Colorado State University

Model Based Systems Engineering analysis for Hardware Selection of a Distributed Surveillance System.

Abstract: Using Model Base System Engineering (MBSE) analyses, we show how these approaches can give further depth to the system, operational, and behavioral architectural domains of distributed sensing and computing environments. The corresponding physical component model leads to a fully functioning prototype of a Situational Strategic Awareness Monitoring Surveillance System (SSAMSS). SSAMSS is a product idea aimed at assisting with minimum cost deployment of supercomputer technology to increase materials surveillance and safeguarding capabilities. Coupled with testing and evaluation simulations to provide validation and verification of SSAMSS at the prototype stage, MBSE analysis is used to verify the eventual system development with increased confidence. Subsystems, components, and parts configuration focusing on Raspberry Pi computing Clusters are assemble optimally to assure system design requirements for rapid deployment, scale, adaptability, intelligence, and cost effectiveness in the surveillance of sensitive materials. Optimization selection of target hardware using MBSE/SE tools allows optimization for costs/performance ratios, peak processing capacity, risk reduction, and requirements considerations.
Keywords: System Engineering, Model Base Systems Engineering, Situational Strategic Awareness Monitoring Surveillance System (SSAMSS), Microcomputer clusters, Intelligent surveillance

Kenly R. Maldonado and Steve Simske; Colorado State University – Systems Engineering; Santa Fe, New Mexico, United States

Kenly Maldonado, kenly.maldonado@colostate.edu
Steve Simske , steve.simske@colostate.edu
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Abstract

The principal objective of this research is to continue creating a system that is quickly deployable, scalable, adaptable, intelligent, and provides cost effective surveillance from product idea to an operational prototype. The product concept of Situational Strategic Awareness Monitoring Surveillance Systems (SSAMSS) has some development loosely based under Systems Engineering (SE) concepts. To further assure the development with a higher level of confidence of the complex system while reducing potentially any gaps the use of Model Based System Engineering (MBSE) tools along with the development of a models should increase assurance that SSAMSS will meet suggested requirements and specifications with the highest levels of confidence regarding the hardware management configuration. This assures that SSAMSS will have hardware that can function at the optimal level through SE, MBSE and simulations analysis will lead to future development of programming- Artificial Intellagnce (AI), Machine Learning (ML) and neural networks (NN), which, will be discussed to maximized collected sensor data to communicate to the stakeholder of different activety at the SSAMSS deployment sites. The contribution of this research will show how to use MBSE tool and methodes to: 1) identify applicable methods and tools through MBSE to improve hardware design selection, 2) couple the MBSE tools with models that can be analysed to increase hardware design confidence, 3) show traceability between the MBSE tools and hardware design and 4) increase system awareness, performace and capabilty with a focsu on the micro cluster configuration.

I. Introduction

Materials safeguarding such as depleted radio active materials, explosive and/or hazardous items throughout the globe depends on tools that are singular systems, costly and personnel intensive. Includes governmental agencies inside and outside the continental United States. The tools to assists in surveilling sensitive materials e.g., depleted radioactive, explosives materials, ammonium nitrate, etc., are handheld, static, coupled with web-databases, lack surveillance, and lack intelligence, e.g., AI, ML, NN or Deep Learning (DL) capabilities. The development of a distributed surveillance system hardware configuration and selection will help increase assurance that the SSAMSS system will be able to perform optimally by using synergies of all the properly selected tools, language and methods to assure a proper hardware and cluster configuration.

II. Background

Situational Strategic Awareness Monitoring Surveillance System (SSAMSS) is being designed to help government agencies .i.e., Nuclear Material Control and Accounting [2], to create a cost-effective way to be coupled along with forms, databases, barcode, procedures, protocols, reports and singular systems i.e., Geiger counters that are currently being used today to safeguard materials today [3]. The standard for domestic safeguarding of sensitive materials are 1. Threat assessment, 2. Physical Protection Areas, 3. Intrusion Alarm Assessment 4. Armed Response 5. Regulatory Initiatives and 6. Regulations, Guidance and Communications [4] which lack deplorability, scalability and intelligence creating a space for SSAMSS to become applicable. This application will be fitted by using Model Based Systems Engineering concepts, tools, language, and approaches to assure proper development of a dynamic surveillance system.

