

DISSERTATION

SITUATIONAL STRATEGIC AWARENESS MONITORING SURVEILLANCE SYSTEM  
(SSAMSS)

Submitted by

Kenly R. Maldonado

Department of Systems Engineering

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Colorado State University

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Doctoral Committee:

Advisor: Steven J. Simske

Erika Miller  
Daniel Herber  
David Dandy

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## ABSTRACT

### SITUATIONAL STRATEGIC AWARENESS MONITORING SURVEILLANCE SYSTEM (SSMASS)

This dissertation takes a Systems Engineering approach for the development of a cost-effective, deployable remote sensing materials safeguarding system. This co-called system-of-systems undergoes the major portions of the Systems Engineering development process to assure with confidence that a Situational Strategic Awareness Monitoring Surveillance System (SSAMSS) is a competitive product considered for actual development. The overall assessment takes a strategic approach by using selective tools to create, confirm and consider whether SSAMSS as a product idea ultimately should be developed into an actual prototypical Model (Engineering Model). Although the dissertation explores whether a prototype should be considerate with confidence and risk consideration it does not actually dive into the physical development of the model due to limited time and actual funding. Through the Systems Engineering V-Model, SSAMSS as a product and enterprise is vetted from the customer needs analyses through unit testing (the bottom of the V-model). This is the point where an actual customer would decide to continue the to incorporate SSAMSS into integration and testing, prototype to operations, maintenance, and retirement. Through simulations, assessment, and analysis it has been determined that SSAMSS as a product and enterprise is a viable option to supersede current material safeguarding systems that are competitive in the marketplace today.

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A tremendous amount of gratitude is owed to Dr. Steven Simske as the positive driving force behind my efforts in completing my dissertation over the span of several years. As a friend, mentor, advisor, and professor his approach to education when helping his students succeed at the highest level is masterfully done. As Jules Renard once quoted, “La verité vaut bien qu’on passe quelques annees sans la trouver!” or “Truth is more valuable if it takes you a few years to find it!” As I take the truth and knowledge that I’ve gained under the guidance, advisement, and expertise by Dr. Simske over the years. I leave not afraid of the truth but with it in hand to seek out the world to make it a better place as taught by Dr. Simske.

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## LIST OF DEFINITIONS

Keyword	Definition
SSAMSS	Situational Strategic Awareness Monitoring Surveillance System
SSAMSS Enterprise	SSAMSS, CubeSat, collector, cluster, sensors, and hardware-software protocol.
SAD SACK	Software and hardware protocols that collectively function together as an SSAMSS Enterprise product.
Systems Engineering <u>Systems Engineering Definition (incose.org)</u>	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.
Sensitive Materials	Susceptibility of a material to physical or chemical changes that can inflict hazards, harm and/or danger to people, plants, animals, and environment.
Remote Sensing	Process of collecting, detecting, and monitoring the characteristics of a geographical location through sensors that filter to acquire and report characteristics.
V-Model [System Lifecycle Process Models: Vee - SEBoK (sebokwiki.org)]	The Systems Engineering Lifecycle process model defined by Systems Engineering Body of Knowledge (SEBoK).
Kano Model Graph	A model of customer's needs that are communicated visually by satisfiers, dissatisfiers, wants and needs.
Radar Chart	Shows multiple variables of data quantitatively through a mapped variable axis visually similar to a spider-web.
Raspberry Pi	A small micro-computer that is modifiable and low cost.
Arduino	Open-source COTS microcontroller at a low cost.
MicroCluster	A parallel-series of Raspberry Pi processors that act like a micro-supercomputer in a mesh-like network.
COTS	Commercial off the shelf hardware-software.
MOTS	Modifiable- off the shelf hardware-software.
Mission Operations	Operational task, activities and/or inputs that change the state of the system.
Scenario	Actions, task, or a set of functions that meet a mission-services
Baseline	A specification of a product that has been reviewed and/or measured as an initial starting point to compare against.
Incident	An event or occurrence specific to materials safeguarding and surveillance.

Customer	Often time a stakeholder a customer is anyone that has an interest and/or provides resources specific to materials safeguarding and surveillance.
International Atomic Energy Agency (IAEA)	Government agency that oversees and promotes peaceful, safe, and organized use of nuclear energy and/or weapons throughout the world.
Parallel Computing	Aligning processors in a way that take advantage of multiple cross linked computer processors that can process several varying sized data packets at once.
Intelligent Smart System Remote Sensing	Remote sensing is the process of detecting and monitoring the physical area locally or globally collecting measurable data specific to cameras or sensory data that is processed by an Intelligent system.
Publish, Prove and Move Method (PPMM)	A method of publishing articles that are used as reinforcement to continue researching (direction is the article topic and magnitude is the acceptance of the article).
True Color of Money	True color of money is what the actual cost of inflation over time is and how it impacts the actual cost through the end of a products completion including manufacturing consideration.

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## CHAPTER 1

Situational Strategic Awareness Monitoring Surveillance System—Microcomputer and  
Microcomputer Clustering used for Intelligent, Economical, Scalable, and Deployable Approach  
for Safeguarding Materials.

## Introduction to Chapter 1

The principal objective of this research is to create a system that is quickly deployable, scalable, adaptable, and intelligent, while providing cost-effective surveillance, both locally and globally. The intelligent surveillance system should be capable of rapid implementation to track (monitor) sensitive materials, e.g., radioactive or weapons stockpiles and person(s) within rooms, buildings, and/or areas in order to predict potential incidents proactively (versus reactively) through intelligence, locally and globally. The system will incorporate a combination of electronic systems that include commercial and modifiable off-the-shelf microcomputers to create a microcomputer cluster which acts as a mini supercomputer which leverages real-time data feed if a potential threat is present. Through programming, software, and intelligence (artificial intelligence, machine learning, and neural networks), the system should be capable of monitoring, tracking, and warning (communicating) the system observer operations (command and control) within a few minutes when sensitive materials are at potential risk for loss. The potential customer is government agencies looking to control sensitive materials and/or items in developing world markets intelligently, economically, and quickly. Several challenges have been communicated through government agencies, regarding gaps within the current industry in (1) monitoring, controlling, and safeguarding radioactive materials, (2) verifying that past nuclear fissile materials have been controlled and disposed of properly, and (3) energy safeguarding and security needs for developing modern tools with real-time data capability to control subsurface energy materials. These issues seem to be prevalent and require root cause problem assessment in order to appropriately attempt to meet the demands being requested from the government market segment. The issues seem to be (1)

that there are not enough qualified personnel, locally and globally, to assist in the safeguarding process and (2) that the tools (systems) being used today cannot address those needs economically [1], effectively and/or intelligently. Identifying the operational, functional, capability, performance, and physical characteristics of a new system that will be able to assist in controlling, monitoring, and intelligently assessing real-time data into valuable information when safeguarding radioactive materials, both locally and globally, is the impetus for the development of situational strategic awareness monitoring surveillance system (SSAMSS). The market segment will focus primarily on foreign markets, e.g., Asia, Africa, Russia, and Latin America. In this article, the root cause of the issue will be discussed in section History-Root Cause Problem. In Sections section Translating Qualitative to Quantitative Needs and Operational Development, we identify and analyze systems currently in use and we asses those systems for the traits desired by the customer. In Section Functional Development, we compare current systems' functionality and assess for gaps. In Section Component Selection, we identify a subset of components that can meet the functional needs of the customer, assess risks, and validate our chosen option. Sections Raspberry PI Cluster and Synergy For SSAMSS propose a system built through clustering Raspberry Pi computers and integrating microcontrollers, sensors, and programming to meet the needs discussed earlier in the article. Finally, we summarize results of our assessment and propose the next steps.

### History-Root Cause Problem

Historically, safeguarding energy materials, e.g., radioactive materials, tends to be personnel intensive and expensive, coupled with tools and security in order to control and monitor those materials [2]. There will never be removal of personnel from the process of safeguarding radioactive materials, but current industry approaches usually require highly trained personnel who operate a major part of the process. This can become more costly in developing nations. Root cause problem gap assessment requires a look at the current industry tools and how they are implemented overall. We assessed the utilization of personnel, hardware, software, applications, and web services, comparing the current industry estimated average utilization, in order to be able to better develop SSAMSS overall. SSAMSS is being developed to use fewer

### Systems Usage Estimate Assessment

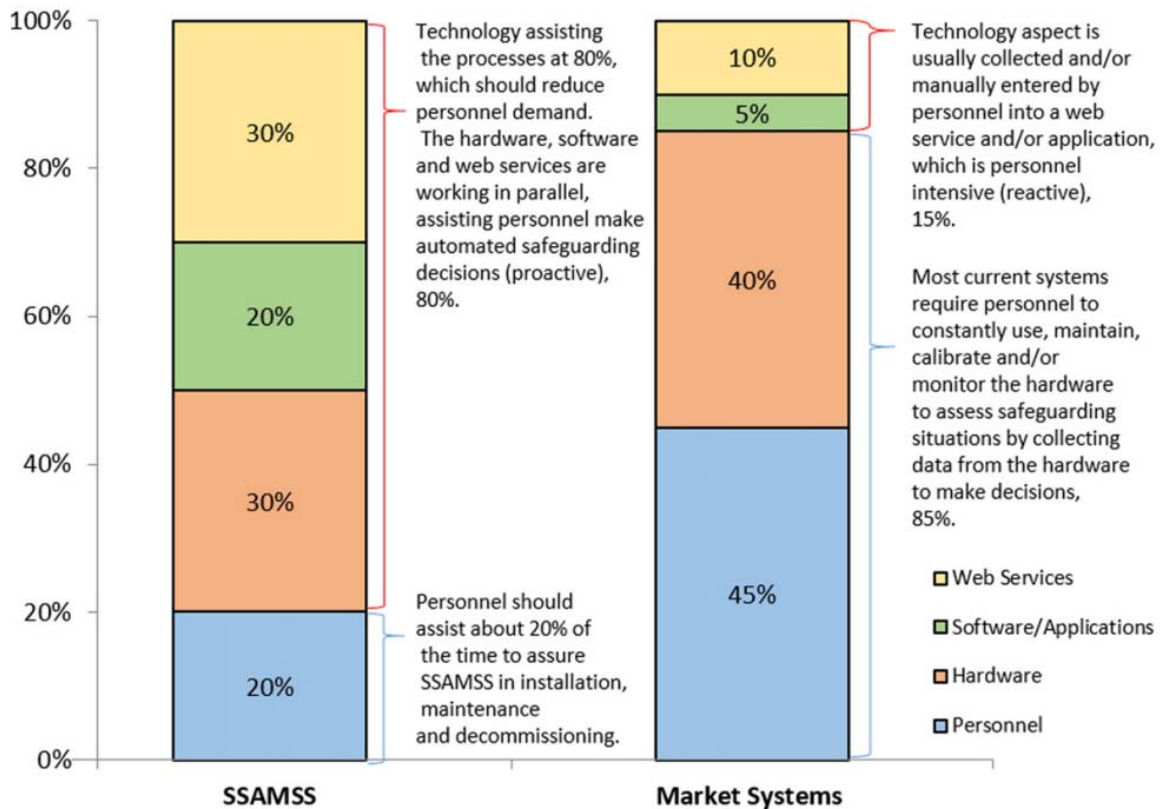


Figure 1: Estimated initial assessment between SSAMSS versus industry (tool) system visually showing potential gaps, e.g., underutilization of technology.

personnel and approach synergy by using hardware, software, and web services with the attempt

to reducing specialized personnel needs in developing nations, as shown in Figure 1. That mixture is attempting to develop a configuration that uses 80% of the effort toward technology and the remaining 20% toward personnel versus the current average of most industry tools being ~85% personnel and hardware intensive with ~15% utilizing technology with greater details developed in Figure 1. Above all, our aim is satisfying the customer requirements that will address those gaps, operationally and functionally, with respect to performance and capabilities. The problem statement developed through the initial assessments is that the industry is utilizing scanning systems that are singular technologies, costly, and require highly qualified personnel to safeguard materials. Those personnel make decisions through manual data assessment collected through those singular technologies. Oftentimes, those personnel are expensive to deploy and are not always available, both locally and globally. To improve the problem development of versatile surveillance with scanning potential, a system is needed that can automatically filter data that, in turn, is used to create information through artificial intelligence (AI). That automation and intelligence, developed in an economical way, is SSAMSS's way of addressing the problem to reduce both potential threats and personnel needed, both globally and locally. Ultimately, closing the gap of underutilization of modern technologies aims to increase effectiveness of personnel usage.

