details may be included in CDD per JCIDS) |
| Affordability Analysis                        | AFI      | DoDI 5000.02T Enc 8, Sec 3  | to promote responsible and sustainable investment decisions while avoiding starting or continuing programs that cannot be produced and supported within reasonable expectations for future budgets                                                                                  |      | x   |   | x | x | combine with CARD                                                                                                                            |
| Work Breakdown Structure (WBS)                | SMC SE   |                             | a means of organizing system development activities based on system and product decompositions; defines the total system of hardware, software, services, data, and facilities, and relates these elements to each other and to the end products                                    |      |     |   | x | x | product breakdown can be captured in AS                                                                                                      |
| Cost Analysis Requirements Description (CARD) | SMC SE   |                             | basis of cost estimates for complex projects; contains a technical, programmatic, and a schedule that are used as the basis for deriving a cost estimate                                                                                                                            |      |     | x |   | x | need cost estimates in order to track actuals against                                                                                        |
| Integrated Master Plan (IMP)                  | SMC SE   |                             | event-driven government document that provides a framework against which all work is measured; consists of program events, significant accomplishments, and accomplishment criteria; should encompass all Integrated Product Team (IPT) and Work Breakdown Structure (WBS) elements |      |     |   | x | x | can be captured in AS                                                                                                                        |

|                                       |        |                               |                                                                                                                                                                                                                                 |  |   |   |   |   |                                                                                                                        |
|---------------------------------------|--------|-------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|---|---|---|------------------------------------------------------------------------------------------------------------------------|
| Acquisition Strategy (AS)             | AFI    | DoDI 5000.02T Enc 2, para 6a  | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives            |  | x | x |   | x | need detailed game plan in order to keep track of what needs to be done, what has been done, and everything in between |
| AoA Report                            | SMC SE | 40 U.S.C 11312                | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement |  | x | x |   | x | need to identify and document possible capability solutions                                                            |
| System Engineering Plan (SEP)         | SMC SE | DoDI 5000.02T Enc 3, Sec 2    | process-oriented document/management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                |  | x | x |   | x | need detailed game plan on how work will be completed and tracked                                                      |
| Life-Cycle Sustainment Plan (LCSP)    | AFI    | DoDI 5000.02 Enc 6, Sec 3     | describe sustainment influences on system design and the technical, business, and management activities to develop, implement, and deliver a product support package                                                            |  | x |   | x | x | very short life-cycle in comparison to other acquisition programs; integrate into Operations Concept                   |
| Requirements Baseline                 | SMC SE |                               | documented performance, functional, architectural, dependability, and constraints specifications                                                                                                                                |  |   |   | x | x | can be captured in CDD                                                                                                 |
| Integrated Master Schedule (IMS)      | SMC SE |                               | integrated, networked model containing all the detailed discrete tasks necessary to realize the IMP accomplishment criteria                                                                                                     |  |   |   | x | x | can be captured in AS                                                                                                  |
| Technology Readiness Assessment (TRA) | AFPAM  |                               | tool for identifying triggers that may become risks and providing inputs with regard to how well these items are managed over time                                                                                              |  |   |   | x | x | capture in CDD                                                                                                         |
| Program Protection Plan (PPP)         | AFI    | DoDI 5000.02T Enc 3, para 13a | to manage the risks to critical program information and mission-critical functions and components associated with the program                                                                                                   |  | x |   | x | x | capture in SEP                                                                                                         |

|                                                  |        |                        |                                                                                                                                                                                                                                                                                       |  |   |   |   |   |                                                          |
|--------------------------------------------------|--------|------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--|---|---|---|---|----------------------------------------------------------|
| System Requirements Document (SRD)               | SMC SE | JCIDS Enclosure D      | defines the performance of the preferred materiel solution; system performance specification has sufficiently conservative requirements to allow for design trade space                                                                                                               |  |   |   | x | x | criteria will be documented in CDD                       |
| Capability Development Document (CDD)            | SMC SE | JCIDS Manual           | provides authoritative, measurable, and testable operational performance attributes, including producibility and supportability, necessary for the acquisition community to design the proposed system(s), including key performance parameters (KPP) and Key System Attributes (KSA) |  | x | x |   | x | need to document performance requirements                |
| Concept of Operations (CONOPS)                   | AFPAM  | JCIDS Manual           | contains operational tasks, events, durations, frequency, operating conditions and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                         |  | x | x |   | x | need to document system and mission operations           |
| Validated Online Life-cycle Threat (VOLT) Report | AFI    | DIA Directive 5000.200 | includes threat modules and is written to articulate the relevance of each module to a specific acquisition program or planned capability                                                                                                                                             |  | x |   | x |   | not required                                             |
| Mission Data Plan                                | AFI    |                        | to capture and address intelligence mission data production shortfalls identified by the intelligence community                                                                                                                                                                       |  |   |   | x |   | not intel related                                        |
| Functional Architecture Baseline                 | SMC SE |                        | decomposes and allocates requirements into sub functions to the point that they can be unambiguously related to subsystems and lower system elements or products that make up the design                                                                                              |  |   |   | x | x | can be captured in CDD                                   |
| Allocated Baseline                               | SMC SE |                        | allocating the system technical requirements and constraints to the elements of the physical hierarchy                                                                                                                                                                                |  |   |   | x | x | can be captured in CDD                                   |
| Item Unique Identification Implementation Plan   | AFI    | DoDI 8320.04           | to identify and track applicable major end items, configuration-controlled items, and government-furnished property                                                                                                                                                                   |  | x |   | x |   | does not meet IUID qualifications per DoDI 8320.04 Enc 3 |

|                                                                                                                                   |     |                            |                                                                                                                                                                                                                                                                                    |   |   |   |   |   |                                                                                                               |
|-----------------------------------------------------------------------------------------------------------------------------------|-----|----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---|---|---------------------------------------------------------------------------------------------------------------|
| Test & Evaluation Master Plan (TEMP)                                                                                              | AFI | DoDI 5000.02T Enc 4 & 5    | primary planning and management tool for the integrated test program                                                                                                                                                                                                               |   | x | x |   | x | means of recording all test plans                                                                             |
| Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)/ National Environmental Policy Act (NEPA) Compliance * | AFI | 42 U.S.C 4321-4347         | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system | x |   | x |   |   | statutory                                                                                                     |
| Information Support Plan (ISP)                                                                                                    | AFI | DoDI 4630.8                | technical document required for all Information Technology and National Security Systems (IT/NSS) that exchange information of any type to other systems                                                                                                                           |   |   |   | x |   | can only be tailored with permission of Joint Staff; can be waived if meet criteria in DoDI 4630.8            |
| Frequency Allocation Application *                                                                                                | AFI | 47 U.S.C. 305              | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                                       | x |   | x |   |   | needed for communication                                                                                      |
| Clinger Cohen Act (CCA) Compliance *                                                                                              | AFI | Title 40 USC, Subtitle III | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu or table 11 of DoDI 5000.02                                                      | x |   | x |   | x | all requirements are met by completion of ICD, CDD, AoA, Acquisition Strategy, PPP per DoDI 5000.02T table 11 |
| Cybersecurity Strategy (CSS)                                                                                                      | AFI | DoDI 8500.01               | plan that provides an overview of the cybersecurity requirements for the system and describes the security controls in place or planned for meeting those requirements.                                                                                                            |   |   |   | x | x | documented in PPP                                                                                             |
| Acquisition Program Baseline (APB)                                                                                                | AFI | DoDD 5000.01               | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                            |   | x | x |   |   | need documented baseline to track development                                                                 |

