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# Model Based Systems Engineering on the AVR-2B Laser Detection Set

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**Abstract:** The use of Model Based Systems Engineering (MBSE) on legacy systems such as the AVR-2B Laser Detection Set is essential for fully grasping the details of the system. MBSE models improve the implementation of the AVR-2B on both the Army's current and future aircraft. From the internal connections between the components in the Internal Block Diagram to the operation in a combat environment shown in the Use Case Diagram, all MBSE diagrams aid all stakeholders involved with understanding the AVR-2B LDS. MBSE is certainly a helpful tool in the development phases of new systems but also with increasing understanding of existing systems. The nine diagrams produced from MBSE can lead to a fast yet effective implementation of survivability systems such as the AVR-2B, which would be an asset to Future Vertical Lift with increasing aerial enemy threats.

*Keywords:* Model Based Systems Engineering (MBSE), AVR-2B, Future Vertical Lift

## 1. Introduction

With enhanced enemy capabilities on the rise, it is imperative to continue to develop the Army's aircraft to combat aerial threats. In addition to improving the effectiveness of the Army's fighting capabilities in flight, increased protection of the aircrew operating during missions is also important. Survivability of aircraft and personnel affects the effectiveness of the Army but also affects costs of resources and timelines of missions (Project Manager for Aviation Electronic Combat, 1998). Project Management Aircraft Survivability Equipment (PM ASE), one of the project managers under Program Executive Officer Intelligence Electronic Warfare & Sensors (PEO IEW&S), is working towards these goals given any type of aircraft (PEO IEW&S, 2021). With avionics training using ASE equipment, pilots will become more effective with the aid of automated technology that detects various missile threats. Human and machine interactions through aircraft survivability technology are necessary to take countermeasures against multi-dimensional enemy attacks in a combat environment (Project Manager for Aviation Electronic Combat, 1998). To achieve this mission of greater interactions, a Model Based Systems Engineering (MBSE) approach will be applied using the nine basic SysML diagrams on the Cameo platform to provide insight to PM ASE on the structure, functions, and implementation of the AVR-2B.

### 1.1 AVR-2B

The AVR-2B Laser Detection Set is a legacy system that PM ASE is currently implementing on aircraft. A potential issue of system implementation is the lack of shared understanding between the system engineers and the system's users, which can be alleviated by using the MBSE approach. The AVR-2B detects aircraft illumination by lasers and provides aircrew visual and audio warnings according to threat lethality via PM ASE's Radar Signal Detecting Set (RSDS). Its main capability is to detect laser rangefinders, designators, and beam rider missiles. After the system detects the missile, it categorizes it into one of the three spectral coverages (AVR-2B Technical Review, 2010). After the AVR-2B categorizes the threat, it transfers the signal to the heads-up display in the cockpit, which signals the threat to the pilot.

### 1.2 Future Vertical Lift

The Future Vertical Lift (FVL) program has been a continuous effort since 2009 to produce new and improved rotorcraft technology to replace the Army's current aircraft, to include the Chinook, Black Hawk, Apache, and Kiowa Warrior, helicopters which were designed in the 1960s and 1970s. FVL seeks to improve "maneuverability, range, speed, payload, survivability, reliability, and reduced logistical footprint of the aircraft (Congressional Research Service, 2021). In addition to enhancing the Army's fighting capabilities, FVL will play a role in aeromedical evacuations. These future improvements will help meet the Army's requirements of performing an aeromedical evacuation within the 1-hour standard, which is when the status of critically wounded soldiers significantly worsens (Bastian, et al. 2012).

Although the idea of FVL has been around for a little over a decade, its project plan has just recently taken flight due to its increase in priority levels for the Army. The demand for modernization of these aircraft led to an increase in budget for the Future Vertical Lift program. In FY2021, the budget was $213.5 million. For FY2022, the Army requested $448.4 million, over twice as much as the year before. According to Research, Development, Test & Evaluation, Army's (FLRAA) timeline, the Army is currently conducting virtual prototyping and will end in 2024. The Army scheduled physical prototyping for 2023 and will run concurrently with the virtual aspect. This event is to continue for the following three years. Flight testing of these prototypes is scheduled for years 2025 through 2029. Furthermore, FVL aircraft are projected to be used by the Army in the early 2030s (Congressional Research Service, 2021). MBSE efforts will be critical to the design, production, and implementation of various systems, especially the AVR-2B LDS, on FVL aircraft.

Applying MBSE to the FVL program would be ideal with the verification and validation of the system design, structure, behavior, requirements, and overall information. Through the early recognition of potential issues and the use of SysML diagrams, the method of communication between all actors, stakeholders, and users becomes streamlined and consistent. This consistency increases the learning rate of how to operate the system and results in better modeling. By applying MBSE, the interactions between legacy systems and new innovations can be understood easier and more uniformly. This would allow for greater ease in designing the combination of these systems and the faster adaptation and production of the systems.