Translating Qualitative to Quantitative Needs

Table 1: Rating Requirement and Categories Table.

Rating of Requirements				Trade-off Assessment
0	Worst	No	None	Initial Cost \$
1	Poor	Some	High	Operations Cost \$
2	Fair	Maybe	Medium	Intelligence
3	Best	Yes	Low	Reliability
				Maintainability
				Scalability

The current industry system performance needs are assessed to translate details out of the most commonly used tools by industry standard; the results are listed in Table 1. Also important is analyzing how these systems address the safeguarding of radioactive materials. The needs are assessed through the customer and the market segment by using an initial gap

Table 2: Trade-off Assessment Matrix between Perfect Systems, SSAMSS product and Current Market Products

Trade-off Assessment Matrix																
Order	Systems	Estimated Initial Min Costs \$	Estimated Initial Ave Costs \$	Estimated Initial Max Costs \$	Initial Cost Rating	Operations Cost \$/ Year	Operations Cost Rating	AI/Communication Intelligence	AI/Communication Intelligence Rating	Reliability	Reliability Rating	Maintainability	Maintainability Rating	Scalability	Scalability Rating	Total
1	SSAMSS	\$ 2,000.00	\$ 3,500.00	\$ 5,000.00	2.5	Low- Medium	3	Yes	3	Best	3	Fair	2	Fair	2	15.5
2	Portable Radiation Portal Monitors (PRPM)	\$ 10,000.00	\$ 17,500.00	\$ 25,000.00	3	High	1	Some	1	Fair	2	Fair	2	Fair	2	11
3	Handheld Devices	\$ 1,000.00	\$ 4,500.00	\$ 8,000.00	2	Low- Medium	1.5	None	0	Fair	2	Best	3	Worst	0	8.5
4	Sensor Devices	\$ 1,000.00	\$ 3,000.00	\$ 5,000.00	2	Low- Medium	1.5	Some	1	Fair	2	Fair	2	Poor	1	9.5
5	Web Application	NA	NA	NA	1.5	Medium- High	2	Some-Maybe	1.5	Best	3	Fair	2	Best	3	13
6	Perfect System	NA	NA	NA	3		3		3		3		3		3	18

assessment. System development requires a more rigorous assessment and analysis to ensure that the new conceptual tool and/or system (SSAMSS) is developed optimally. This optimization during development helps by meeting the criteria through proper review of key elements to ensure performance. These criteria of the new system also have to be accepted by industry, market, and customer segments to confirm future acceptance. A tradeoff assessment matrix coupled with a rating requirement table is a sufficient way to rate systems against one another. Rating the systems from best to worst and then scaling them numerically helps give an

overall weighted score, as shown in Table 2. Taking qualitative data and being able to quantify those details of the systems enables a better understanding of what the customer and the market consider as value-add. The next step is to input the most common systems, (1) handheld devices, (2) sensor devices, (3) portable radiation portal monitors (PRPM), (4) web applications, (5) the ideal system based on current industry needs, and (6) SSAMSS concept to a weighted score as shown in Figure 2. This comparison turns qualitative data into quantitative data and ensures that proper development is heading in a positive direction.

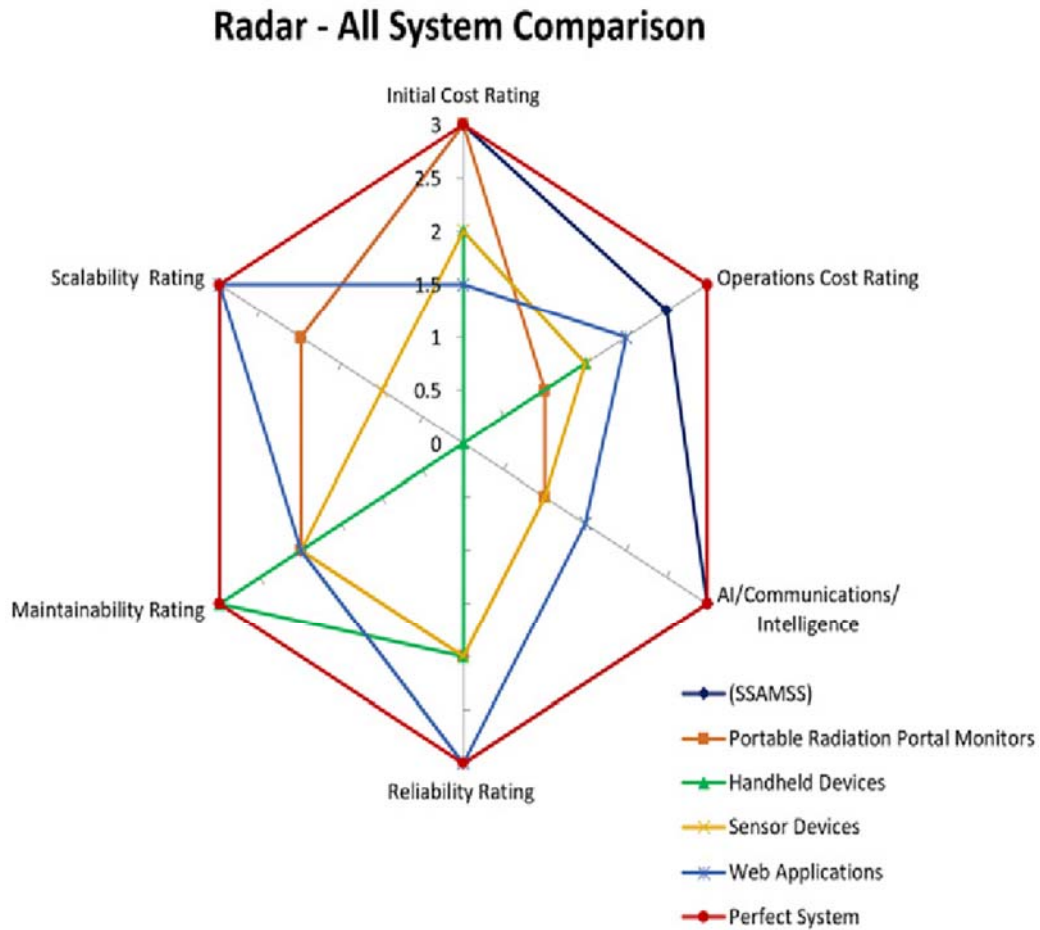


Figure 2: Radar Operational System Requirements Comparison Chart amongst Market Products

Operational Development

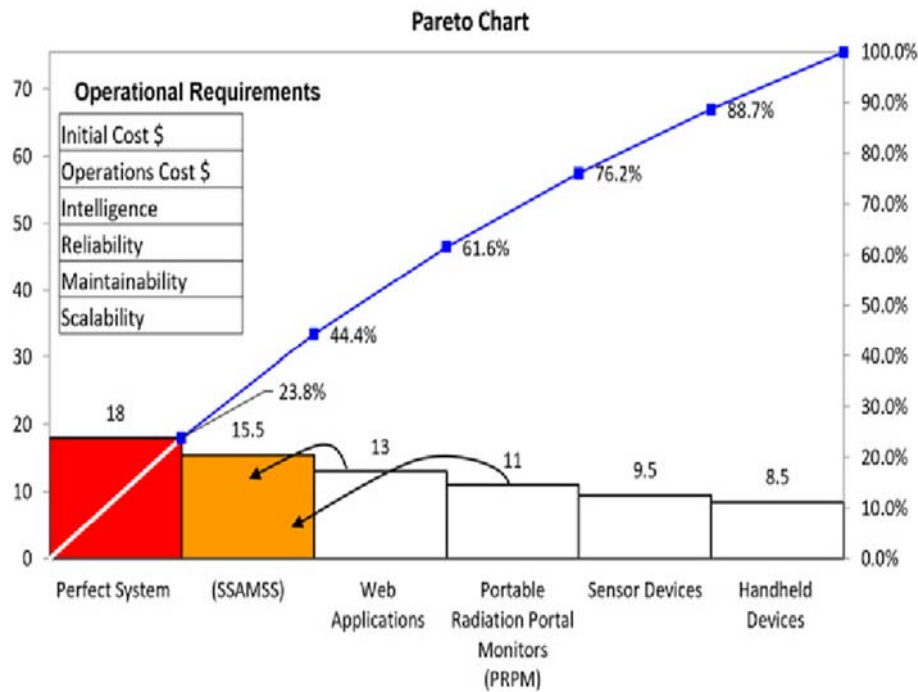


Figure 3: Pareto Operational Comparison between Product and Industry Systems

Through market research, surveys, data, and related articles from Homeland Security and Department of Energy, categories were chosen as value-add for operation consideration. These organizations found the following categories to be of value operationally: (1) initial cost \$; (2) operations cost \$; (3) AI, communication, and intelligence; (4) reliability; (5) maintainability; (6) scalability. The majority of the systems seem to be focused more on (1) initial cost \$, (2) scalability, (3) maintainability, and (4) reliability. The radar comparison chart was one out of the two charts that were chosen to assess the current technologies against individual tool scores, categorical scores, and operational requirements. Visualization of that data to assess those systems' strengths and weaknesses operationally helped turn qualitative data into quantitative data, and then into critical information. Comparing the current system (tools) requirements not only to other tools but also against what a perfect system would be and against SSAMSS concepts is useful in providing guidance to the future of these systems and in ensuring that they are heading in the right direction. Further assessment of a perfect system could be coupled with

a Kano graph (Figure 4), which graphs customer satisfaction and functionality and compares them to excitement attributes (customer delighters), performance attributes (customer satisfiers), and threshold attributes (customer dissatisfiers) to help predict future customer requirements. Another attribute to consider is Moore's law when selecting and projecting hardware components for SSAMSS. Being able to accurately project the future component selection can be beneficial. The Pareto bar chart (Figure 3) was developed in order to give another visualization to better understand the rated information. Pareto charts show that 20% of the effort creates 80% of the yield that can then be reviewed further by another concept, the 4/50 rule. This rule states that 4% of the effort should produce 50% of the benefit. These concepts could potentially help maximize which of the six operational requirements to focus on. They could optimize and/or maximize efforts toward focusing on the gaps with more precise assessments. Further assessment of the graph shows the overall scores of the comparisons. It also shows that (1) compared to a perfect system, you can see the gaps numerically within the other systems, (2) SSAMSS is really a PRPM and web application combined and (3) is potentially used as a guide to further understand where future development of these types of systems may be going. The graphs in this section reaffirm that SSAMSS's initial assessment of the industry's gaps is being addressed