III. Approach

The approach will be using SE, MBSE- SysML to focus on the development of the microccluster. The micrcoluster is a critical system for SSAMSS complemented by a system that collects data and transmits it back to the microcluster for processing. This will be used to understand and consider the SSAMSS dynamic surveillance system elements to assure proper development. We will be using high level requirements as a starting point but help secure a configuration hardware selection from SSAMSS.

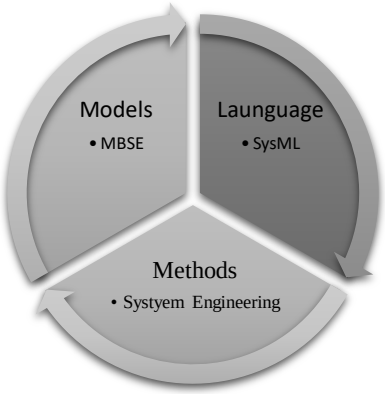


Figure 1: SysML, MBSE and SE approach to hardware selection

Defining how and what SE, MBSE and SysML will be utilized to increase, 1) hardware design confidence, 2) hardware design selection and 3) traceability as shown in figure 1.

Table of Definitions		
Term	Definition	Applicability
Systems Engineering (SE) [5]	Systems Engineering is a transdisciplinary and integrative approach to enable the successful realization, use, and retirement of engineered systems, using systems principles and concepts, and scientific, technological, and management methods.	Establishing an appropriate lifecycle model, baselining and modelling requirements and selected solution architecture for each phase of the endeavor. performing design synthesis and system verification and validation;
Model-Based System Engineering (MBSE) [6]	Model-based systems engineering (MBSE) is the formalized application of modeling to support system requirements, design, analysis, verification, and validation activities	System Functional Flows (i.e., System Architecture), System Requirements

	beginning in the conceptual design phase and continuing throughout development and the later life cycle phases.	Traceability and System and Organizational Process Flows
System Modeling Language (SysML)[7]	A general-purpose modeling language for systems engineering applications.	It supports the specification, analysis, design, verification, and validation of a broad range of systems and systems-of-systems.

Table 1: SysML, MBSE and SE Definitions and applicability

The use of SysML through the program Modelio software will increase the configuration options. Having a software program to assure selection by using specific diagrams. Those diagram that are selected could eventually be turned into dynamic models. The focus on diagrams will help to pick the overall hardware and primary configuration selection options. The SSAMSS cluster will focus in on options by starting from listed below while referencing diagram 1[8]:

- Requirement Diagrams
- Block Definition Diagrams
- Package Diagram
- Domain Diagram
- Complex Systems Dynamics

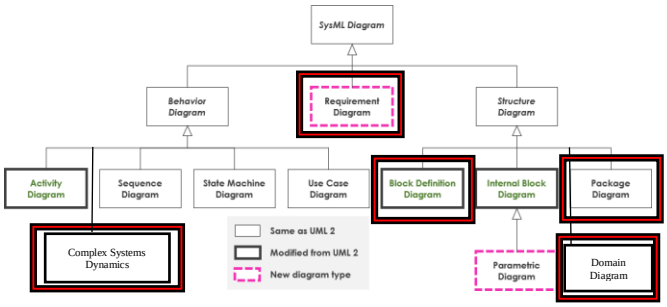


Diagram 1: SysML framework

By adding the complex systems dynamics diagram and the domains there is more understanding of what the customer and system are developed to do. Through the domain diagram there will be further development to look at peak cost, peak processing, and overall operational equipment effectiveness for SSAMSS vs general products used to eventually compare deltas. The deltas comparison can show the overall effectiveness of SSAMSS when compared to other products used for safeguarding of materials.