|                                       |        |                 |                                                                                                                                                                                        |   |   |   |   |   |                                                                                                            |
|---------------------------------------|--------|-----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---|---|------------------------------------------------------------------------------------------------------------|
| Design Baseline                       | SMC SE |                 | represents build-to system design and process specifications; provides the basis for manufacturing, buying, coding, and subsequent integration of the products that make up the system |   |   | x |   |   | need a system design                                                                                       |
| Capability Production Document (CPD)  | SMC SE | JCIDS Manual    | provides authoritative, testable capability requirements and performance attributes to include KPPs and KSAs to enter the P&D phase of an acquisition program                          |   | x | x |   | x | If there are no changes, a revalidated CDD may be submitted for the CPD required at MS C per DoDI 5000.02T |
| Product Baseline                      | SMC SE |                 | represents as-built system design and process specifications                                                                                                                           |   |   |   | x |   | only needed when mass producing                                                                            |
| Acquisition Decision Memorandum (ADM) | SMC SE | DoDI 5000.02T   | documents MDA decisions after each review                                                                                                                                              |   | x | x |   |   | need documentation of each decision                                                                        |
| Decision database                     | SMC SE |                 | a record of the basis for each decision that is made in developing and maintaining each baseline                                                                                       |   |   |   | x | x | combine with Design Baseline                                                                               |
| Post Implementation Review (PIR) *    | AFI    | 40 U.S.C. 11313 | to compare actual program results with established performance objectives                                                                                                              | x |   | x |   |   | to establish lessons learned                                                                               |

Each deliverable has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another deliverable. An ‘x’ in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for deliverables to be kept with some tailoring. An indicator in the Waive column only is to completely waive. An indicator in the Waive column and Tailor column is for deliverables to be waived by combining it into another deliverable.

## Appendix F: Complex Deliverables Tailored

| Deliverable                                                     | Org  | Reference                   | Description                                                                                                                                                                                                                  | Stat | Reg | K  | W | T | Justification                                                                                                                                                                                               |
|-----------------------------------------------------------------|------|-----------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|-----|----|---|---|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Stakeholder Identification and Expectations definition Baseline | NASA | 5.2.2.2.a(1)                | captures the stakeholder expectations identified as needs, goals, and objectives                                                                                                                                             |      |     |    | x | x | captured in Concept definition Baseline                                                                                                                                                                     |
| Analysis of Alternatives (AoA) Study Guidance                   | DoD  | DoDI 5000.02T para 6d(1)(b) | regulatory guidance to guide the AoA; informs preparation of AoA Study Plan; prepared by DCAPE                                                                                                                               |      | x   |    | x |   | normally provided prior to program start; not necessary to develop guidance directed at self                                                                                                                |
| AoA Study Plan                                                  | DoD  | DoDI 5000.02T para 6d(1)(b) | regulatory guidance to guide the AoA; prepared by lead DoD Component                                                                                                                                                         |      | x   |    | x |   | normally developed prior to program start in response to Study Guidance; no DCAPE to respond to                                                                                                             |
| Formulation Authorization Document (FAD)                        | NASA |                             | describes the purpose of the project, including a clear traceability from the goals and objectives in the Mission Directorate strategies and/ or Program Plan                                                                |      |     |    | x |   | not required for small projects per <\$150M guidance                                                                                                                                                        |
| Formulation Agreement (FA)                                      | NASA |                             | establishes technical and acquisition work that needs to be conducted during Formulation and defines the schedule and funding requirements during Phase A and Phase B for that work                                          |      |     |    | x | x | no agreement until CSRA agrees to development at KDP A; necessary info can be added in Concept definition Baseline                                                                                          |
| Defense Intelligence Threat Library                             | DoD  | DIA Directive 5000.200      | maintains projections of technology and adversary capability trends over the next 20 years                                                                                                                                   |      | x   |    | x |   | part of VOLT which is not needed for ACAT III                                                                                                                                                               |
| Initial Capabilities Document (ICD)                             | DoD  | CJCSI 3170.01               | specifies one or more capability requirements and associated capability gaps which represent unacceptable operational risk if left unmitigated                                                                               |      |     | S4 |   | x | capability requirements are identified by sponsor or similar agency in some form of documentation (details may be included in CDD per JCIDS); required to meet statutory Clinger-Cohen Act (CCA) compliance |
| Concept Definition                                              | NASA |                             | captures and communicates a feasible concept that meets the goals and objectives of the mission, including results of analyses of alternative concepts, the concept of operations, preliminary risks, and potential descopes |      |     |    | x | x | combine with ICD                                                                                                                                                                                            |

|                                        |      |                            |                                                                                                                                                                                                                                                                 |  |  |   |   |   |                                                       |
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| Affordability Analysis                 | DoD  | DoDI 5000.02T Enc 8, Sec 3 | to promote responsible and sustainable investment decisions while avoiding starting or continuing programs that cannot be produced and supported within reasonable expectations for future budgets                                                              |  |  |   | 3 | x | combine with CADRe                                    |
| Cost Analysis Data Requirement (CADRe) | NASA |                            | basis of cost estimates for complex projects; contains a technical, programmatic, and a schedule that are used as the basis for deriving a cost estimate                                                                                                        |  |  | x |   | x | need cost estimates in order to track actuals against |
| Work Breakdown Structure (WBS)         | AF   |                            | a means of organizing system development activities based on system and product decompositions; defines the total system of hardware, software, services, data, and facilities, and relates these elements to each other and to the end products                |  |  |   | x | x | product breakdown can be captured in AS               |
| Cost & Schedule Baseline               | NASA |                            | baselined estimated life-cycle costs and schedule                                                                                                                                                                                                               |  |  |   | x | x | combine with CADRe                                    |
| Program Plan                           | NASA |                            | defines the goals and objectives of the program, the environment within which the program operates, and the Management Agreement commitments of the program, including identifying the high-level requirements on both the program and each constituent project |  |  |   | x |   | not required for small projects per <\$150M guidance  |
| Technology Readiness Assessment (TRA)  | NASA |                            | Identify the specific new technologies that are part of this project; their criticality to the project's objectives, goals, and success criteria; and the current status of each planned technology development, including TRL and associated risks             |  |  |   | x | x | combine with Concept definition Baseline              |
| Engineering Development Assessment     | NASA |                            | Identify major engineering development risks and any engineering prototyping or software model development that needs to be accomplished during phases A and B to reduce development risk                                                                       |  |  |   | x | x | combine with Concept definition Baseline              |

|                                                    |      |              |                                                                                                                                                                                                                                                                                     |  |  |  |   |   |                                                          |
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| Communications Plan                                | NASA | 4.3.4.2.2    | Describe plans to implement a diverse, broad, and integrated set of efforts and activities to communicate with and engage target audiences, the public, and other stakeholders in understanding the project, its objectives, elements, and benefits                                 |  |  |  | x | x | will be addressed in whatever document is used as the FA |
| Heritage Assessment Documentation                  | NASA |              | Identify the major heritage hardware and software assumptions and associated risks and the activities and reviews planned to validate those assumptions                                                                                                                             |  |  |  | x | x | capture in Acquisition Plan                              |
| Measure of Effectiveness (MOE) definition Baseline | NASA | 5.2.2.2.a(3) | capture the stakeholders' view of what would be considered the successful achievement of each expectation                                                                                                                                                                           |  |  |  | x | x | capture in Acquisition Plan                              |
| Integrated Master Plan (IMP)                       | DoD  |              | event-driven government document that provides a framework against which all work is measured; consists of program events, significant accomplishments, and accomplishment criteria; should encompass all Integrated Product Team (IPT) and Work Breakdown Structure (WBS) elements |  |  |  | x | x | can be captured in AS                                    |
| Technology Development Plan                        | NASA | NPD 7500.2   | describes the technology assessment, development, management, and acquisition strategies needed to achieve the project's mission objectives                                                                                                                                         |  |  |  | x | x | capture in Acquisition Plan                              |
| Safety & Mission Assurance (SMA) Plan              | NASA | NPD 8730.5   | addresses life-cycle SMA functions and activities, including SMA roles, responsibilities, and relationships                                                                                                                                                                         |  |  |  | x | x | captured in PPP                                          |
| Risk Management Plan                               | NASA | NPR 8000.4   | Summarizes how the program or project will implement the NASA risk management process                                                                                                                                                                                               |  |  |  | x | x | combine in SMA plan                                      |
| Acquisition Plan                                   | NASA | NPR 7120.5E  | documents an integrated acquisition strategy that enables the program to meet its mission objectives and provides the best value to NASA                                                                                                                                            |  |  |  | x |   | combine with Acquisition Strategy                        |