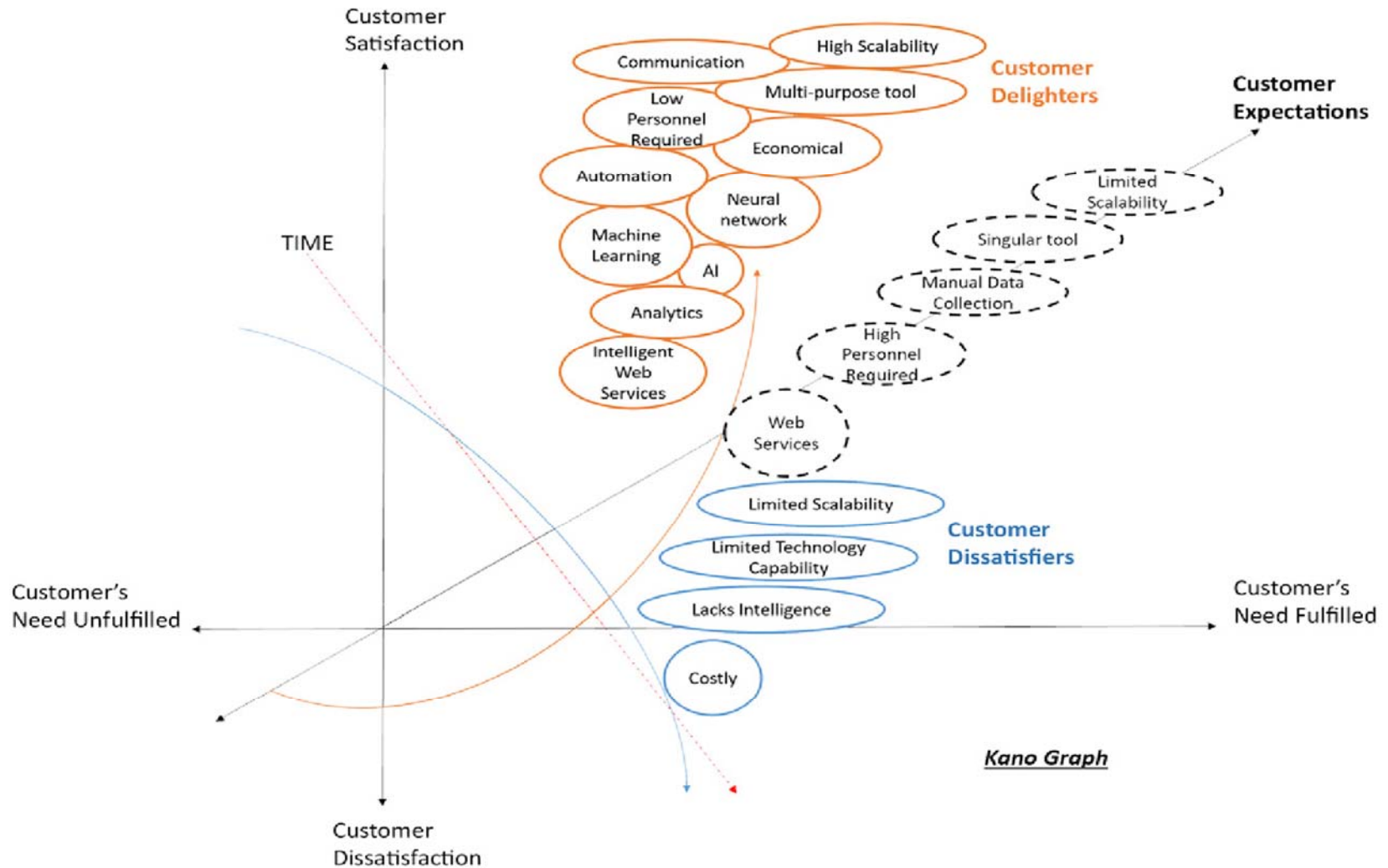






Figure 4:Kano Graph of Customer Expectation

## Functional Development

Reviewing the tools operationally is necessary to understand what is wanted overall by the customers and market segment at the highest level. The next step is to review those same systems in a comparison requirement matrix to assess their functional requirement gaps.

Industry wise, the systems are used to (1) track, (2) monitor, (3) control, and (4) assist in safeguarding radioactive materials that are shown in Table 3. There is an increasing need for technologies to assist in safeguarding materials at this time since the demand to safeguard

*Table 3: Functional Comparison Table of Industry-Market Tools competing against SSAMSS.*

<b>Current vs SSAMSS Functional Requirement Comparison</b>				
<b>Today's Requirements</b>	Web-based, manual entry, barcode scanners, specially trained personal intensive	Singular advanced technologies, web based, specially trained personnel intensive	Single technology, specially trained personnel intensive	Single technology with expansion options, specially trained personnel intensive
<b>Examples</b>	National Source Tracking System (Web)	Portable Sensor	Hand held	Portable Radiation Portal Monitors
<b>Visual Examples</b>				
<b>Requirement Gaps</b>	Error prone, human factors, training, labor intensive, misplaced barcodes, stolen or lost material, reactive approach, no AI, matrix	Human factors, cost, training factor, Singular utilization, reactive approach, no AI, scalability is costly	Error prone, human factors, labor intensive, training, misplaced reading information, reactive approach, no AI, scalability is costly	labor intensive, training, large, takes up a lot of space, reactive approach, no AI, only a scanner, scalability is costly
<b>SSAMSS Addressing those Requirement Gaps</b>	Web-based capabilities, programmability, multi-utilization, economical, automation through intelligence	Web-based capabilities, programmability, adaptability to new technology attachments, multi-utilization, economical, physical device	Web-based capabilities, programmability, multi-utilization, economical, physical device	Web-based capabilities, programmability, multi-utilization, economical, physical device, takes up small space, quickly expandable, AI, cost effective, scanner plus surveillance system

radioactive materials globally is on the rise. Many of the current systems are specific to trained personnel who require the system to function the majority of the time as an extension to an

individual. These systems are maintenance intensive and lack intelligence to assist in reducing the overall load of safeguarding materials. Another related consideration was commercial off-the-shelf (COTS) smart surveillance systems (state of the art). These systems, although current, are expensive to purchase per unit, cost more to deploy logistically, are not as adaptable to integrating other sensors into the system and are not being utilized in safeguarding materials by the government.

### Component Selection

Table 4: Risk Assessment Importance Rating Table

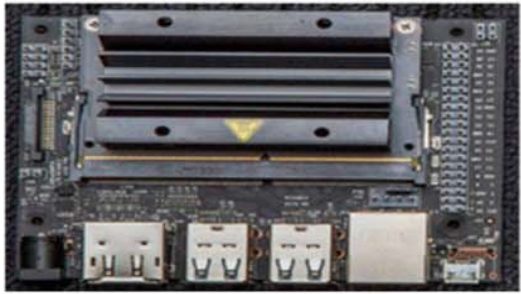


<b>Microcomputer (Component) Design Risk Assessment [Raspberry Pi (Pi) vs Jetson (J)]</b> (80/20 or 4/50 approach will help refine these vulnerabilities)	
<i>Category to Compare between Components</i>	<i>Importance Rating (related to failure)</i>
[A] If the component cannot compute properly (Processing Power)?	<b>1</b>
[B] If the component is too costly (Costly per Unit)?	<b>2</b>
[C] If the component does not work consistently (Reliability)?	<b>3</b>
[D] If the component is difficult to fix (Maintainability)?	<b>4</b>

Capitalizing on Moore’s law, small capable computers should be considered as viable component options. Small computers and/or microcomputers can be configured in hybrid configurations to increase performance. For example, when using microcomputers in parallel, they can be set up to have computational nodes and processing nodes that compute large data sets into information. These options for components give an opportunity to meet the functional and operational objective’s identified needs economically. The microcomputer was reviewed and ultimately selected for its modularity, processing power, and economical affordability. Our process was to compare microcomputers (Table 5) that were able to meet our development a

variable that can compute to the level of, if not higher than, the current industry system tools.

Commercial off-the-shelf and modified off-the-shelf (MOTS) are two available options to meet customers' needs. Market demographics and remote location, usually in developing nations outside of the United States, are the targeted demographics.

Table 5: Components Comparison: Jetson Nano vs Raspberry Pi vs Arduino

			
	<i>Jetson Nano Dev Kit</i>	<i>Raspberry Pi 4</i>	<i>Arduino R3</i>
	<i>MicroComputer (MicroProcessor)</i>		<i>MicroController</i>
<b>MSRP</b>	\$99	\$35-55	\$22
<b>CPU</b>	Quad-core ARM® Cortex-A57 MPCore processor (1.43 Ghz)	1.5 GHz 64-bit quad-core ARM Cortex-A72 CPU	Intel Quark (x86) (32-bit)
<b>GPU</b>	Nvidia Maxwell™ architecture with 128 Nvidia CUDA cores	VideoCore VI graphics, 4Kp60 HEVC video	-
<b>RAM</b>	4 GB 64-bit LPDDR4	1GB, 2GB & 4GB LPDDR4 SDRAM	32K bytes of Flash memory/2K bytes of SRAM
<b>Connectivity</b>	Gigabit Ethernet	Dual Band 802.11ac WiFi, Bluetooth 5.0, Gigabit Ethernet	-
<b>Ports</b>	USB: 4x USB 3.0, USB 2.0 Micro-B Camera: 1x MIPI CSI-2 DPHY lanes (Raspberry Pi camera compatible) LAN: Gigabit Ethernet, M.2 Key E	USB: 4x USB 3.0, 4k HDMI, Audio, Camera Connector	PWM Digital I/O Pins 6
<b>Pins</b>	40-Pin GPIO	40-Pin GPIO	Digital I/O Pins 14 (of which 6 provide PWM output)
<b>Power Consumption</b>	~ 4 Amps/ 5 Volts	~2 Amp / 5 Volts	~ 1 A/4.5 Volts

In order to ensure a proper selection of the primary component, the microcomputer, a process of reviewing and assessment was completed. The first review was to select the top three viable options to develop SSAMSS. Then these three options were compared against each other in a table to see advantages and disadvantages the microcomputer components had to offer.

Through the comparison, it was determined that one of the microcomponents was a microcontroller (Arduino) and that the other two were microprocessors (microcomputers). The microcontroller is excluded as a viable primary component but could be utilized in SSAMSS build as a hybrid option if needed. That left Raspberry Pi and the NVidia Jetson Nano (microprocessors) as the two potential components to pick to develop SSAMSS around [3].

Both are capable but have huge price differences, and one may be potentially more costly to get in foreign locations. Further assessment was needed to ensure that the correct component for SSAMSS was selected. Through the risk assessment, shown in Table 5, Table 6 and Table 7, the Raspberry Pi 4 was compared against the NVidia Jetson. This helped to answer the primary questions about what the components need to do in order to perform optimally to ensure functionality and operational compliance in order to develop SSAMSS effectively. This was then placed in a risk assessment decision matrix to weigh the collected risk assessment. The result showed that, overall, the Raspberry Pi 4 microcomputer was the best option. However, the hybrid options are another route if needed, as both components have high processing capabilities to complete AI. The new technology will be intelligent with an emphasis on artificial intelligence, machine learning, and neural networking. It must be capable to not only assess potential threats but also communicate that information, both locally and globally. Most of the current systems are developed in a reactive way and are initially costly. Those costs are high operational costs, scale-up costs, and maintenance costs. These systems are expensive and

also lack intelligence and usually have limited communication capabilities and versatile functionality. These are the reasons for the component selection being crucial; it not only has to be economical and durable but also be able to perform the AI aspects that are required (benchmarking processing and AI comparison are fairly close to each other as shown in Table 5, Table 6 and Table 7).