## 2. Literature Review

MBSE is a quickly growing form of systems engineering. It is defined as the "formalized application of modeling to support system requirements, design, analysis, optimization, verification, and validation" (Gregory, et al. 2020). In this process, nine models are created for a given system, these models are: Use Case Diagram, Block Definition Diagram, Package Diagram, Internal Block Diagram, Requirements Diagram, Activity Diagram, State Machine Diagram, Sequence Diagram, and Parametric Diagram. These diagrams are created using a software platform that links the diagrams together to create a holistic view of the system and allows for a common understanding through common language and consistency within the models.

This process differs from the previously used Document-Based Systems Engineering (DBSE). In DBSE, all documents, plans, designs, and implementation considerations are created and stored in separate documents (Gregory, et al. 2020). By manually creating separate documents of a given system, the system struggles to have any consistency with regards to precision and accuracy. The multiple, separate, individual documents will make maintaining constant and consistent documentation and nomenclature difficult (Subarna, 2020).

Subarna (2020) highlights that "as the real-world systems get increasingly complex and inter-disciplinary, multi-disciplinary fields, smarter systems, and products, the need for better systems engineering method arises." The benefit of using MBSE are that the time to design and implement a system is reduced by more than 50% (Subarna, 2020). By saving time and money, the creation and implementation of the system becomes a faster and more efficient process. An additional benefit of using MBSE is that the ability to validate and verify the system earlier in the life cycle can result in faster improvement turnover and a better overall product (Subarna, 2020).

An MBSE pilot program at NASA Langley applied MBSE to the Materials International Space Station Experiment-X (MISSE-X). The case study was created to determine the benefits of applying MBSE to aviation and to compare this method to previously used DBSE. This study resulted in a couple main conclusions on the benefits of MBSE over DBSE. The benefits were the centralized and consistent access to information that became integrated across the design, structure, behavior, and requirements of the MISSE-X system. The standardized method of communication and nomenclature of the system provided the development teams a faster learning rate and understanding of the system, which assisted their ability to communicate with and meet the needs of the stakeholders and clients (Vipavetz, 2012). MBSE is not without challenges. Specifically, there are challenges of limited baseline knowledge of MBSE and SysML, as well as relying on support from the previously used DBSE (Vipavetz, 2012). As in the case of Subarna's investigation, there is a more efficient exchange and understanding of information between the engineering team and the stakeholders. This increased understanding and line of clear communication can result in a better final work product.

## 3. Methodology

All nine MBSE models represent the AVR-2B legacy system. The Package Diagram displayed in Figure 1 groups and nests the rest of the models under the four main types: Behavior Models, Data and Information Models, Requirements Models, and Structural Models.

The Use Case diagram displays the cases the system is used in and displays the actors and stakeholders and their influence within the system. The second model made was the Block Definition Diagram (BDD), which displays the systems structural hierarchy. It breaks down the AVR-2B into the main components and their corresponding subcomponents. The next diagram is the Internal Block Diagram (IBD), which is used to describe and display the internal structure of the system and the relationships and interfaces between other components and subcomponents. The Requirements Diagram displays the specific requirements and sub-requirements that are linked to each component and subcomponent. The Activity Diagram shows how the functions of the system operate over time. The next diagram is the State Machine Diagram, which represents the different statuses that the system can exist in and how it transitions between them. The Sequence Diagram is used to represent the interaction between structural entities of a system through a sequence of message exchanges between the entities. The final diagram is the Parametric Diagram, which is used to express how one or more performance constraints, equations, and inequalities are bound to the properties of a block or activity.