IV. Requirement Process

The requirements assessment is utilized by finding and formalizing the safeguarding needs from previous reviews [9] of what customers considered of value. The requirement(s) are developed under the SysML and linked through traceability. The high-level customer requirements are:

- Initial Costs
- Operational Costs
- Intelligence
- Reliability
- Maintainability
- Scalability

Those requirements then are transcended into the primary requirement categories and/or derived to assure the primary development of the dynamic surveillance system. In this case the further development of categories and/or derived requirements are understood to be:

- Functional,
- Performance
- Technical
- Specific

There will be furthered development in the future assessment of the requirements and along with the MBSE process. This will take a few iterations, but for now are assumed for the purpose of prototyping and selecting hardware configuration for SSAMSS starting from high level requirements that feed into derived and/or specific requirements as reference in the diagram:

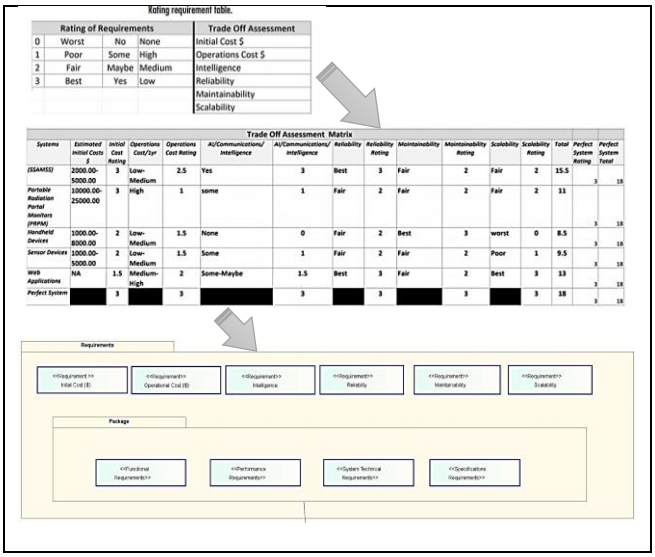


Diagram 2: Vetting of Requirements using previous requirement assessment for SSAMSS

V. Developing Domains

The customers domain perspective is critical in assuring that the correct perspectives are gauged and measured. The domains that are reliant to safeguarding materials for a dynamic system and matter to the customer are 1) Global Safety – assuring the safeguarding, protecting, handling, monitoring, storage and controlling of sensitive materials, 2) Average Products - currently used that the government is familiar with webs, Geiger counter, etc. , 3) Environment – location where these materials are left, stored, monitored and controlled and above all, 4) Customer consideration- labs, governments, agency that safeguard sensitive materials to assure global safety. All of these domains come

together to develop an idea of what is important in order for SSAMSS to succeed under these domains as referencing figure 2.

Figure 2: Assessed Domains for Product Development

VI. Complex Systems Dynamics

Development of a system is complicated, but development of a dynamic system of system is complex with a hardware distribution microcluster to assure awareness, capability, and confidence to reduce security incidents. As the diagram was developed, we have the domains that are suggested to be valued by the customer and to better develop through SysML and MBSE to assure selection of potent valued measures. These measures will help in future research to different deltas between dynamic surveillance system and average product comparisons to assure confidence of system development as shown in Figure 3.

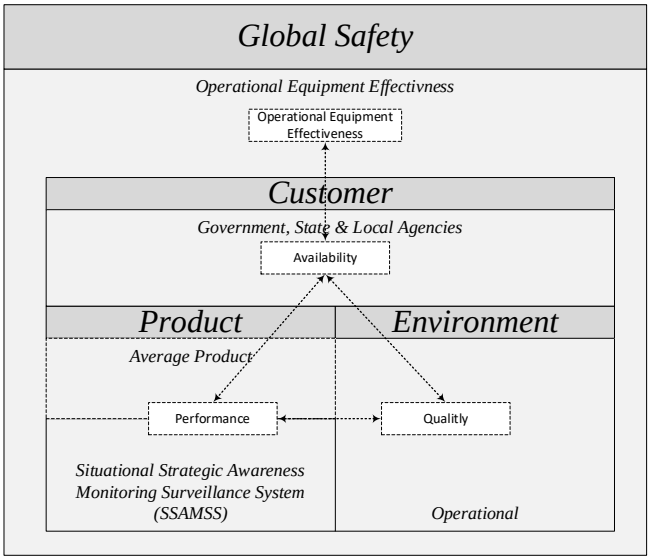


Figure 3: Assessed Domains for Product Measurements

To assure peak cost assessment of future studies it was suggested to assess the measure of value per domain. This current study is looking primarily at performance and parallel Pi Processor computing at low costs. The suggested equation(s) and details to help with cost performance analysis will be:

- Operational Equipment Effectiveness (OEE):
  - SSAMSS vs Average Product
  - Equation: (Availability)*(Performance)*(Quality) = OEE
- Availability:
  - SSAMSS vs Average Product
  - Equation: (Actual Production Time)/ (Potential Production Time) = Availability %
- Performance:
  - SSAMSS vs Average Product Processing Power
  - Equation: (Actual Output)/ (Theoretical Output) = Performance %
- Quality:
  - SSAMSS vs Average Product Environmental life span
  - Equation: (Good Output)/ (Actual Output) = Quality %

Future data assessment will be deployed to eventually create a dynamic model that can be created for analysis the listed equations per Pi nodes against SSAMSS vs Average Product usage through added variables that feed into the complex system dynamics through a future stock and flow model.

VII. Casual Loop Diagrams

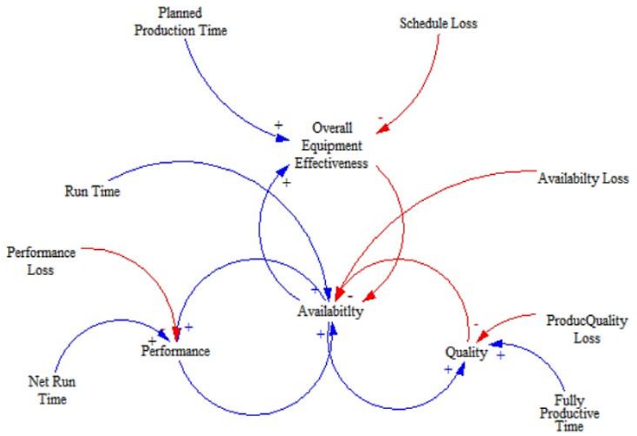


Figure 4: Complex Loop Diagram with Variable Assessment of Measures

Development of a Casual Loop Diagram of the domains will assist in showing how complex the overall model happens to be. This can be transformed into a stock and flow diagram that could be used to make a dynamic mathematical model showing the effects of all area domains of the model. Using Vemsim software package to create a causal loop diagram and model that shows the connecting variables. Those variables feed into the Performance, availability, quality, and overall equipment effectiveness that shows cost performance through the developed model. The performance is a critical area to look at since this is where the clustering of processors and data would ultimately lye.

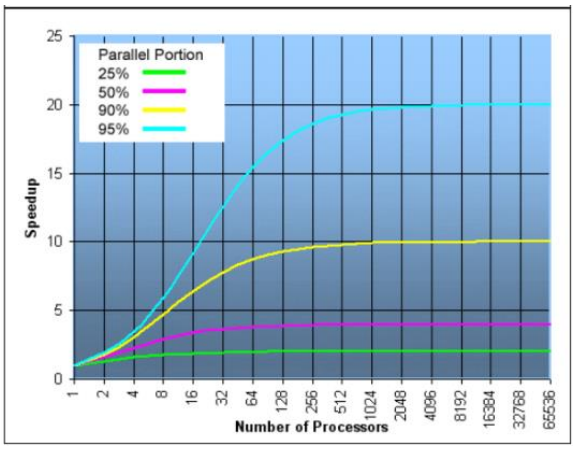


Figure 4: Complex Loop Diagram with Variable Assessment of Measures

Their primary measure for the performance aspect when comparing SSAMSS vs average product is single vs parallel computing (hardware) and down the line parallel programming (software). This is where the SSAMSS cluster will benefit from Amdahl's law through cost effective configuration and hardware Pi processors which states, "Amdahl's Law was named after Gene Amdahl, who presented it in 1967.