Table 6: Risk Assesemnt Table between compatitivite components selection

Evaluator	Probability of Risk Occurrence	Consequence of Failure Occurrence	Risk Importance A	Risk Importance B	Risk Importance C	Risk Importance D	Result
Raspberry Pi	2	3	2	1	3	3	2.3
Jetson	3	4	1	4	4	4	3.3

Table 7: Risk Assessment Decsion Matrix

<b>Probability</b>	Very High	L	M	H	H (J, B)	H
	Likely	L	M (J, D)	M (J, C)	H	H
	Possible	L	L (Pi, D)	M (Pi, C) ,	M	H
	Unlikely	L	L	L	M (Pi, A)	H
	Very Likely	L	L	L	L (Pi, B) , (J, A)	M
		Insignificant	Minor	Moderate	Major	Catastrophic
		<b>Consequences</b>				

## Raspberry Pi Cluster

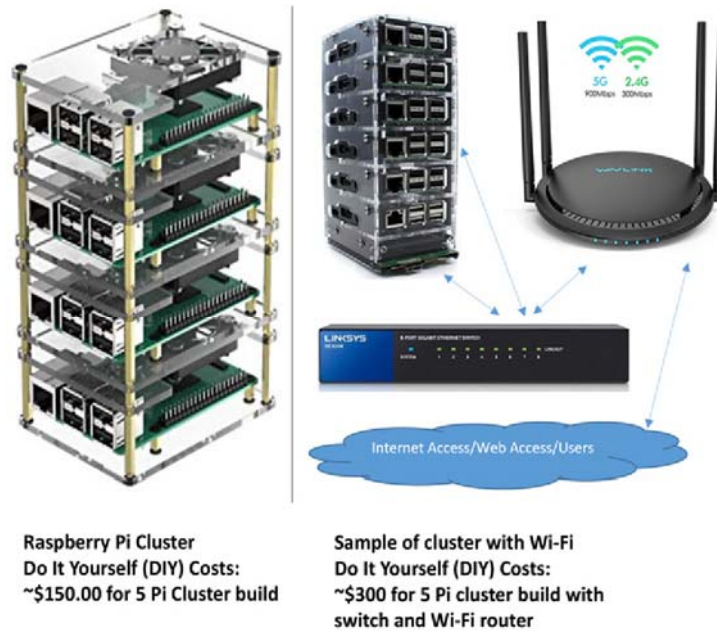


Figure 5: Raspberry Pi microcomputer cluster DIY example

New systems should utilize parallel computing, parallel processing, and parallel analysis through control (master/server) node and processing (worker/client) nodes. The parallel computing focus will be on AI, analytics, and image processing as tasks that will be required in order to ensure that SSAMSS can handle all the data. In turn, that data will become valuable information to assist in safeguarding radioactive materials, both locally and globally. This will be done by fully taking advantage of the clustering capability that can be performed through combining more than one Raspberry Pi as a detailed example has been created in Figure 5. Through clustering Pi devices, together SSAMSS should be able to process video, images, and/or data that will be collected by available sensors, options, cameras, images, radioactive detectors, vibration sensors, and other options [4]. Another beneficial aspect, which is still

economical, is that you are able to have several types of sensors to connect into the Pi collector. This can be used to create hybrid systems such as coupling the Pi with Arduino (microprocessor and microcontroller). Onsite economical micro supercomputing that has modularity with low power consumption is a great benefit for SSAMSS. In comparisons, other smart surveillance systems similarly used by governments, i.e., China, use cameras with AI to track commuters and/or individuals. These systems, e.g., Sense Time, have large infrastructures that require large costs (\$63,261 a day to operate), maintenance, and employees. Another disadvantage of these systems is that they are not easily deployable and/or scalable. This is where the benefits of SSAMSS come into play as being a system that can be intelligent, economical, and deployable when safeguarding materials. These clusters are composed of a multitude of interconnected microcomputers that have the capability to perform high processing power at an economical scale. Using the Watershed algorithm, You Only Look Once (Yolo) for example, it can filter through large sets of images. The cluster will have the processing power to process multiple forms of sensory data beyond image files. This data will be turned into valuable information to assist in safeguarding. The cluster [5] could be developed to have a server program on the master node and client programs on the worker node. This will assist the parallel computing process by collecting images and performing object detection. These and other more in-depth processes will be used in an economical way due to the Pi clusters. The Pi collectors, on the other hand, act as the eyes while the cluster acts as the brain to make programmed decisions and communicate those decisions out to the web services while informing the appropriate parties. Raspberry Pi clusters are the best option to develop SSAMSS intelligence capabilities. Although this technically is a micro supercomputer, it does have certain limitations such as SD card capacity [6].

## Synergy For SSAMSS

Microprocessors (Raspberry Pi 4), microcontrollers (Arduino) microclusters, sensors (infrared, thermal camera, pixel camera, stereovision camera, night vision camera, vibration, radioactive sensor, and/or other options), and programming (e.g., Python, Linux, or Tensor Flow Lite) can be used in a combined way to create system synergy [8]. The microcomputer (microprocessor) can be coupled with sensors and/or if the sensor is not capable, potentially a microcontroller to assist SSAMSS to meet its objectives. Writing in Python, parallel computing and parallel processing is how we will tie together the components. The development of SSAMSS needs to have a system that is executable while capable of meeting the operational, functional, and performance objects. At the same time, it encompasses similar physical characteristics in order to entice customers through market familiarity as shown in Figure 7. Image processing along with data processing will play a significant role in how SSAMSS utilizes object detection and object counting. The collected data from the Pi sensors will turn collected raw data into actionable information. The importance of SSAMSS is the cluster that should be able to perform a high number of operations through parallel computing as data is distributed throughout that cluster. Power consumption of a single Pi is 2A at 5V or 10 W of power consumption. For a small cluster of 5 Pi units, the power consumption would be 60 W. The power consumption of the Pi units can be decreased by selecting a skimmed-down version to build the cluster, similar to a Pi 0 versus a Pi 4. This data will be collected from selected sensors such as infrared detectors, vibration sensors, camera, and/or different camera types. The cluster and parallel computing should be able to handle algorithms which will be programmed to execute simultaneously from parallel devices running in sync to produce a final output. The

primary focus for programming within these clusters will be the Python language. Utilization of other skimmed-down program languages and algorithms will be key in developing the programming using script libraries that are geared toward image processing, utilities, and algorithms. As shown in Figure 6, the suggested system overview is how the system will work between the customer and the device. Another benefit of these calculations could be used to assess how many nodes are needed to process images. Python-scripted equations can be used to assist in the processing of power and cost. This was done by a group of researchers looking at Python language equations to calculate the number of nodes needed to process images on a Raspberry Pi cluster [7]

$$N_{\text{compute}} = \text{math.ceil}(N_{\text{images}} \times T_{\text{seq}}) / N_{\text{cpu-act}} \quad (1)$$

where

- $N_{\text{compute}}$ —number of required computing nodes in the cluster;
- $N_{\text{images}}$ —number of images per second that could be loaded in sequential order to the cluster system;
- $T_{\text{seq}}$ —time to process one segment of arrived images where one image has reserved one CPU core;
- $N_{\text{cpu-act}}$ —number of CPU cores on Raspberry Pi that are reserved for processing from head node.

*Equation 1: Python language equations to calculate the number of nodes needed to process images on a Raspberry Pi cluster [7]*

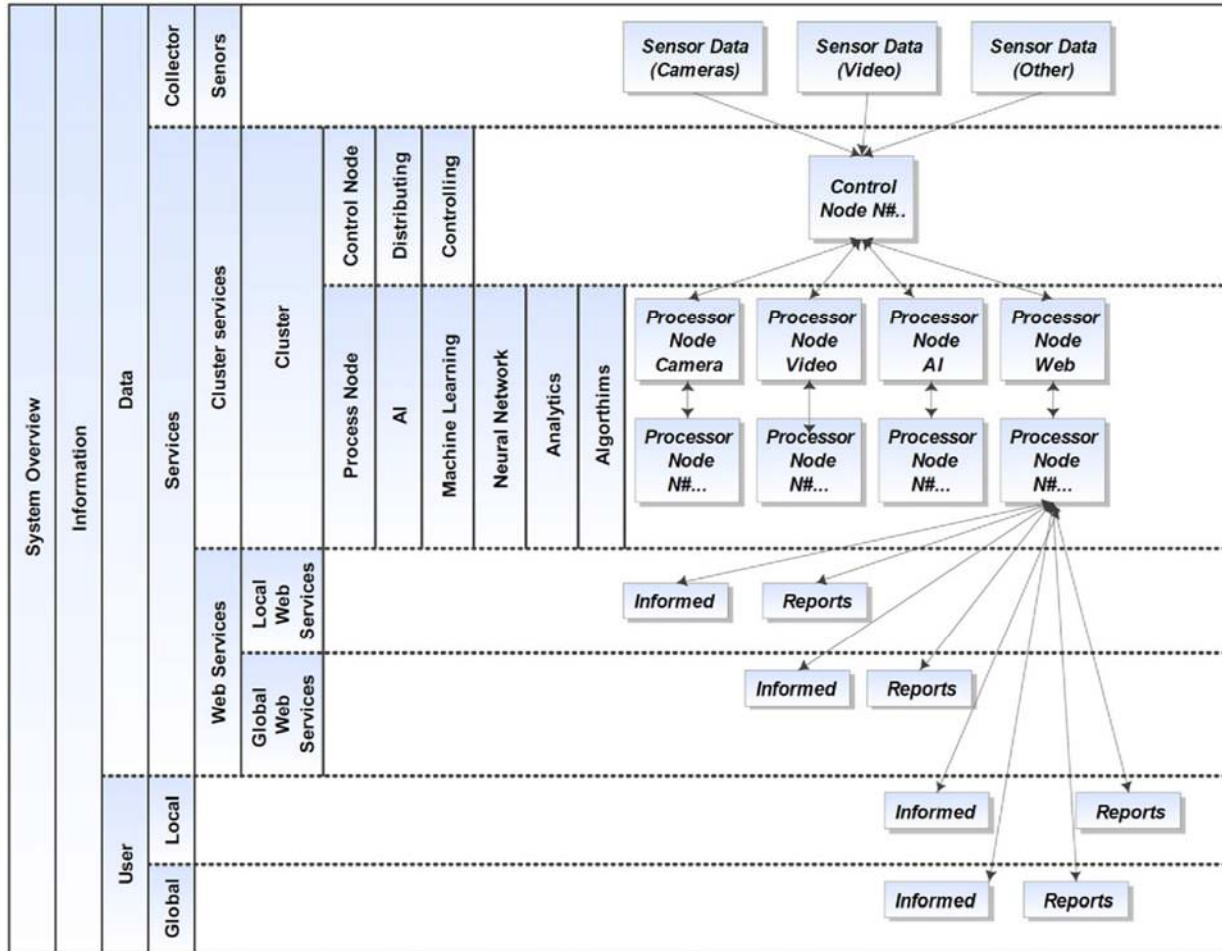


Figure 6: Suggested system overview.

Another Python tool is `Osu_BW.py` which tests the bandwidth between master and worker nodes through messaging and timing by utilizing an open source Raspbian OS (Linux-based OS), message passing interface (an image processing application), and an SSH connection. This Secure Shell Protocol (SSH) connection enables a RivestShamir-Adleman (RSA) encryption algorithm to ensure security while logging into the system [8]. Singularly, the Pi is able to perform well. Collectively, (series/parallel) Pi controllers with proper configuration will give SSAMSS the structure required to be able to deliver its objectives both economically and effectively. Connecting sensors (vibration, thermal, radiation detection, and others) and cameras (stereo vision, thermal, 3D, night vision, and pixel camera to process video and images) working together will process the collected data. Just like the human eye, there will be

a breakdown of how to process images, (1) classification, (2) localization, (3) single/multiple object detection, and (4) image segmentation [9]. There are examples where development of stereovision, thermal, infrared, and night vision cameras and/or other sensors are coupled with a single Raspberry Pi microcomputer [10]. What makes SSMASS different when compared to other examples [11] is a scalable Raspberry Pi microcluster at location that is processing the data. That data will be turned into information through intelligent analytics from the micro supercomputer.