|                                            |      |                              |                                                                                                                                                                                                                                 |  |   |    |   |   |                                                                                                                                                                                       |
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| Acquisition Strategy (AS)                  | DoD  | DoDI 5000.02T Enc 2, para 6a | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives            |  |   | S3 |   | x | need detailed game plan in order to keep track of what needs to be done, what has been done, and everything in between; required to meet statutory Clinger-Cohen Act (CCA) compliance |
| Acquisition Strategy Meeting (ASM) minutes | NASA |                              | decision-making forum where senior Agency management reviews and approves project acquisition strategies                                                                                                                        |  |   |    | x |   | no ASM involved                                                                                                                                                                       |
| AoA                                        | DoD  | 40 U.S.C 11312               | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement |  |   | S2 |   | x | need to identify and document possible capability solutions; required to meet statutory Clinger-Cohen Act (CCA) compliance                                                            |
| System Engineering Plan (SEP)              | DoD  | DoDI 5000.02T Enc 3, Sec 2   | management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                          |  |   | 3  |   |   | need detailed game plan on how work will be completed and tracked                                                                                                                     |
| Review Plan                                | NASA | 4.3.4.3                      | Summarizes the project's approach for conducting a series of reviews including internal reviews and program life-cycle reviews                                                                                                  |  |   |    | x | x | capture in Acquisition Plan                                                                                                                                                           |
| Life-Cycle Sustainment Plan (LCSP)         | DoD  | DoDI 5000.02 Enc 6, Sec 3    | describe sustainment influences on system design and the technical, business, and management activities to develop, implement, and deliver a product support package                                                            |  | x |    | x | x | very short life-cycle in comparison to other acquisition programs; integrate into CONOPS                                                                                              |
| Configuration Management Plan              | NASA | SP 6105                      | Describes the organization, tools, methods, and procedures for configuration identification, configuration control, traceability, and accounting/ auditing                                                                      |  |   |    | x | x | capture in Acquisition Plan                                                                                                                                                           |

|                                      |      |                        |                                                                                                                                                                                                                                                                                            |  |   |  |   |   |                                                                                                |
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| Human Rating Certification Package   | NASA | NPR 8705.2             | Focuses on the integration of the human into the system, preventing catastrophic events during the mission, and protecting the health and safety of humans involved in or exposed to space activities, specifically the public, crew, passengers, and ground personnel                     |  |   |  | x |   | no human integration                                                                           |
| Requirements Baseline                | NASA | NPR 7123.1C            | agreed upon need, capability, capacity, or demand for personnel, equipment, facilities, or other resources or services                                                                                                                                                                     |  |   |  | x | x | capture system requirements in CDD                                                             |
| Infrastructure Requirements & Plans  | NASA |                        | include the acquisition, renovation, and/or use of real property/facilities, aircraft, personal property, and information technology                                                                                                                                                       |  |   |  | x |   | Deemed not necessary for Class D missions due to low dollar value                              |
| Integrated Master Schedule (IMS)     | DoD  |                        | integrated, networked model containing all the detailed discrete tasks necessary to realize the IMP accomplishment criteria                                                                                                                                                                |  |   |  | 4 | x | can be captured in AS                                                                          |
| Technology Targeting Risk Assessment | DoD  | DIA Directive 5000.200 | country-by-country assessment conducted by the DoD entities within the DISE that quantify risks to critical program information (CPI) and related enabling technologies for weapons systems, and advanced technologies or programs                                                         |  | x |  | x |   | only required for programs that identify critical program information (CPI) per DAG Ch 7-5.1.4 |
| Software Management Plan             | NASA | NPR 7150.C             | how the project will develop and/or manage the acquisition of software required to achieve project and mission objectives                                                                                                                                                                  |  |   |  | x | x | capture in Acquisition Plan                                                                    |
| Human Systems Integration Plan       | NASA | NPR 7123.1B            | interdisciplinary and comprehensive management and technical process that focuses on the integration of human considerations into the system acquisition and development processes to enhance human system design, reduce life-cycle ownership cost, and optimize total system performance |  |   |  | x |   | no human integration                                                                           |
| Security Plan                        | NASA | NPD 1600.2             | describes the project's plans for ensuring security and technology protection                                                                                                                                                                                                              |  |   |  | x | x | capture in Project Plan                                                                        |

|                                                          |      |                               |                                                                                                                                                                                                                                        |  |  |    |   |   |                                                                                                                                            |
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| Program Protection Plan (PPP)                            | DoD  | DoDI 5000.02T Enc 3, para 13a | to manage the risks to critical program information and mission-critical functions and components associated with the program                                                                                                          |  |  | S3 |   |   | cybersecurity plans required for IT due to signal send/receive capabilities; required to meet statutory Clinger-Cohen Act (CCA) compliance |
| Capability Development Document (CDD)                    | DoD  | JCIDS Manual                  | specifies capability requirements, in terms of developmental performance attributes (KPPs, KSAs, and APAs), and other related information necessary to support development of one or more increments of a materiel capability solution |  |  | S2 |   | x | need to document performance requirements; required to meet statutory Clinger-Cohen Act (CCA) compliance                                   |
| System Requirements Document (SRD)                       | DoD  | JCIDS Enclosure D             | defines the performance of the preferred materiel solution; system performance specification has sufficiently conservative requirements to allow for design trade space                                                                |  |  |    | 3 | x | criteria will be documented in CDD                                                                                                         |
| Technical Performance Measures (TPM) definition Baseline | NASA | 5.2.2.2.c(1)                  | the important key driving requirements, key performance parameters, leading or lagging indicators, or other measures to track efforts                                                                                                  |  |  |    | x | x | capture in Requirements Baseline                                                                                                           |
| Technical, Schedule, & Cost Control Plan                 | NASA | 4.5.3.2.2                     | Describes how the program or project plans to control program or project requirements, technical design, schedule, and cost to achieve its high-level requirements                                                                     |  |  |    | x | x | capture in Acquisition Plan                                                                                                                |
| Information Technology Plan                              | NASA | NPR 2830.1                    | Describes how the program or project will acquire and use information technology including IT security requirements                                                                                                                    |  |  |    | x | x | capture in Acquisition Plan                                                                                                                |
| Functional Architecture Baseline                         | AF   |                               | decomposes and allocates requirements into sub functions to the point that they can be unambiguously related to subsystems and lower system elements or products that make up the design                                               |  |  |    | x | x | can be captured in CDD                                                                                                                     |
| Architecture definition Baseline                         | NASA | 5.2.2.2.c(2)                  | decomposition of the defined functional and performance requirements by functions, time, and behaviors                                                                                                                                 |  |  |    | x | x | capture in Requirements Baseline                                                                                                           |
| Mission Architecture                                     | NASA |                               | credible and responsive to program requirements and constraints on the project, including resources                                                                                                                                    |  |  |    | x | x | capture in Operations Concept                                                                                                              |