In general terms, Amdahl's Law states that in parallelization, if P is the proportion of a system or program that can be made parallel, and 1-P is the proportion that remains serial, then the maximum speedup S(N) that can be achieved using N processors is:

$$S(N)=1/((1-P)+(P/N))$$

As N grows the speedup tends to 1/(1-P).

Speedup is limited by the total time needed for the sequential (serial) part of the program. For 10 hours of computing, if we can parallelize 9 hours of computing and 1 hour cannot be parallelized, then our maximum speedup is limited to 10 times as fast. If computers get faster the speedup itself stays the same. [10]"

VIII. Building Blocks

After getting a better understanding of the complex dynamic system the actual packaging of the diagram under SysML is developed and understood. Starting with the SSAMSS MicroCluster Unit and all the other hardware and software components that are developed within the overall SSAMSS enterprise, "A Package diagram is a static structural diagram that shows the relationships among packages and their contents. Package can be stereotyped (customized) for organizing model elements into models, views, model libraries, and frameworks. [11]" The development of the SSAMSS packages assists in assuring that there is solidified understanding of how SSAMSS is structurally setup that can be used to further develop and select the hardware configuration. The overall block diagram shows the traceability as showing in figure 6 and 7 to the requirements and connection to the whole SSAMSS enterprise system.

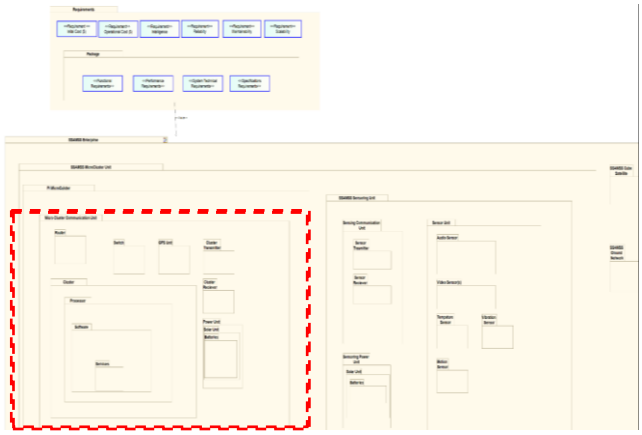


Figure 5: SysML SSMASS Requirement and Enterprise Package

The overall enterprise system is structurally realized with a focusing in on the SSAMSS MicroCluster unit configuration and hardware selection to create confidence in robust selections. The package diagram of the SSAMSS MicroCluster shows all the hardware and software considerations with a primary focus in on the Hardware then in future development the software.

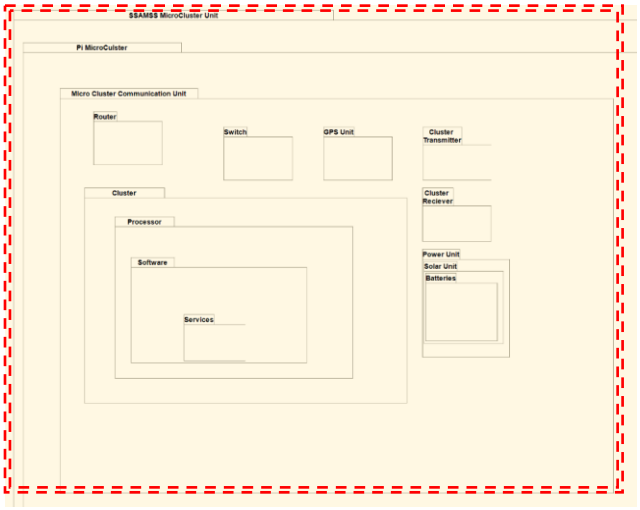


Figure 6: SysML SSMASS Microcluster Package Focus

IX. Simple and Complex Process block Diagram

SSAMSS simple process diagram concept is starting to take physical form and being able to view how the system may be developed overall. This physical development is conceptual, but it should not just meet operational and functional needs but be able to meet the performance and physical characteristics and requirements. Other considerations for future assessment is the logical, structural and architecture of SSAMSS, which, are factors that are needed to be understood to develop the hardware and software aspect, concurrently. There is still more assessment that needs to be considered energy, digital and materials aspect to assure SSAMSS overall development while referencing figure 7.