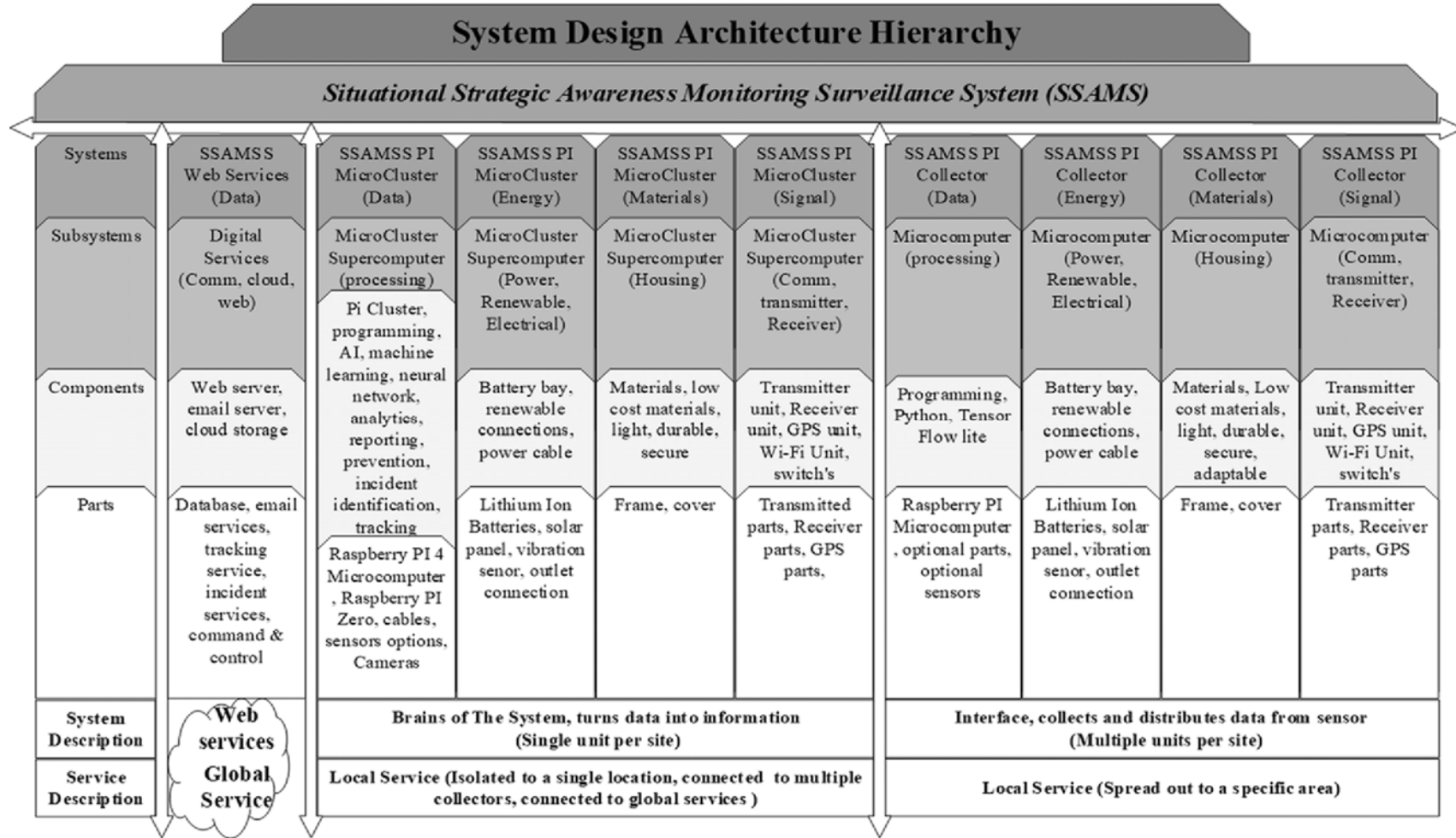


Figure 7: SSMAS architectural concept visualization diagram

## Chapter 1 Conclusion

SSAMSS is a system that is feasible to construct and addresses current industry gaps. The diagram shown in Figure 8 gives visualization on how SSAMSS overall should work to address industry gaps. Objectively, as a concept, it is trying to reduce costs associated with modern day systems and reduce personnel intensity by using affordable, commercial, and modifiable off-the-shelf components to build a system that is less personnel intensive and more technology intensive. This is to help reduce costs, maintainability, modularity, scalability, and deployability. Through the research, it appears that modern day systems (tools) are user and hardware intensive (45% total personnel and 55% technology/hardware) unlike SSAMSS (20% total personnel versus 80% technology/hardware). Addressing the root cause problem objectively led to feasible component building. This then led to selecting Raspberry Pi microcomputers, Pi sensors, and Pi clusters. The next phase will be to develop the logical, hardware, software, programming, energy, and signal architecture in order to start developing a prototype. The development of SSAMSS is important since people are utilizing microcomputers for safeguarding purposes in some fields. What those groups do not understand yet is that adding an onsite and scalable cluster or micro supercomputer will add tremendous value while safeguarding valuable assets economically.

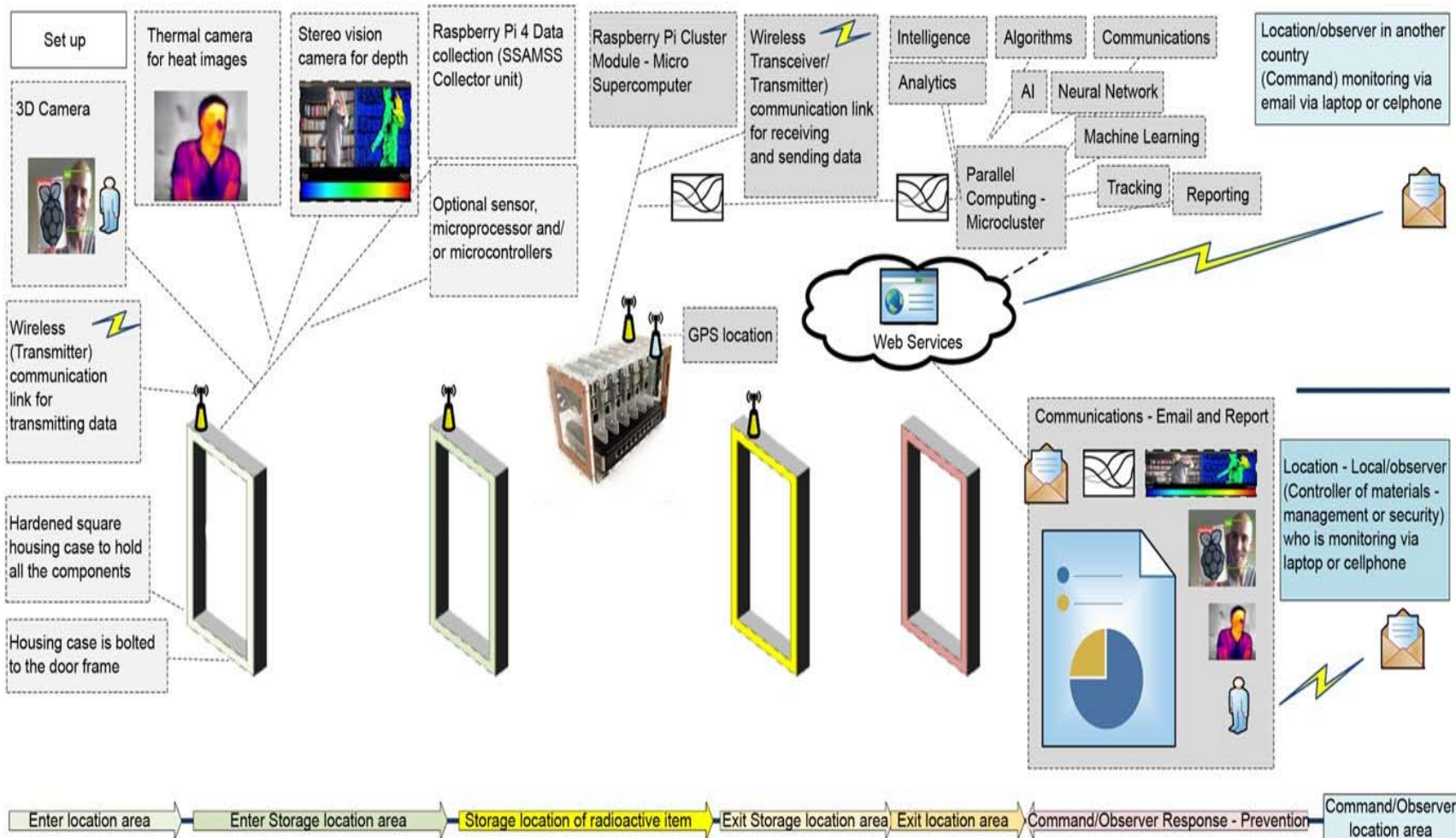


Figure 8: SSMASS local concept visualization diagram

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## CHAPTER 2

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

## Introduction to Chapter 2

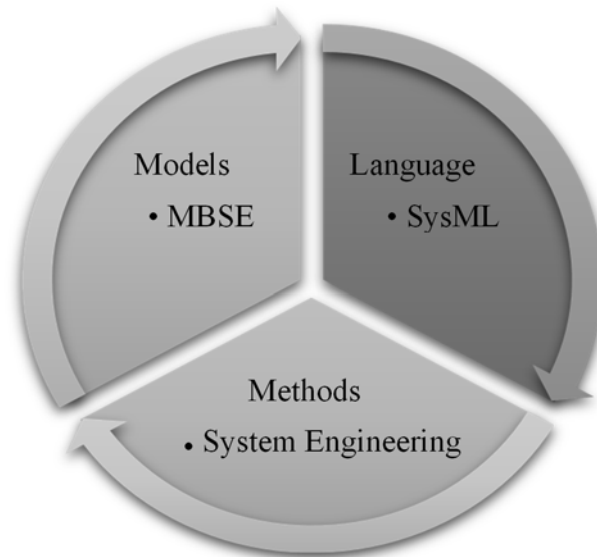
Using Model Based System Engineering (MBSE) analyses, we show how these approaches can give further depth to the system, operational, and behavioral architectural domains of distributed sensing and computing environments. The corresponding physical component model leads to a fully functioning prototype 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. 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- The contribution of this research will show how to singularly use MBSE tool and methods to: 1) identify applicable methods and tools through MBSE to improve isolated hardware design selection, 2) couple the MBSE tools with models that can be analyzed to increase hardware design confidence, 3) show traceability between the MBSE tools and hardware design and 4) increase system awareness, performance and capability with a focus on the micro cluster configuration. Materials safeguarding such as depleted radioactive 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 assist 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. Materials safeguarding such as depleted radioactive 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.

## 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



*Figure 9: SysML, MBSE & SE approach to hardware selection as singular tools*

to safeguard materials today [3]. The standard for domestic safeguarding of sensitive materials is 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.

## Approach

The approach will be using SE, MBSE- SysML to focus on the development of the microcluster. The microcluster 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. 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 9. The use of SysML through the program Modelio software will increase the configuration options specific in regard to an isolated stand-alone approach. Having a software program to assure selection by using specific diagrams can assure development of specific parts while using these as singular tools. 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 Diagrams
- Domain Diagrams
- Complex Systems Dynamics Diagrams

By adding the complex systems dynamics coupled with domains diagram it creates a deeper understanding of what the customer and system are developed i.e., function and perform. Through the domain diagram there will be further development to look at peak cost, peak processing, and overall operational equipment.

*Table 8: SysML, MBSE and SE Definitions and Applicability*

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 beginning in the conceptual design phase and continuing throughout development and the later life cycle phases.	System Functional Flows (i.e., System Architecture), System Requirements Traceability and System and Organizational Process Flows

Systems 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.
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The effectiveness of SSAMSS as a multi-functioning product vs general singular products are used to compare deltas. The deltas comparison can show the overall effectiveness of SSAMSS when compared to other products used for safeguarding of materials.