|                                                      |      |                              |                                                                                                                                                                                                                                                              |  |   |    |   |   |                                                                                                                               |
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| Spacecraft Architecture                              | NASA |                              | how the major project components will be integrated and are intended to operate together and with heritage systems, as applicable, to achieve project goals and objectives                                                                                   |  |   |    | x | x | capture in Acquisition Plan                                                                                                   |
| Allocation of Requirements Baseline                  | NASA | 5.2.2.2.c(3)                 | shows how the requirements are allocated to the architecture elements of the next lower level of the product hierarchy                                                                                                                                       |  |   |    | x | x | capture in Project Baseline                                                                                                   |
| Initial trend of required leading indicators         | NASA | 5.2.2.2.c(4)                 | document presenting trends for the leading indicators that have been identified by the Agency as required for each program/project                                                                                                                           |  |   |    | x |   |                                                                                                                               |
| Staffing Requirements & Plans                        | NASA |                              | All elements of personnel management including, identifying, recruiting, selecting, managing, and evaluating the team members to achieve a coherent, efficient, and effective team                                                                           |  |   |    | x | x | capture in Project Plan                                                                                                       |
| Concept of Operations (CONOPS)/ Mission Profile (MP) | DoD  | JCIDS Manual                 | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                               |  |   | S3 |   | x | need to document system and mission operations; integrated Core Logistics Determination which is statutory                    |
| Validated on-line Life-Cycle Threat (VOLT) Report    | DoD  | DIA Directive 5000.200       | includes threat modules and is written to articulate the relevance of each module to a specific acquisition program or planned capability                                                                                                                    |  | x |    | 3 |   | not required for ACAT III; can use VOLT from similar type program/project per DAG Ch 7-5.1.1; MDA can waive per DoDI 5000.02T |
| Should Cost Target                                   | DoD  | DoDI 5000.02T para 6d(3)(b)1 | to proactively target cost reduction and drive productivity improvement into programs                                                                                                                                                                        |  | x |    | x | x | to control and reduce costs; combine with affordability analysis                                                              |
| Preliminary Design Solution definition               | NASA | 5.2.2.2.d(1)                 | translates the outputs of the logical decomposition process into a design solution definition that is in a form consistent with the product life-cycle phase and product layer location in the system structure and that will satisfy phase success criteria |  |   |    | x | x | capture in Project Baseline                                                                                                   |

|                                                       |      |                                 |                                                                                                                                                                                         |   |   |   |    |   |                                                                                                                           |
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| Interface definition Baseline                         | NASA |                                 | controls system product development efforts when the efforts are divided between Government programs, contractors, and/or geographically diverse technical teams                        |   |   |   | x  |   | all inhouse                                                                                                               |
| Core Logistics Determination *                        | DoD  | DoDI 5000.02T Enc 6, para 3d(2) | applicability of core depot-level maintenance and repair capability requirements                                                                                                        | x |   |   | S2 | x | no maintenance or repair once launched; information documented in LCSP per DoDI 5000.02T; LCSP being integrated to CONOPS |
| Implementation Plans Baseline                         | NASA |                                 | identifies how components will be acquired (make or buy) with associated costs and schedules                                                                                            |   |   |   | x  | x | capture in Project Plan                                                                                                   |
| Item Unique Identification (IUID) Implementation Plan | DoD  | DoDI 8320.04                    | to identify and track applicable major end items, configuration-controlled items, and government-furnished property                                                                     |   | x |   | x  |   | does not meet IUID qualifications per DoDI 8320.04 Enc 3                                                                  |
| Integration Plans Baseline                            | NASA | 5.2.2.2.f(1)                    | describe how the products will be integrated including procedures, environment, and configuration of the items                                                                          |   |   |   | x  | x | capture in Project Plan                                                                                                   |
| Test & Evaluation Master Plan (TEMP)                  | DoD  | DoDI 5000.02T Enc 4 & 5         | primary planning and management tool for the integrated test program                                                                                                                    |   |   | 3 |    |   | means of recording all test plans                                                                                         |
| Environmental Management Plan                         | NASA | NPR 8580.1                      | Describes the program's NEPA strategy at all affected Centers, including decisions regarding programmatic NEPA documents                                                                |   |   |   | x  | x | capture in Acquisition Plan                                                                                               |
| Nuclear Safety Launch Approval Plan                   | NASA | NPR 8715.3                      | Describes potential risks associated with a planned launch of radioactive materials into space, on launch vehicles and spacecraft, and during flight                                    |   |   |   | x  |   | no radioactive materials                                                                                                  |
| Partnership Agreements                                | NASA |                                 | documents roles and contributed items and plans for getting commitments for contributions and finalizing open inter-agency agreements, domestic partnerships, and foreign contributions |   |   |   | x  |   | all inhouse                                                                                                               |
| Safety Data Packages                                  | NASA | NPR 8715.3                      | data and information to support each section of the SMA Plan for each major milestone review to include the Safety and Mission Success Review                                           |   |   |   | x  |   | represent risk mitigation at KDPs                                                                                         |

|                                                                                                                                   |     |                              |                                                                                                                                                                                                                                                                                    |   |   |    |    |   |                                                                                                                                                 |
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| Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)/ National Environmental Policy Act (NEPA) Compliance * | DoD | 42 U.S.C 4321-4347           | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system | x |   | S4 |    |   | statutory                                                                                                                                       |
| Bandwidth Requirements Review                                                                                                     | DoD | Sec 1047, Public Law 110-417 | a formal review process to ensure that the bandwidth requirements needed to support such program are or will be met                                                                                                                                                                |   | x |    | x  | x | data documented in ISP to reviewed by appropriate agency; since waiving ISP, review will be based on data provided in the CDD per DoDI 5000.02T |
| Information Support Plan (ISP)                                                                                                    | DoD | DoDI 8330.01                 | describes IT and information needs, dependencies, and interfaces for programs; focuses on efficient and effective exchange of information that, if not properly managed, could limit or restrict the operation of the program                                                      |   | x |    | x  | x | can provide IT supportability analysis in CONOPS per DoDI 8330.01                                                                               |
| Spectrum Supportability Risk Assessment (SSRA)                                                                                    | DoD | DoDI 4650.01                 | written determinations that the electromagnetic spectrum necessary to support the operation of the system during its expected life-cycle is or will be available in accordance with DoD Instruction 4650.01                                                                        |   |   | x  |    |   | to ensure no interference with other systems electromagnetic spectrum                                                                           |
| Information Technology (IT) and National Security System (NSS) Interoperability Certification                                     | DoD | DoDI 8330.01                 | Joint Interoperability Test Command (JITC) certifies interoperability of IT with joint, multinational, and/or interagency interoperability requirements                                                                                                                            |   | x |    | x  |   | may request waiver for DoD Component-unique IT per DoDI 8330.01                                                                                 |
| Request for Proposal (RFP)                                                                                                        | DoD | FAR                          | include specifications and statement of work                                                                                                                                                                                                                                       |   | x |    | x  |   | not contracting with commercial agency                                                                                                          |
| Frequency Allocation Application *                                                                                                | DoD | 47 U.S.C. 305                | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                                       | x |   | S3 |    |   | to obtain transmission frequencies                                                                                                              |
| Clinger-Cohen Act (CCA) Compliance *                                                                                              | DoD | Title 40 USC, Subtitle III   | For all programs that acquire IT, MDA will not initiate program or allow phase change until all CCA required actions are completed. Listed in Milestone Document Identification (MDID) at dau.edu or table 11 of DoDI 5000.02                                                      | x |   |    | S3 | x | all requirements are met by completion of ICD, CDD, AoA, Acquisition Strategy, PPP per DoDI 5000.02T table 11                                   |