SSAMSS Input-->Process-->Output			
System	***Inputs***	***Process***	***Outputs***
SSAMSS	Interface Data	Transmission	Command and control data
	Images Data	Process	Intelligence reports data
	Sensor Data	Analyses	Reactive monitor and controlling commands
	Attached Components Data	AI/Machine Learning	
	Secure Data	Spatially Intelligence	
		Security	

Figure 7: SSAMSS Simple Process Map

Process Map Details continue the process map and further understand logically how SSAMSS could meet its functional objectives. Visually the interacts between the systems, subsystems, components work functionally and what it is supposed to be doing, which, is 1) track, 2) monitor, 3) control, 4) communicating and 5) safeguard materials through a dynamic survallance system approach refrence figure 8. The system is digitally and analytically filtering data from the environment then communicating that information back to a specific person and/or command center, locally and globally. SSAMSS takes the data, process the information, logical and intelligently while predicating potential threats compared to current products used.

SSAMSS Detials Complex Process			
System (Bi-directional communication)	***Inputs (variable's x)***	***Process (activities)***	***Outputs (variables y)***
SSAMSS Interface (Primary Subsystem)	[1] collect data [2] secure data	[3]transmit Data [4] obey primary system's commands [5] stay connected to primary system	[6] collect data securely and successfully given to primary system
SSAMSS MicroCluster Supercomputer (Primary System)	[7] collect data securely and successfully from the primary subsystem [8] partition data from specifically configured primary subsystem	[8] properly store partitioned data [9] review partitioned data and use programming of AI/Machine learning to make consideration's/analysis about personal and locations based of data (potential incidents and threat agent) [10] communicate with command and control if needed [11] command primary subsystem	[12] communicate with command and control [13] intelligence consideration of collected data [14] command primary subsystem to collect data and follow personal if required (potential incidents and threat agents)

Figure 8: SSAMSS Complex Process Map

X. Simple and Complex Process Block Diagram

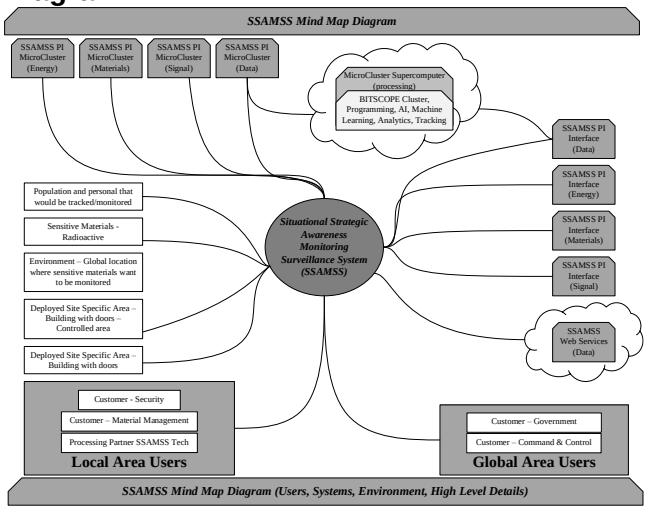


Figure 9: SSAMSS Mind Map Diagram

SSAMSS has a combination of systems (microcomputers and microcomputer clusters) and subsystems programmed to work collectively to create synergy to reduce gaps and deficiencies, which, fill the requirements need to address the government customer segment. The SSMASS objective(s) is to 1) collect, filter, compile and process data in a timely manner (combined and compile that data effectively, securely and quickly), 2) track materials, personnel, threat agents and incidents intelligently, 3) process the data in an effective way, 4) be economical and 5) be quickly scalable, adaptable and deployable. Those subsystems, which, extremely crucial due to the processing aspect 1) artificial 2) intelligence, 3) analytics, 4) machine learning, 5) neural networks, algorithms, 6) predictability, probability, statistics 7) and network, web communication, messing and tracking.