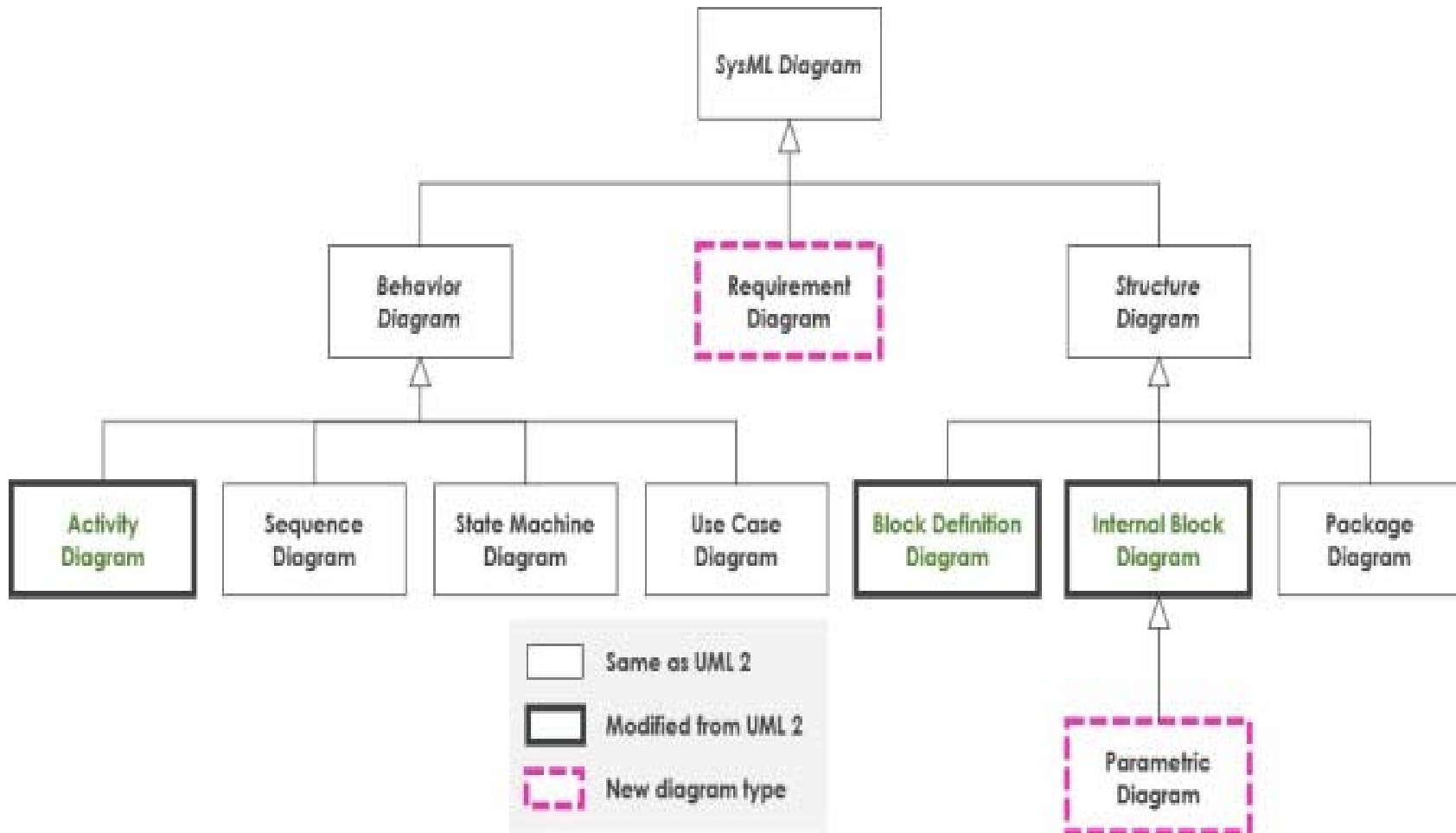


Table 9: SysML frame using as individual tool set in the development of SSAMSS specific hardware selection process.

## 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:

Rating of Requirements				Trade-off Assessment
0	Worst	No	None	Initial Cost \$
1	Poor	Some	High	Operations Cost \$
2	Fair	Maybe	Medium	Intelligence
3	Best	Yes	Low	Reliability
				Maintainability
				Scalability

Trade-off Assessment Matrix																
Order	Systems	Estimated Initial Min Costs \$	Estimated Initial Ave Costs \$	Estimated Initial Max Costs \$	Initial Cost Rating	Operations Cost \$/ Year	Operations Cost Rating	AI/Communication/ Intelligence	AI/Communication/ Intelligence Rating	Reliability	Reliability Rating	Maintainability	Maintainability Rating	Scalability	Scalability Rating	Total
1	SSAMSS	\$ 2,000.00	\$ 3,500.00	\$ 5,000.00	2.5	Low- Medium	3	Yes	3	Best	3	Fair	2	Fair	2	15.5
2	Portable Radiation Portal Monitors (PRPM)	\$ 10,000.00	\$ 17,500.00	\$ 25,000.00	3	High	1	Some	1	Fair	2	Fair	2	Fair	2	11
3	Handheld Devices	\$ 1,000.00	\$ 4,500.00	\$ 8,000.00	2	Low- Medium	1.5	None	0	Fair	2	Best	3	Worst	0	8.5
4	Sensor Devices	\$ 1,000.00	\$ 3,000.00	\$ 5,000.00	2	Low- Medium	1.5	Some	1	Fair	2	Fair	2	Poor	1	9.5
5	Web Application	NA	NA	NA	1.5	Medium- High	2	Some-Maybe	1.5	Best	3	Fair	2	Best	3	13
6	Perfect System	NA	NA	NA	3	<del>Low- Medium</del>	3	<del>Yes</del>	3	<del>Best</del>	3	<del>Fair</del>	3	<del>Fair</del>	3	18

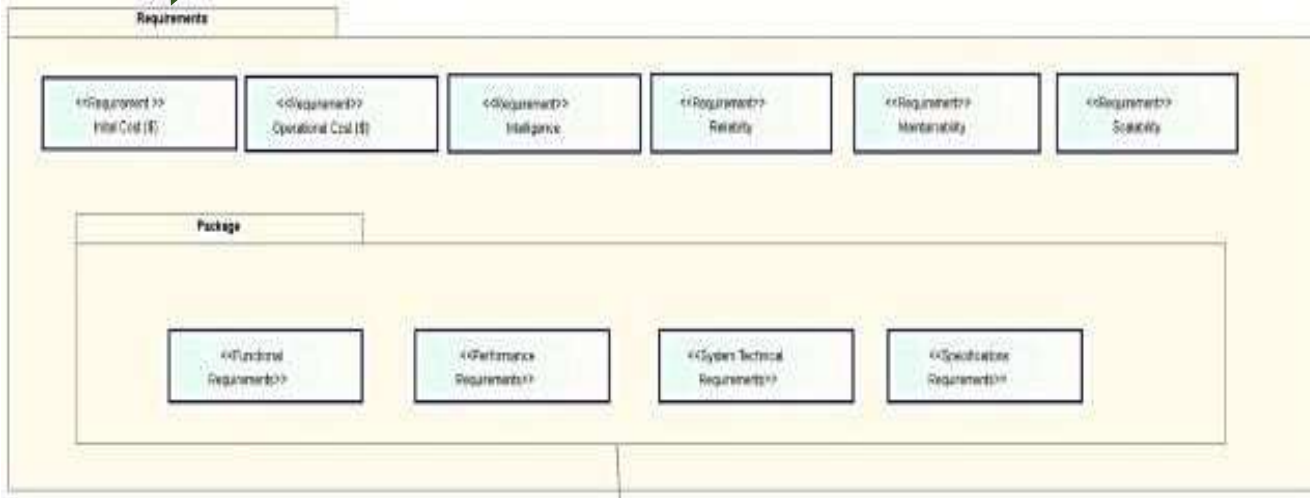


Figure 10: Vetting of Requirements using previous requirement assessment for SSAMSS to reflect MBSE-SysML

## Developing Domains

The customer's domain perspective is critical in assuring that the correct perspectives are gauged and measured. The domains that are relevant 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 –

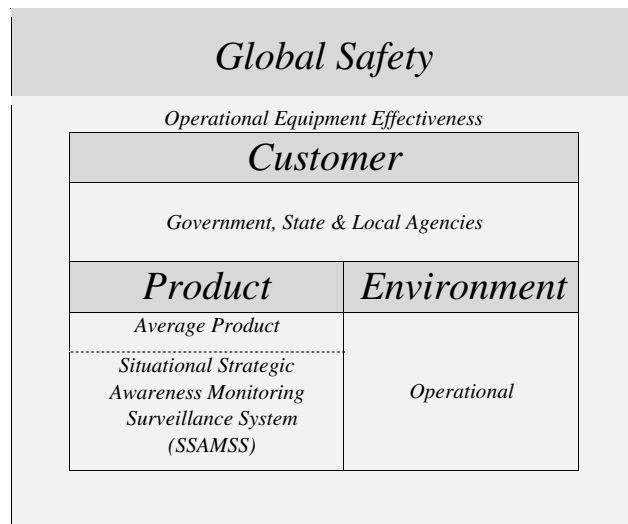


Figure 11: Assessed Domains for Product Development

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 these domains come together to develop an idea of what is important in order for SSAMSS to succeed under these domains as referencing Figure 11.

## Complex System 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.

Initial confidence of system development starts with the domains and mathematical performance formulas as shown in Figure 12. To assure peak cost assessment of future studies

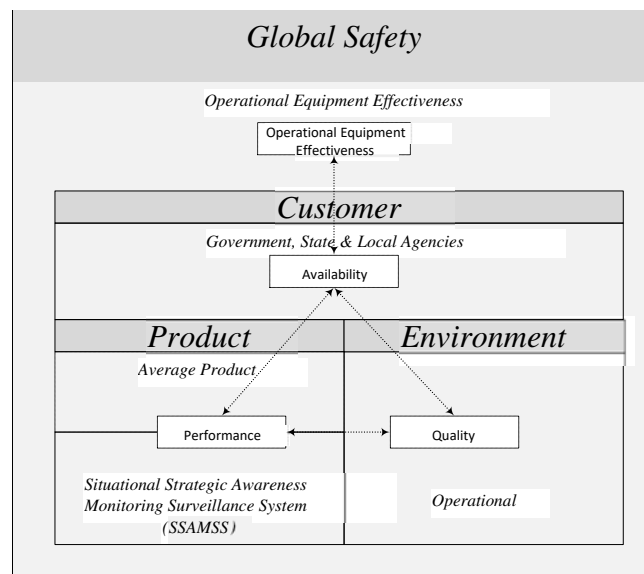


Figure 12: Assessed Domains for Product Measure

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:  $(\text{Actual Production Time}) / (\text{Potential Production Time}) = \text{Availability \%}$
- Performance:
  - SSAMSS vs Average Product Processing Power
  - Equation:  $(\text{Actual Output}) / (\text{Theoretical Output}) = \text{Performance \%}$
- Quality:
  - SSAMSS vs Average Product Environmental life span
  - Equation:  $(\text{Good Output}) / (\text{Actual Output}) = \text{Quality \%}$

*Equation 2: Mathematical cost performance formulas.*

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.