|                                        |      |              |                                                                                                                                                                                         |  |   |   |   |   |                                                                                                                          |
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| Cybersecurity Strategy (CSS)           | DoD  | DoDI 8500.01 | plan that provides an overview of the cybersecurity requirements for the system and describes the security controls in place or planned for meeting those requirements.                 |  | x |   | x | x | documented in appendix of PPP per DoDI 8500.01                                                                           |
| Waveform Assessment Application        | DoD  | DoDI 4630.09 | Application to the DoD CIO for approval of the development or modification of waveforms                                                                                                 |  | x |   | x |   | not required when using commercial communication services or COTS waveforms that have not been modified per DODI 4630.09 |
| Acquisition Program Baseline (APB)     | DoD  | DoDD 5000.01 | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager |  |   | 3 |   |   | need documented baseline to track development                                                                            |
| Project Plan                           | NASA | NPR 7120.5E  | defines the scope of the project, the implementation approach, the environment within which the project operates, and the baseline commitments of the project                           |  |   |   | x |   | combine with SEP                                                                                                         |
| Joint Cost & Schedule Confidence Level | NASA |              | to measure the likelihood of completing all remaining work at or below the budgeted levels and on or before the planned completion of the development phase                             |  |   |   | x | x | capture in Project Baseline                                                                                              |
| External Cost & Schedule Commitments   | NASA |              | includes applicable model inputs, rationale/justification for analogies, and details supporting bottom-up cost and schedule estimates                                                   |  |   |   | x |   | all inhouse                                                                                                              |
| Design Solution definition Baseline    | NASA |              | represents build-to system design and process specifications; provides the basis for manufacturing, buying, coding, and subsequent integration of the products that make up the system  |  |   | x |   |   | need to document final design                                                                                            |
| Design Documentation                   | NASA |              | series of documents that captures and communicates to others the specific technical aspects of a design                                                                                 |  |   |   | x | x | capture in Project Baseline                                                                                              |

|                                                                     |      |                              |                                                                                                                                                                                                                                |  |   |   |   |   |                                                                                                            |
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| Capability Production Document (CPD)                                | DoD  | JCIDS Manual                 | specifies capability requirements, in terms of production performance parameters (KPPs, KSAs, and APAs), and other related information necessary to support production of a single increment of a materiel capability solution |  |   | x |   | x | If there are no changes, a revalidated CDD may be submitted for the CPD required at MS C per DoDI 5000.02T |
| Product Baseline                                                    | AF   |                              | represents as-built system design and process specifications                                                                                                                                                                   |  |   |   | x |   | only needed when mass producing                                                                            |
| Technology Transfer Control Plan                                    | NASA | NPR 2190.1                   | Describes how the program or project will implement the export control requirements                                                                                                                                            |  |   |   | x |   | no transfer; all inhouse                                                                                   |
| Range Safety Risk Management Process Documentation                  | NASA | NPR 8715.5                   | focus on the protection of the public, workforce, and property during range flight operations                                                                                                                                  |  |   |   | x |   | does not apply to projects developing a payload that will that fly onboard a vehicle                       |
| Operational Test Plan (OTP)                                         | DoD  | DoDI 5000.02T Enc 5, para 3e | documents the test design, supporting methodology, and analytic details required for the specific operational test                                                                                                             |  | x |   | x |   | info will be listed in TEMP                                                                                |
| Developmental Test & Evaluation (DT&E) Assessment                   | DoD  |                              | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                               |  |   | x |   |   | need to report results of DT&E                                                                             |
| Expendable Launch Vehicle (ELV) Payload Safety Process Deliverables | NASA | NPR 8715.7                   | payload design, fabrication, testing, vehicle integration, launch processing, launch, and planned recovery                                                                                                                     |  |   |   | x | x | complete requirements specified by launch vehicle provider's interface control document (ICD)              |
| Operations Handbook                                                 | NASA | NPR 7120.5E                  | provides information essential to the operation of the spacecraft                                                                                                                                                              |  |   | x |   | x | need some form of documenting how to operate CubeSat                                                       |
| Mission Operations Plan                                             | NASA | 4.4.1.3                      | Discusses how the project will implement the associated facilities, hardware, software, and procedures required to complete the mission                                                                                        |  |   |   | x | x | capture in Operations Concept                                                                              |
| Mission Data Plan                                                   | AF   |                              | to capture and address intelligence mission data production shortfalls identified by the intelligence community                                                                                                                |  |   |   | x |   | not intel                                                                                                  |
| Mishap Preparedness & Contingency Plan (MPCP)                       | NASA | NPR 8621.1                   | address coordination and cooperation actions to be taken by all parties                                                                                                                                                        |  |   |   | x | x | capture in SMA Plan                                                                                        |
| Orbital Debris Assessment Report (ODAR)                             | NASA | NPR 8715.6                   | for planned breakups, reentry of major components that potentially could reach the surface, the planned orbital lifetime, and the use of tethers                                                                               |  |   |   | x | x | capture in V&V Report                                                                                      |

|                                                                                      |      |                     |                                                                                                                                                                                                                               |   |   |    |   |   |                                                             |
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| Planetary Protection Plan                                                            | NASA | NPR 8020.12         | the control of terrestrial microbial contamination associated with space vehicles intended to land, orbit, fly by, or otherwise encounter extraterrestrial solar system bodies                                                |   |   |    | x |   | not leaving LEO                                             |
| Director, OT&E (DOT&E) Report of Initial OT&E (IOT&E)                                | DoD  | 10 U.S.C 2399       | determine a system's operational effectiveness and operational suitability prior to FRP                                                                                                                                       |   | x |    | x |   | only for programs on DOT&E oversight list per DoDI 5000.02T |
| Operational Test Agency (OTA) Report of Operational Test & Evaluation (OT&E) Results | DoD  | DoDI 5000.02T Enc 5 | all records, reports, and data from every OT&E and LFT&E event                                                                                                                                                                |   |   | x  |   | x | AFIT is OTA so may be documented in any agreed upon manner  |
| Live Fire Test & Evaluation (LFT&E) Report                                           | DoD  | 10 U.S.C. 2366      |                                                                                                                                                                                                                               |   | x |    | x |   | only for programs on DOT&E oversight list per DoDI 5000.02T |
| DoD Component LFT&E Report                                                           | DoD  | 10 U.S.C 2399       |                                                                                                                                                                                                                               |   | x |    | x |   | only for programs on LFT&E oversight list per DoDI 5000.02T |
| End of Mission Plans                                                                 | NASA | NPR 8715.6          | describes the project management approach and the mission overview; spacecraft description; assessment of spacecraft debris released during and after passivation; assessment of spacecraft potential for on-orbit collisions |   |   |    | x | x | capture in Project Plan                                     |
| Final Certification for Flight/Use                                                   | NASA | 5.2.2.2.h(3)        | certifies to stakeholders that product is ready to put into the operational phase                                                                                                                                             |   |   |    | x | x | can be captured in V&V Report                               |
| Acquisition Decision Memorandum (ADM)                                                | DoD  | DoDI 5000.02T       | documents MDA decisions after each review                                                                                                                                                                                     |   |   | x  |   |   | need documentation of each decision                         |
| Decision database                                                                    | AF   |                     | a record of the basis for each decision that is made in developing and maintaining each baseline                                                                                                                              |   |   |    | x | x | combine with Design Baseline                                |
| Post Implementation Review (PIR) *                                                   | DoD  | 40 U.S.C. 11313     | to compare actual program results with established performance objectives                                                                                                                                                     | x |   | S3 |   |   | to establish lessons learned                                |

The deliverables with a “\*” are statutory requirements so they must be completed by law. Additionally, an “S” in the keep column identifies a statutory document or a document that itself is not statutory but must be completed to be in compliance with another statutory requirement. A number in any column represents the frequency the

event appears among the four frameworks. Only frequencies of three or greater were identified.