The mind map diagram shows in reference figure 9 how all three systems connected to the overarching SSAMSS to communication with the local and global area customer to help track materials, personnel, threat agents and incidents. SSAMSS meets and addresses those industry gaps and deficiencies (combining them together create a synergy that can help reduce incidents by meshing thermal images, depth sensors images, vibration sensors, and volume calculations analytics and intelligence) new technological opportunities. The area(s) being observed by SSAMSS indicate when potential incident and/or threat agents are being considered through digital monitoring, capture and follow those details in order to report that information back to the customer on a global and local level in order to improve safeguarding of those materials at risk via web.

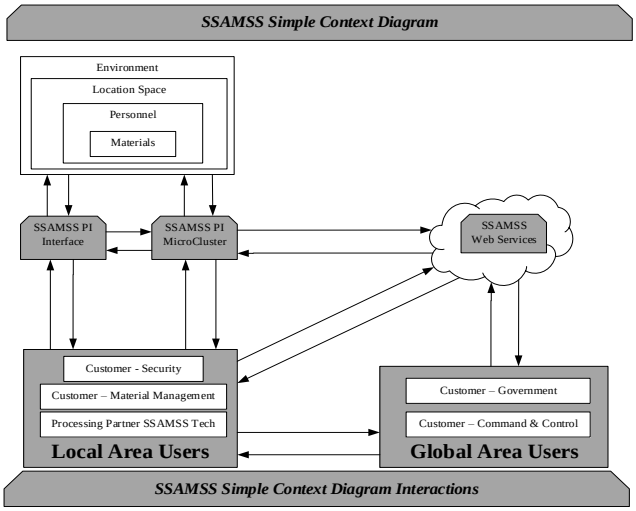


Figure 10: SSAMSS Simple Context Diagram

SSAMSS is a combination of systems (microcomputers and microcomputer clusters) and subsystems programmed to work collectively to create synergy to reduce gaps and deficiencies, which, fill the requirements through the SysML approach which needs to address the government customer segment. The SSAMSS objective(s) is to 1) collect, filter, compile and process data in a timely manner (combined and compile that data effectively, securely and quickly), 2) track materials, personnel, threat agents and incidents intelligently, 3) process the data in an effective way, 4) be economical and 5) be quickly scalable, adaptable and deployable. Those subsystems, which, extremely crucial due to the processing aspect 1) artificial 2) intelligence, 3) analytics, 4) machine learning, 5) neural networks, algorithms, 6) predictability, probability, statistics 7) and network, web communication, messing and tracking reference figure 10.

XI. Options, Configuration and Selection

As we understand the Dynamic surveillance model through the development of SSAMSS while taking an actual look at the hardware configuration options I and II to assure confidence in

appropriate selection process. Reviewing the configuration to assure reduced risks and redundancy is available. Measuring several characteristics of both the configuration types to ultimately select the best which will meet the customer requirements to assure optimal performance, availability, quality, and equipment effectiveness. As you can see the table 2 shows the configuration diagrams and hardware types I and II for comparison against the SSAMSS overall surveillance system. We can assess the packets sent per configuration. It seems that configuration II has a bottle neck due to only utilizing a single point of data processing unlike the cluster which distributes the packets per Pi, ultimately having a bottle neck to process data packets. That choke point is also a risk as a failure area with the Pi Turning and if the component fails then it loses access to all the Pi integrated into the board. The best approach from a visual review is to assure a successful selection is to review both configuration through measures of Comparison table.