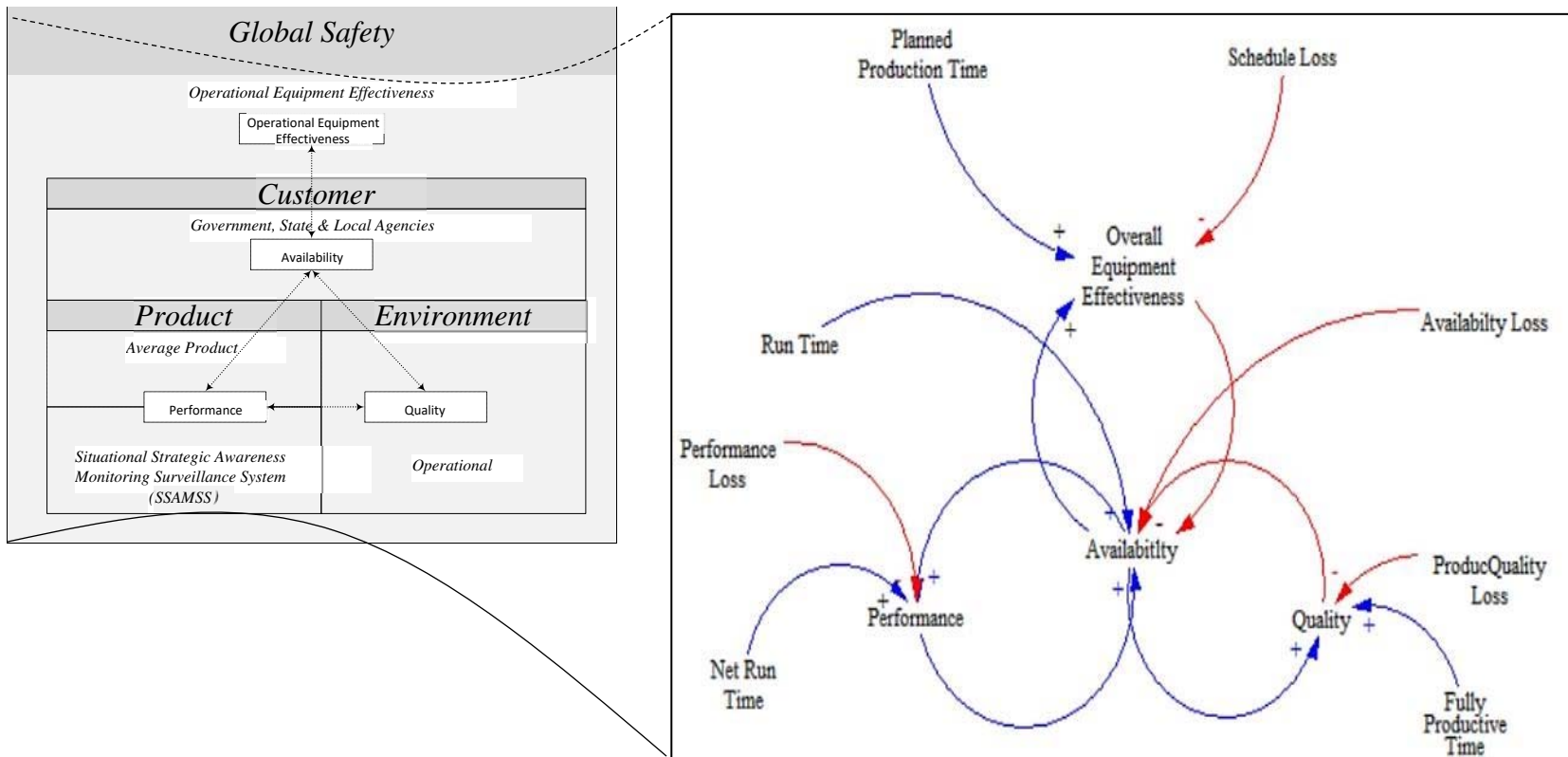


Figure 13: Complex Loop Diagram with Variable Assessment of Measures

## Causal Loop

Development of a Causal 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 the Vensim software package, a causal loop diagram and model that shows the connecting variables was created. 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 lie. Their primary measure

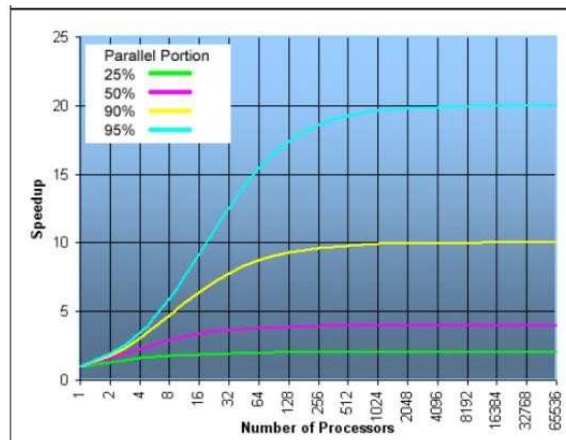


Figure 14: Variable of Measures - Amdahl's Law

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  $1/(1-P)$ .

*Equation 3: Amdahl's Law*

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]”

## 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 15 and Table 10 to the requirements and connection to the whole SSAMSS enterprise system. 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.

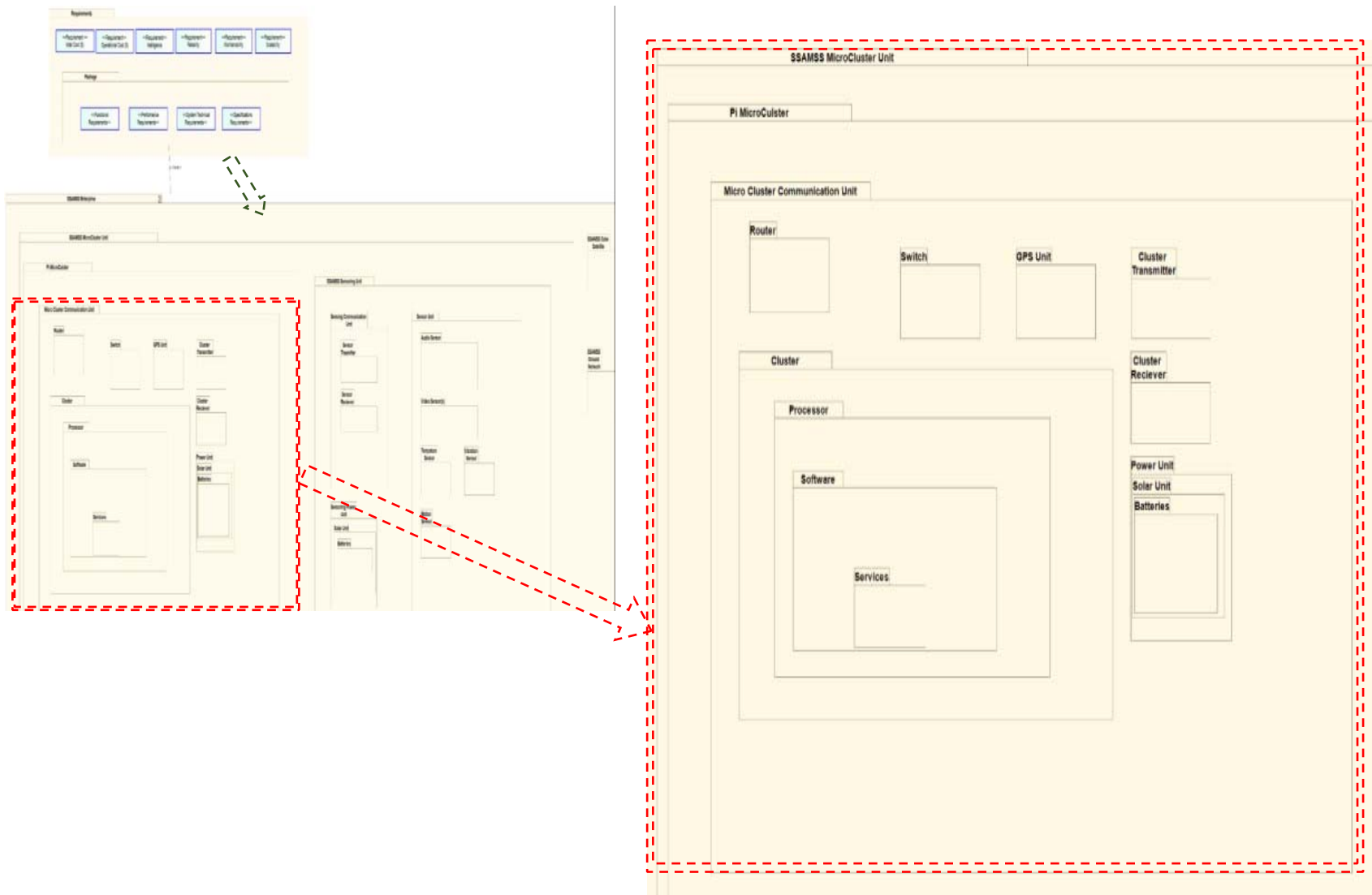


Figure 15: SysML SSMASS Requirement and Enterprise Pack & SysML SSMASS Microcluster Package Focus

## Simple and Complex Process Block Diagrams

Table 10: SSAMSS Simple Process Map

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

SSAMSS straightforward 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 are 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 Table 10. 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 surveillance system approach reference Table 11. 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.

Table 11: SSAMSS Complex Process Map

SSAMSS Details Complex Process			
System (Bi-directional communication)	Inputs (variable's x)	Process (activities)	Outputs (variable's y)
SAMSS 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 Syst	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]	[12] communicate with command and control [13] intelligence consideration of collected data [14] command primary subsystem to collect data and follow personal if required

		communicate with command and control if needed [11] command primary subsystem	(potential incidents and threat agent)
--	--	--	--

## Simple and Complex Product Diagrams

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, messaging and tracking.

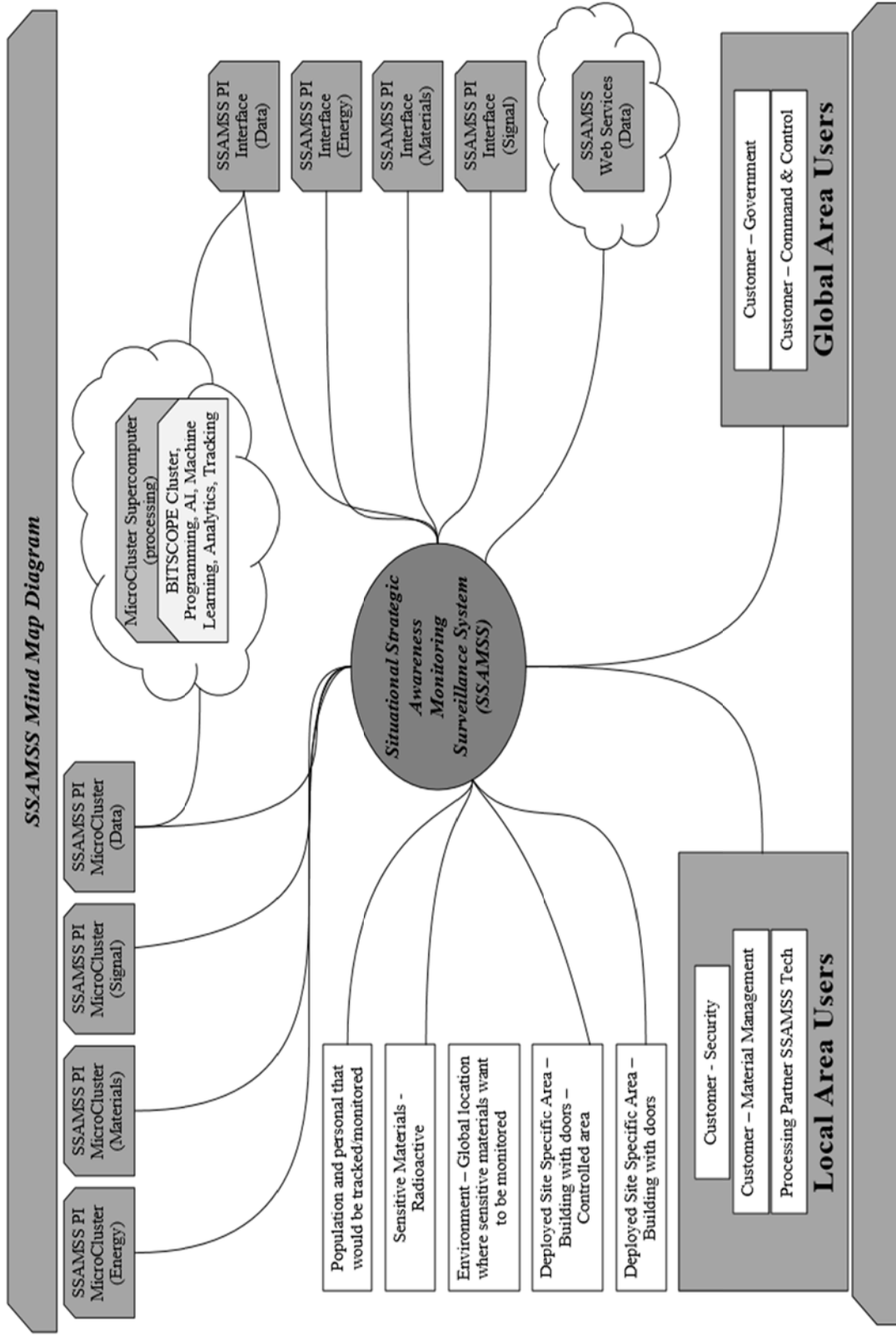


Figure 16: SSAMSS Mind Map Diagram

The mind map diagram shows in reference Figure 16 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. 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, messaging and tracking reference Figure 17.