Each deliverable has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another deliverable. An 'x' in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for deliverables to be kept with some tailoring. An indicator in the Waive column only is to completely waive. An indicator in the Waive column and Tailor column is for deliverables to be waived by combining it into another deliverable.

## Appendix G: Simple Deliverables Tailored

| Deliverable                           | Org  | Reference  | Description                                                                                                                                  | Keep | Waive | Tailor | Justification                                   |
|---------------------------------------|------|------------|----------------------------------------------------------------------------------------------------------------------------------------------|------|-------|--------|-------------------------------------------------|
| Student Portfolio                     | MIT  |            | the individual work of each student as a contribution to the larger project                                                                  |      | x     |        | not applicable to AFIT                          |
| Statement of Work (SOW)               | NPS  |            | document broad responsibilities, deliverables, and the work activities required in a given project                                           | x    |       |        | identify what is expected between organizations |
| end-of-semester report                | U-M  |            | to capture the major concepts, plans and progress for the lab                                                                                |      | x     |        |                                                 |
| Requirements Analysis                 | MIT  |            | assesses potential materiel solutions that could satisfy capability requirements                                                             |      | x     | x      | capture in PMP                                  |
| SysML Block Definition Diagrams (BDD) | USNA |            | defines relationships between parts of the structures and shared components; includes Requirements Verification Matrix                       | x    |       |        |                                                 |
| Mission Assurance Plan                | NPS  | NPD 8730.5 | addresses life-cycle Safety & Mission Assurance (SMA) functions and activities, including SMA roles, responsibilities, and relationships     | x    |       | x      | need safety plan                                |
| Risk Management Plan                  | NPS  | NPR 8000.4 | Summarizes how the program or project will implement the NASA risk management process                                                        |      | x     | x      | combine w/ Mission Assurance Plan               |
| Figures of Merit (FOM)                | MIT  |            | capture the stakeholders' view of what would be considered the successful achievement of each expectation                                    |      | x     | x      | capture in SysML BDD                            |
| Tech Memo                             | U-M  |            | documents major milestones                                                                                                                   |      | x     | x      | capture in SEMP                                 |
| Master Schedule                       | NPS  |            | integrated, networked model containing all critical milestones, major events, life-cycle reviews, and KDPs throughout the project life-cycle |      | x     | x      | in PMP                                          |
| Design Document                       | MIT  |            | captures the organization, requirements, trades, design, budgets, and test results of the project                                            |      | x     |        | disbursed among multiple other documents        |
| Conceptual Design                     | MIT  |            | presents feasible ways of accomplishing the stakeholder expectations                                                                         |      | x     | x      | building to Critical design                     |
| Preliminary Design                    | MIT  |            | initial design solution to meet requirements                                                                                                 |      | x     | x      | building to Critical design                     |
| Requirements Verification Matrix      | USNA |            | to ensure that all requirements defined for a system are tested in the test protocols                                                        |      | x     | x      | captured with SysML Diagrams                    |

|                                              |      |             |                                                                                                                                                                                                                                                                                                                  |   |   |   |                                                                   |
|----------------------------------------------|------|-------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|-------------------------------------------------------------------|
| System Engineering Management Plan (SEMP)    | NPS  |             | a foundation for the implementation of the engineering effort by identifying the deliverables during each phase and defining the quality assurance plan and methodology for the project                                                                                                                          | x |   | x | need detailed game plan on how work will be completed and tracked |
| Master Product Breakdown Structure           | NPS  |             | detailed information defining the satellite system, mission operations system, and ground support system and related subsystems                                                                                                                                                                                  |   | x | x | capture in PMP                                                    |
| Certification & Requirements Document (CARD) | NPS  |             | delineates the design, construction, performance, and verification requirements; defines all tests, analyses, inspections, and certification methods                                                                                                                                                             |   | x | x | captured in SEMP and PMP                                          |
| Concept of Operations (CONOPS)               | USNA |             | operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission                                                                                                            | x |   |   |                                                                   |
| Environmental Management Plan                | NPS  | NPR 8580.1  | Describes the program's NEPA strategy at all affected Centers, including decisions regarding programmatic NEPA documents                                                                                                                                                                                         | x |   |   |                                                                   |
| Software Management Plan                     | NPS  | NPR 7150.C  | how the project will develop and/or manage the acquisition of software required to achieve project and mission objectives                                                                                                                                                                                        |   | x | x | capture in PMP                                                    |
| Logistics Plan                               | NPS  | NPD 7500.1B | Describes how the program or project will implement a maintenance and support concept, enhancing supportability, supply support, maintenance planning, packaging, handling and transportation, training, manpower, required facilities, and logistics information systems for the life of the program or project |   | x | x | capture in PMP                                                    |
| Interface Control Document (ICD)             | USNA |             | a record of all interface information; provides the details and describe the interface or interfaces between subsystems or to a system or subsystem                                                                                                                                                              | 4 |   |   |                                                                   |
| Project Management Plan (PMP)                | NPS  |             | defining document for the program's mission and objectives and describes the technical approach that will be used by the development team                                                                                                                                                                        | x |   | x | need various functional plans                                     |
| Critical Design                              | MIT  |             | final design that meets the requirements with adequate margins                                                                                                                                                                                                                                                   | x |   | x | documented system design                                          |

|                                                 |        |                |                                                                                                                                                                                                                                                                |   |   |   |                                                                                             |
|-------------------------------------------------|--------|----------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|---------------------------------------------------------------------------------------------|
| Dimensional Verifications                       | CS-101 |                | shows adherence to the dimensional requirements specified in the CubeSat-to-dispenser ICD                                                                                                                                                                      |   | x |   | capture in compliance letter                                                                |
| Radio Frequency License                         | CS-101 | 47 CFR Part 97 | must obtain appropriate license in order to transmit signals                                                                                                                                                                                                   | x |   |   |                                                                                             |
| Remote Sensing License                          | CS-101 |                | must obtain appropriate license in order to take pictures or videos of Earth                                                                                                                                                                                   | x |   | x | can waive if non-Earth imaging                                                              |
| Data Budget                                     | USNA   |                | calculation of data being generated and stored, and memory allocation                                                                                                                                                                                          |   | x |   | capture in SEMP                                                                             |
| Transmitter Surveys                             | CS-101 |                | series of questions about the CubeSat's communication system used to help the LV provider perform EMI/EMC analysis to verify that the CubeSat meets RF inhibit requirements                                                                                    |   | 3 | x | from ICoD, capture in Compliance Letter                                                     |
| Mass Properties Report                          | CS-101 |                | identifies the CubeSat's total mass, center of gravity, moments of inertia (MOIs), and products of inertia (POI) relative to each axis                                                                                                                         |   | 3 | x | from ICoD, capture in Compliance Letter                                                     |
| Materials List                                  | CS-101 |                | usually a Word document identifying every material used on the CubeSat along with its mass (or expected mass), its location on the CubeSat, and its out-gassing properties including Total Mass Loss (TML) and Collected Volatile Condensable Materials (CVCN) |   | 3 | x | from ICoD, combine with Mass Properties in Compliance Letter                                |
| Battery Report                                  | CS-101 |                | verify that proper battery circuit protection is in place                                                                                                                                                                                                      |   | x | x | from ICoD, capture in Compliance Letter                                                     |
| Electrical Report                               | CS-101 | CDS para 3.3   | to verify electrical requirements listed in CubeSat-to-dispenser ICD                                                                                                                                                                                           |   | 3 | x | from ICoD, capture in Compliance Letter                                                     |
| Thermal Vacuum Bakeout Testing Report           | CS-101 |                | to allow the CubeSat's materials to outgas any possible contaminants before the actual launch                                                                                                                                                                  |   | 3 | x | from ICoD, capture in Compliance Letter                                                     |
| Venting Analysis                                | CS-101 |                | identify the vent and non-vent volumes, and the venting area locations on the CubeSat                                                                                                                                                                          |   | x | x | from ICoD, capture in Compliance Letter                                                     |
| Missile System Prelaunch Safety Package (MSPSP) | CS-101 |                | covers all the hazards that the CubeSat could pose to the LV, the dispenser, other CubeSats, and personnel handling or in proximity of the CubeSat                                                                                                             |   | x | x | ensures safety at launch, separation, and re-entry; from ICoD, capture in Compliance Letter |