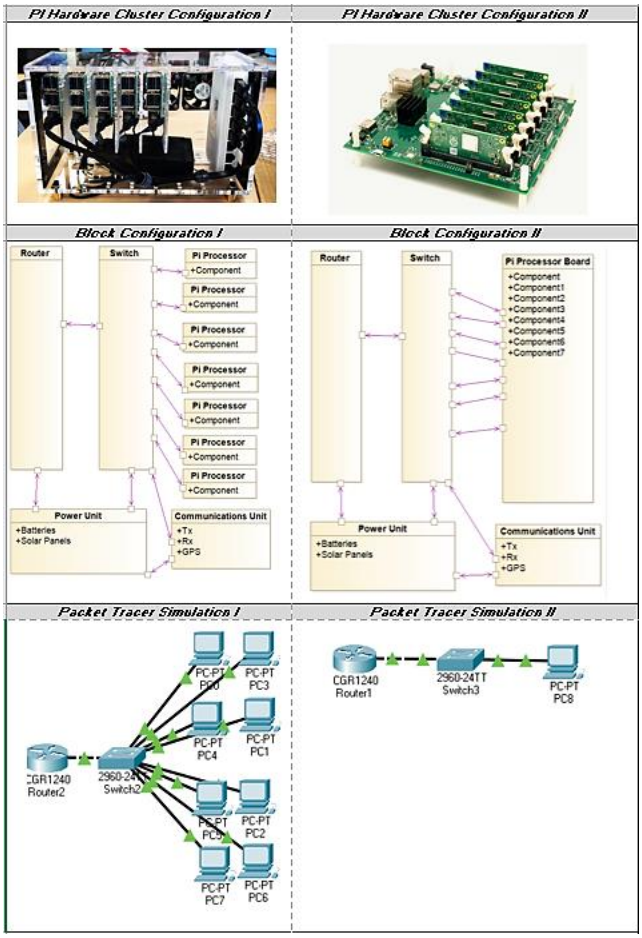


Table 2: Hardware, Block and Simulation of the configuration options

XII. Conclusion

The process of looking at the SysML, MBSE, Diagrams and models have shown that there is a configuration that is robust and lowest risk. That robustness will create confidence in the overall dynamic surveillance system called SSAMSS that will be used to safeguard materials. The redundancy, accessibility and configuration hardware and configuring option I. The table below show why Configuration and hardware selection I is the overall best for SSAMSS as its option:

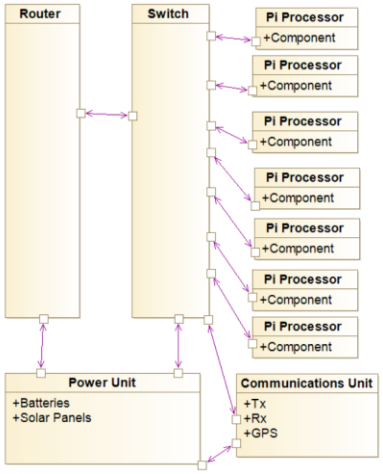
Measures of Comparison Table			
Measures	Configuration I	Configuration II	Best Selection
Hardware Costs:	$50.00 per Pi Processor	$50.00 per Pi $300.00 turning Pi board which holds 7 Pi's	Configuration I
Space:	Takes up about 50% more space	Smaller and more compact and saves about 50% more space	Configuration II
Redundancy:	Each Pi is a redundancy processer that can take distributed data packets	Each Pi Turning Board can hold 7 Pi's but are chocked by only having a single connection to get to those Pi's	Configuration I
Risk:	If one Pi fails it can still distribute to the other processors at the same rate	If the Turning board fails it loses all access to the 7 boards. If one of the boards fail it would be difficult to repair as the board is operational and would need to be shut down	Configuration I
Maintainability:	Replace without stopping operation would be easy in this configuration	It is difficult to replace the Turning board and or Pi under operations plus limited manufacturing of the Pi Turning board.	Configuration I
Overall Best Selection: 			Configuration I (5 out of 6)

Table 3: Measures Comparison Table with Hardware Configuration Option I

Author Biography

Kenly R. Maldonado received a degree in Information and Communication Technologies from the New Mexico State University (2015) and a Master of Science in Information Management from Arizona State University (2017). Currently, Kenly is a PhD student in Systems Engineering at Colorado State University under Dr. Steve Simske focusing on surveillance, data processing, microcomputer clustering and systems engineering. He works at Sandia National Laboratory – High Confidence Systems Environments as a R & D S&E System Engineer working on a variety of systems.

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