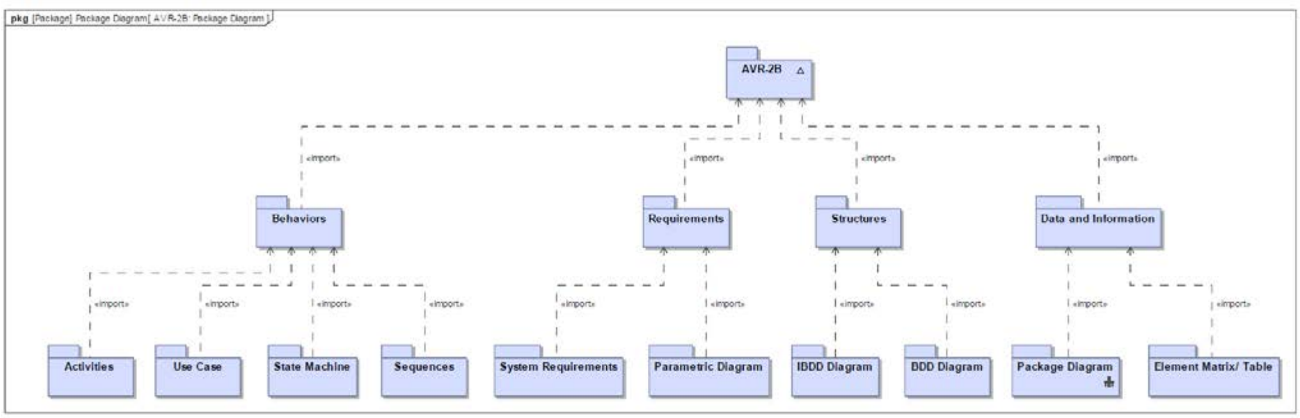


Figure 1. Package Diagram

## 4. Results

Four out of the nine MBSE models are analyzed. These four diagrams capture the organization of the system model, functions of the AVR-2B, how they work in different states, and the main actors and stakeholders that are involved with the AVR-2B system. The Use Case Diagram can be seen in Figure 2. Interactions between the AVR-2B and its direct and indirect actors are mapped out. The direct actors include individuals who work closely with the system such as the aircraft mechanics and aircrew. The non-human but still direct actors are the aerial threats (laser rangefinder, laser designator, and laser beam rider) that trigger the laser detection system. The indirect actors that do not have hands on interactions are still involved and oversee AVR-2B operations. Program Executive Office (PEO) Aviation is one of the few in this group. The last category of actors is the different types of aircraft platforms that the AVR-2B can operate on such as the Chinook and Black Hawk helicopters, which crosses over with Future Vertical Lift.

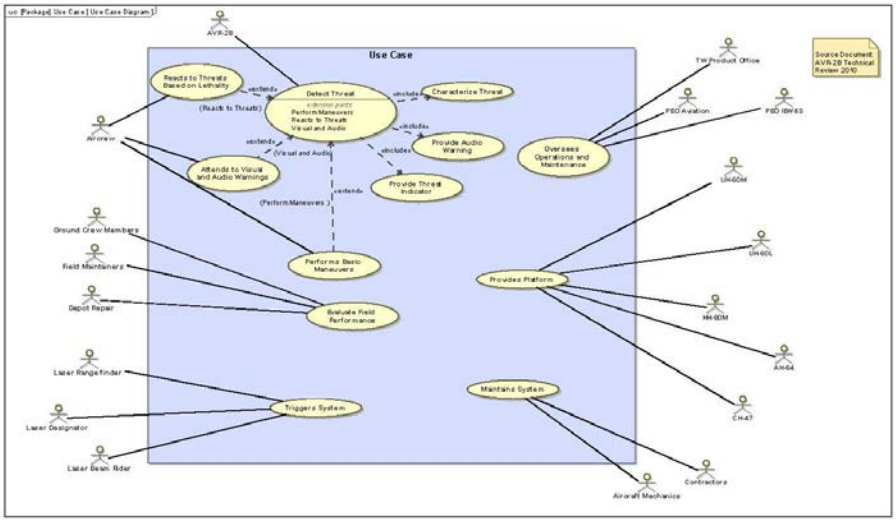


Figure 2. Use Case Diagram

Figure 3 presents the Activity Diagram for the AVR-2B's overall detection activity. The information used to create this diagram was found in the AVR-2B Technical Review 2010 that was provided by PM ASE. One key takeaway of this Activity Diagram is that the system detects false alarms in addition to threats. The system is then able to report them on the display in the cockpit of the aircraft where the aircrew can be notified. The "Alert Aircrew" action occurs towards the end of the flow. This activity is important because it determines how the pilot maneuvers the aircraft and counteracts the threats. Another note to point out is the categorization of aerial threats. The AVR-2B can categorize the incoming beam rider missiles based on their level of lethality. The Activity Diagram is simple, yet it displays a visual presentation of the different paths of actions that the AVR-2B can take based on the threats in its environment.

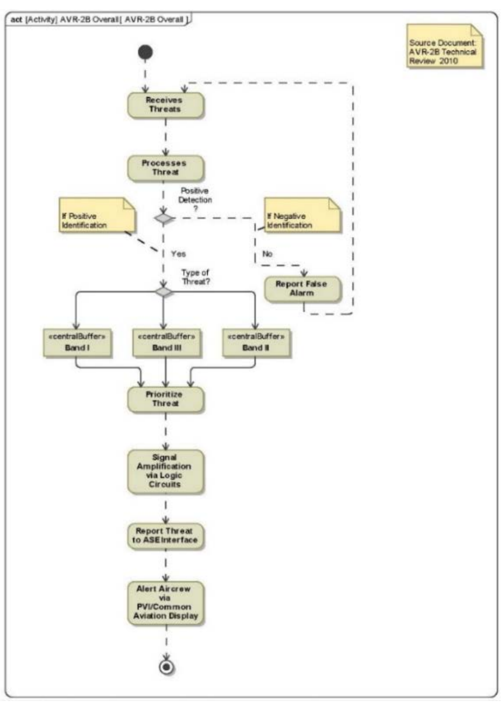


Figure 3. Activity Diagram (overall)