|                                         |        |                  |                                                                                                                                                                                                                                                                                                                 |   |   |   |                                                |
|-----------------------------------------|--------|------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|---|---|------------------------------------------------|
| Orbital Debris Assessment Report (ODAR) | CS-101 | 47 CFR 25.114(d) | assures all interested parties that CubeSat will not pose an unacceptable hazard to other orbiting spacecraft, will deorbit in a reasonable amount of time, and that no unacceptably large piece of the CubeSat is going to survive reentry when it deorbits and burns up in the atmosphere                     |   | x | x | from ICoD, capture in Compliance Letter        |
| Security Plan                           | NPS    | NPD 1600.2       | describes the project's plans for ensuring security and technology protection                                                                                                                                                                                                                                   |   | x | x | capture in PMP                                 |
| Testing Procedures & Reports            | CS-101 |                  | states which requirements are being verified and the specific evidence in the report that verifies each requirement                                                                                                                                                                                             | 4 |   |   | needed to confirm CubeSat performs as required |
| Data Management Plan                    | NPS    | NPR 7120.5E      | describes how the project will manage the scientific data generated and captured by the operational mission                                                                                                                                                                                                     |   | x | x | capture in PMP                                 |
| Mission Operations Plan                 | NPS    | NPR 7120.5E      | Discusses how the project will implement the associated facilities, hardware, software, and procedures required to complete the mission                                                                                                                                                                         |   | x | x | capture in PMP                                 |
| Day-in-the-Life (DITL) Testing Report   | CS-101 |                  | will show that the CubeSat's timers and inhibit design function correctly, adhering to the appropriate mission ICD requirements                                                                                                                                                                                 |   | x | x | capture in Test Results                        |
| Dynamic Environment Testing Report      | CS-101 |                  | show that the CubeSat will survive the vibrations and shocks that it will experience during launch                                                                                                                                                                                                              |   | x | x | capture in Test Results                        |
| Test Results                            | MIT    |                  | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                                                                                                                | x |   |   | to confirm system's readiness level            |
| CubeSat Acceptance Checklist            | CS-101 |                  | confirms CubeSat adheres to dimensional requirements specified in the CubeSat-to-dispenser ICD                                                                                                                                                                                                                  |   | x | x | from ICoD, capture in Compliance Letter        |
| Compliance Letter                       | CS-101 |                  | statement from the CubeSat developer guaranteeing that the CubeSat is compliant with the entire CubeSat-to-dispenser Interface Control Document (ICoD), and that no prohibited components are aboard; includes mass properties, materials list, battery report, electrical report, CubeSat acceptance checklist | x |   | x | need to provide to LVP                         |
| Lessons Learned Reports                 | MIT    |                  | reflects on all issues encountered during development and offers solutions to avoid in the future                                                                                                                                                                                                               | x |   |   | to not repeat mistakes                         |

Each deliverable has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another deliverable. An 'x' in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for deliverables to be kept with some tailoring. An indicator in the Waive column only is to completely waive. An indicator in the Waive column and Tailor column is for deliverables to be waived by combining it into another deliverable.

A number in any column represents the frequency the event appears among the eight frameworks. Only frequencies of three or greater were identified.

## Appendix H: Final Deliverables Tailored

| Deliverable                                    | S/C/B | Org  | Reference                    | Description                                                                                                                                                                                                                     | Stat | K  | W | T | Justification                                                                                                                                                                                                 |
|------------------------------------------------|-------|------|------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------|----|---|---|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Statement of Work (SOW)                        | S     | NPS  |                              | document broad responsibilities, deliverables, and the work activities required in a given project                                                                                                                              |      | x  |   |   | identify what is expected between organizations                                                                                                                                                               |
| Initial Capabilities Document (ICD)            | C     | DoD  | CJCSI 3170.01                | specifies one or more capability requirements and associated capability gaps which represent unacceptable operational risk if left unmitigated                                                                                  |      | S4 |   | x | capability requirements are identified by sponsor or similar agency in some form of documentation (details may be included in CDD per JCIDS); required to meet statutory Clinger-Cohen Act (CCA) compliance * |
| SysML Block Definition Diagrams [w/ Interface] | S     | USNA |                              | captures the requirements & design; defines relationships between parts of the structures and shared components; includes Requirements Verification Matrix; used to build to Design Solution definition Baseline                |      | x  |   |   | record all sub-system interfaces                                                                                                                                                                              |
| Cost Analysis Data Requirement (CADRe)         | C     | NASA |                              | basis of cost estimates for complex projects; contains a technical, programmatic, and a schedule that are used as the basis for deriving a cost estimate                                                                        |      | x  |   | x | need cost estimates in order to track actuals against                                                                                                                                                         |
| Acquisition Strategy (AS) [& PMP]              | B     | DoD  | DoDI 5000.02T Enc 2, para 6a | comprehensive, integrated plan that identifies the acquisition approach and key framing assumptions, and describes the business, technical, and support strategies to manage program risks & meet program objectives            |      | S4 |   | x | need detailed game plan in order to keep track of what needs to be done, what has been done, and everything in between; required to meet statutory Clinger-Cohen Act (CCA) compliance *                       |
| AoA Report                                     | C     | DoD  | 40 U.S.C 11312               | assesses potential materiel solutions that could satisfy validated capability requirement(s) documented in the ICD, and supports a decision on the most cost-effective solution to meeting the validated capability requirement |      | S2 |   | x | need to identify and document possible capability solutions; required to meet statutory Clinger-Cohen Act (CCA) compliance *                                                                                  |