Lastly, various states of the AVR-2B LDS are shown in the State Machine Diagram in Figure 4. The system has two modes: Tactical and Training. In the Tactical Mode, the pilot is alerted to laser illumination from incoming threats. Alerts are audible in the cockpit and displayed on the pilot's Dedicated Electronic Warfare Display (DEWD). In the Training Mode, the system provides "combat-realistic tactical training" with the aid of the MILES/AGES laser training system (AN/AVR-2B(V) Laser Detection Set Theory of Operations Manual 2006). In the "Start-Up" and "Standby" states displayed in the diagram demonstrate that the system cannot carry out its primary function of detecting incoming missiles if the system is not yet calibrated to perform. This results in a longer amount of time to detect threats, which could potentially put the aircraft, aircrew, potential passengers, and cargo in danger. PM ASE can use the State Machine Diagram and the rest of the MBSE models to further their understanding of the AVR-2B's components and how it functions in its environment.

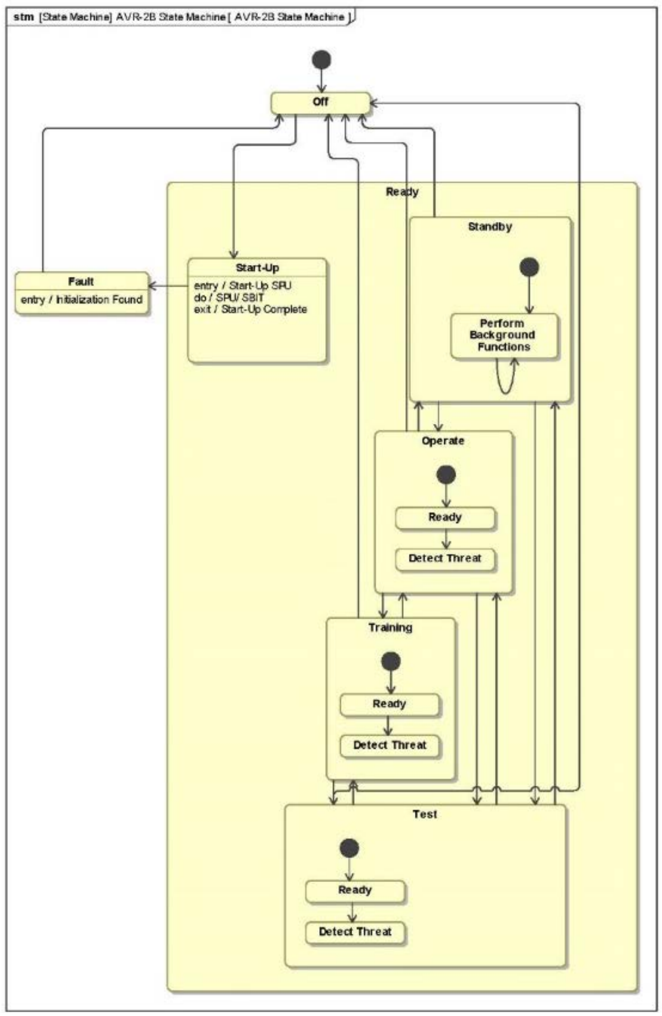


Figure 4. State Machine Diagram

## 5. Conclusion

Although the nine MBSE diagrams provide valuable information about the AVR-2B, there are some limitations. Classified system information could not be included, which limited further detail of the MBSE models. Additionally, a limitation also results from the difficulty of learning SysML language and formatting for certain models that had not been taught in our academic classes. We learned how to properly format the diagrams and use the SysML language through the University of Alabama- Huntsville's MBSE Course. We then retrieved the necessary information from the AVR-2B manuals and documents that PM ASE provided to create the diagrams for the AVR-2B. The area for future work of this system is to incorporate the additional classified information into the models. This provides the users, design engineers, and all other stakeholders a clearer understanding of the structure, behavior, requirements, and information regarding the system.

In the future, the adoption of MBSE should become the standardized method for conducting analysis on systems and programs such as Future Vertical Lift. For FVL, aircraft survivability equipment like the AVR-2B LDS is paramount for detecting incoming threats. Using MBSE to verify and validate potential systems will result in faster transition from the development phase to implementation of the system, leading to a more effective and efficient understanding of complex systems and better products for Army aviators. The advantages of MBSE over previously used DBSE will be apparent when engineers are able to simulate activity and state flows of the system, which will drive improved future innovations. Additionally, MBSE will aid the rapid adaptation of legacy systems such as the AVR-2B to meet new requirements for future systems by quickly altering and changing the components, their interfaces, and the linkage to other functions and systems.

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