|                                                                                                                                   |   |     |                               |                                                                                                                                                                                                                                                                                    |   |    |  |   |                                                                                                                                              |
|-----------------------------------------------------------------------------------------------------------------------------------|---|-----|-------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|----|--|---|----------------------------------------------------------------------------------------------------------------------------------------------|
| System Engineering Plan (SEP)                                                                                                     | B | DoD | DoDI 5000.02T Enc 3, Sec 2    | management tool to guide the system engineering activities on the program; technical approach to balance system performance, life-cycle cost, and risk                                                                                                                             |   | 4  |  |   | need detailed game plan on how work will be completed and tracked                                                                            |
| Program Protection Plan (PPP)                                                                                                     | C | DoD | DoDI 5000.02T Enc 3, para 13a | addresses life-cycle Safety & Mission Assurance (SMA) functions and activities, including SMA roles, responsibilities, and relationships; and manage the risks to critical program information and mission-critical functions and components associated with the program           |   | S4 |  |   | cybersecurity plans required for IT due to signal send/receive capabilities; required to meet statutory Clinger-Cohen Act (CCA) compliance * |
| Capability Development Document (CDD)                                                                                             | C | DoD | JCIDS Manual                  | specifies capability requirements, in terms of developmental performance attributes (KPPs, KSAs, and APAs), and other related information necessary to support development of one or more increments of a materiel capability solution                                             |   | S2 |  | x | need to document performance requirements; required to meet statutory Clinger-Cohen Act (CCA) compliance *                                   |
| Concept of Operations (CONOPS)/ Mission Profile (MP)                                                                              | B | DoD | JCIDS Manual                  | contains operational tasks, events, durations, frequency, operating conditions, and environment in which the recommended materiel capability solution is to perform each mission and each phase of the mission; contains Core Logistics Determination *                            |   | S4 |  | x | need to document system and mission operations; integrated Core Logistics Determination which is statutory                                   |
| Test & Evaluation Master Plan (TEMP)                                                                                              | B | DoD | DoDI 5000.02T Enc 4 & 5       | primary planning and management tool for the integrated test program                                                                                                                                                                                                               |   | 7  |  |   | means of recording all test plans                                                                                                            |
| Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)/ National Environmental Policy Act (NEPA) Compliance * | B | DoD | 42 U.S.C 4321-4347            | will include identification of ESOH risks and their status, identification of hazardous materials, wastes, and pollutants; covers all known or projected system-related activities that may trigger compliance requirements including testing, fielding, and support of the system | x | S4 |  |   | statutory                                                                                                                                    |
| Spectrum Supportability Risk Assessment (SSRA)                                                                                    | C | DoD | DoDI 4650.01                  | written determinations that the electromagnetic spectrum necessary to support the operation of the system during its expected life-cycle is or will be available in accordance with DoD Instruction 4650.01                                                                        |   | x  |  |   | to ensure no interference with other systems electromagnetic spectrum                                                                        |

|                                                   |   |        |                     |                                                                                                                                                                                                                                                                                                                 |   |    |  |   |                                                                                                            |
|---------------------------------------------------|---|--------|---------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|----|--|---|------------------------------------------------------------------------------------------------------------|
| Frequency Allocation Application *                | B | DoD    | 47 U.S.C. 305       | required for all systems/equipment that use electromagnetic spectrum while operating in U.S.                                                                                                                                                                                                                    | x | S5 |  |   | to obtain transmission frequencies                                                                         |
| Remote Sensing License                            | S | CS-101 |                     | must obtain appropriate license in order to take pictures or videos of Earth                                                                                                                                                                                                                                    |   | x  |  | x | can waive if non-Earth imaging                                                                             |
| Acquisition Program Baseline (APB)                | C | DoD    | DoDD 5000.01        | a summary of the program cost, schedule, and performance baselines, and is the fundamental binding agreement between the MDA, the CAE (if applicable), the PEO, and the Program Manager                                                                                                                         |   | 3  |  |   | need documented baseline to track development                                                              |
| Design Solution definition Baseline               | B | NASA   |                     | represents build-to-system design and process specifications; provides the basis for manufacturing, buying, coding, and subsequent integration of the products that make up the system                                                                                                                          |   | 3  |  |   | need to document final design                                                                              |
| Capability Production Document (CPD)              | C | DoD    | JCIDS Manual        | specifies capability requirements, in terms of production performance parameters (KPPs, KSAs, and APAs), and other related information necessary to support production of a single increment of a materiel capability solution                                                                                  |   | x  |  | x | If there are no changes, a revalidated CDD may be submitted for the CPD required at MS C per DoDI 5000.02T |
| Developmental Test & Evaluation (DT&E) Assessment | C | DoD    |                     | Analysis of the system & sub-system progress in achieving performance metrics, technical risk, software maturity                                                                                                                                                                                                |   | x  |  |   | need to report results of DT&E                                                                             |
| Operations Handbook                               | C | NASA   | NPR 7120.5E         | provides information essential to the operation of the spacecraft                                                                                                                                                                                                                                               |   | x  |  | x | need some form of documenting how to operate CubeSat                                                       |
| Operational Test & Evaluation (OT&E) Results      | B | DoD    | DoDI 5000.02T Enc 5 | all records, reports, and data from every OT&E and LFT&E event                                                                                                                                                                                                                                                  |   | 4  |  | x | results of full system tests in space simulated environments                                               |
| Compliance Letter                                 | S | CS-101 |                     | statement from the CubeSat developer guaranteeing that the CubeSat is compliant with the entire CubeSat-to-dispenser Interface Control Document (ICoD), and that no prohibited components are aboard; includes mass properties, materials list, battery report, electrical report, CubeSat acceptance checklist |   | x  |  | x | need to provide to LVP                                                                                     |
| Acquisition Decision Memorandum (ADM)             | C | DoD    | DoDI 5000.02T       | documents MDA decisions after each review                                                                                                                                                                                                                                                                       |   | x  |  |   | need documentation of each decision                                                                        |

|                                    |   |     |                 |                                                                           |   |    |  |  |                              |
|------------------------------------|---|-----|-----------------|---------------------------------------------------------------------------|---|----|--|--|------------------------------|
| Post Implementation Review (PIR) * | B | DoD | 40 U.S.C. 11313 | to compare actual program results with established performance objectives | x | S4 |  |  | to establish lessons learned |
|------------------------------------|---|-----|-----------------|---------------------------------------------------------------------------|---|----|--|--|------------------------------|

The deliverables with a “\*” are statutory requirements so they must be completed by law. Additionally, an “S” in the keep column identifies a statutory document or a document that itself is not statutory but must be completed to be in compliance with another statutory requirement. A number in any column represents the frequency the event appears among the 12 frameworks. Only frequencies of three or greater were identified.

Each deliverable has four possible outcomes: keep as is, keep with tailoring actions, waive completely, or waive by tailoring into another deliverable. An ‘x’ in the Keep column only is kept as is. An indicator in the Keep column and Tailor column is for deliverables to be kept with some tailoring. An indicator in the Waive column only is to completely waive. An indicator in the Waive column and Tailor column is for deliverables to be waived by combining it into another deliverable.

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| REPORT DOCUMENTATION PAGE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                      |                                   |                                            | Form Approved<br>OMB No. 074-0188                                       |                                                                                                    |
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| 14. ABSTRACT<br>AFIT's Center for Space Research and Assurance (CSRA) has developed several small satellites without a detailed developmental framework in place but future work will focus on CubeSat development with the intent of managing multiple builds concurrently. With the goal of each satellite being completed in three years, a comprehensive process needs to be established. Research revealed that the Department of Defense (DoD), U.S. Air Force (USAF), and National Aeronautics and Space Administration (NASA) guidance on the acquisition and systems engineering processes require more reviews and deliverables than appropriate for CSRA's projects. The development processes from other universities divulge some aspects of the much larger DoD or NASA processes were borrowed and incorporated. All these processes were explored and tailored to meet the specific needs of CSRA. To effectively scrutinize each process, the frameworks were divided into life-cycles, deliverables, and entrance/exit criteria before being tailored. The research provided qualitative data so visual mapping was used to compare and tailor the life-cycles. The deliverables were recorded and organized to develop a comprehensive list that was tailored to those that are value-added to CubeSat development. Once the appropriate entrance/exit criteria were applied to the life-cycle and deliverables, a fully tailored framework was defined. |                      |                                   |                                            |                                                                         |                                                                                                    |
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