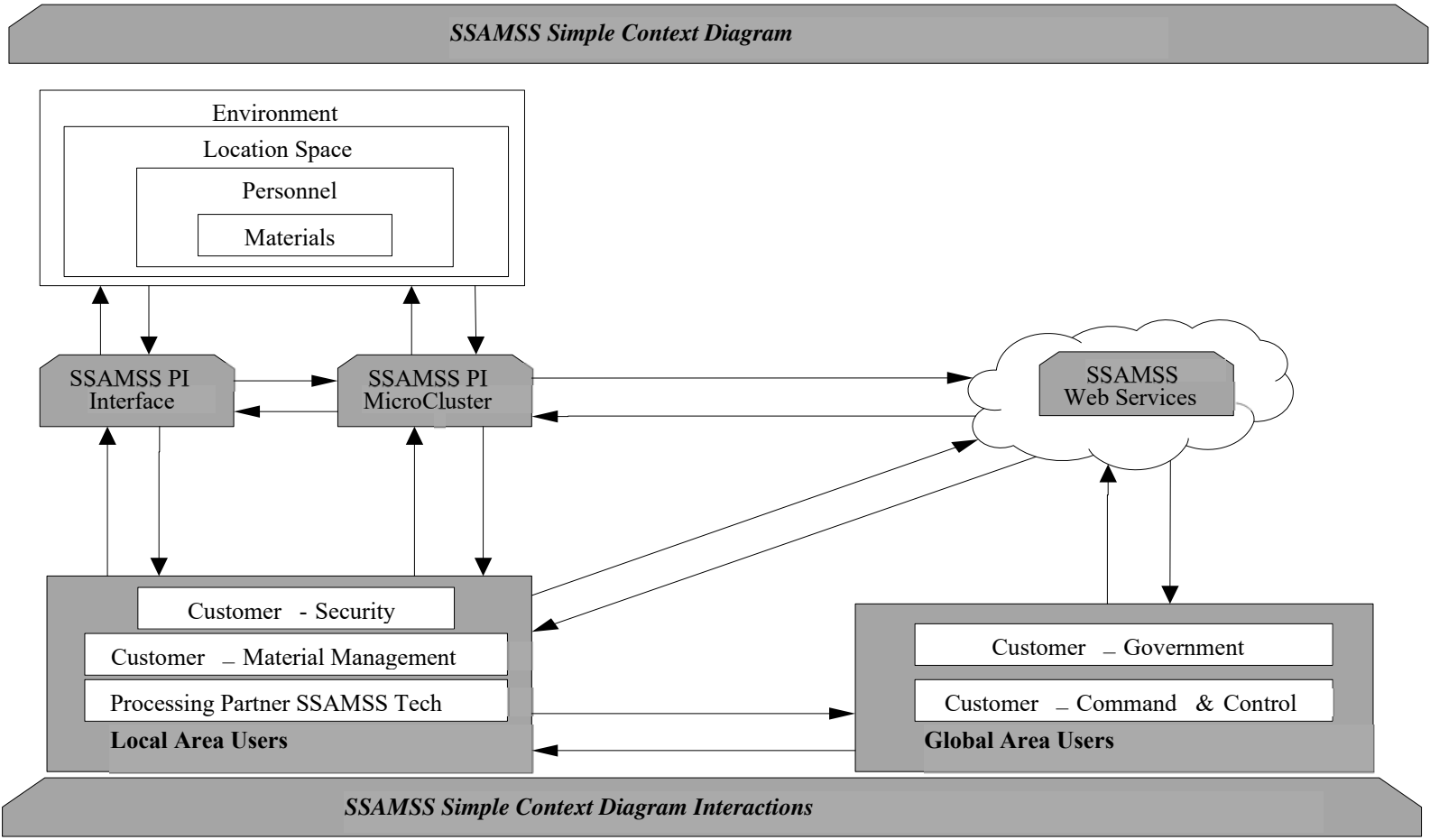
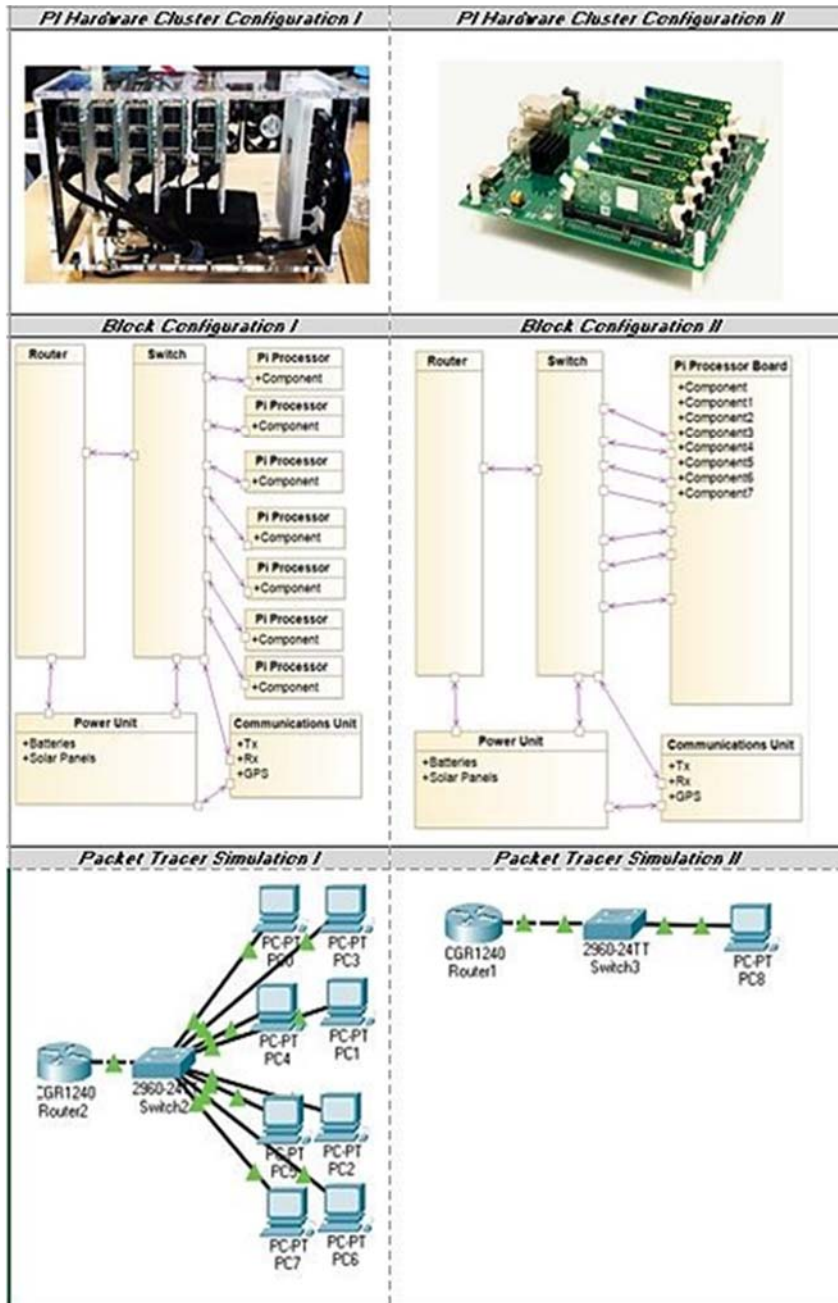


Figure 17: SSAMSS Simple Context Diagram

## Options, Configurations and Selection

Table 12: Hardware, Block and Simulation of the configuration options



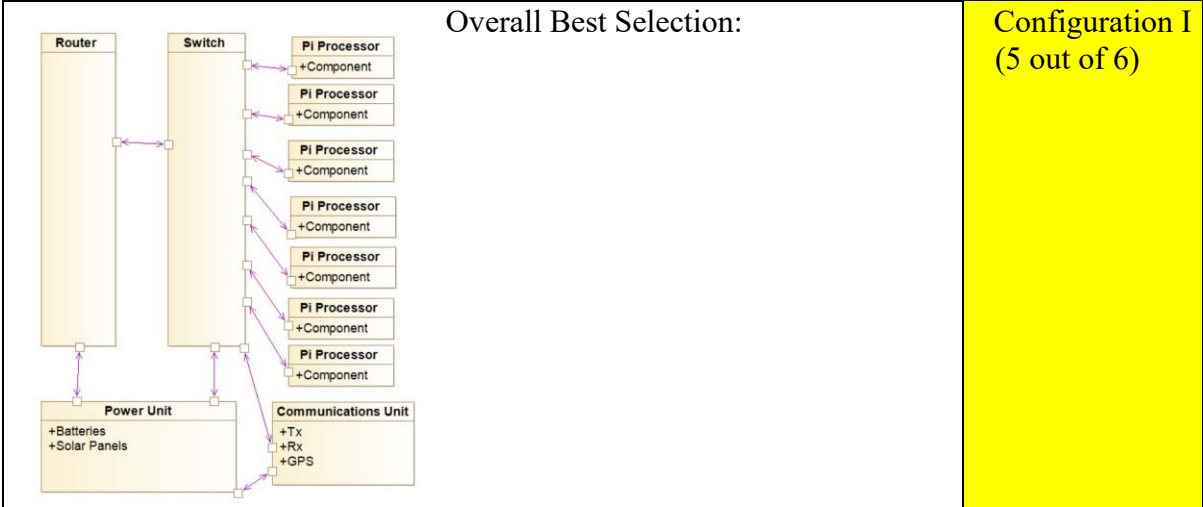
As we understand the Dynamic surveillance model through the development of SSAMSS while taking an actual look at the hardware configuration options I and II to assure confidence in appropriate selection process. Reviewing the configuration to assure reduced risks and redundancy is available. Measuring 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 12 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 configuration through measures of Comparison Table.

## Chapter 2 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. Table 13 as shown below details why Configuration and hardware selection I is the overall best selection for SSAMSS as its overall option:

Table 13: Measures Comparison Table with Hardware Configuration Option I

<i>Measures of Comparison Table</i>			
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 processor that can take distributed data packets	Each Pi Turning Board can hold 7 Pi's but are choaked 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 n	It is difficult to replace the Turning board and or Pi under operations plus limited manufacturing of the Pi Turning board.	Configuration I



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## CHAPTER 3

Remote Sensing Surveillance using SSAMSS Coupled with Synergistic CubeSat Technologies

## Introduction to Chapter 3

The principal objective of this research is to continue the development and research of the Situational Strategic Awareness Monitoring Surveillance System (SSAMSS), which is a smart sensing system, while introducing the Situationally Aware Deployment of Sensing Analytics, Communication, and Knowledge (SAD SACK). Through partial modeling analysis and simulations, we were able to show SSAMSS as a product that could be developed in layers and phases. Through a phased development approach, there has been steadily increased development of both SSAMSS and initialization of the SAD SACK protocol, demonstrating its applicability as a smart sensing system while incorporating Systems Engineering concepts and approaches. These System Engineering concepts and approaches have led to additional development providing confidence that SSAMSS and SAD SACK provide a prototypical technical system to help contribute cost effective safeguarding of sensitive materials. The synergism ultimately is a meshing of theoretical and practical use to assure that a system is being developed while geared toward customers (IAEA, NCR and/or Government labs or agencies) and industries that can benefit from a prototype smart sensing system. Through pseudo-random number generators and scenarios, the product was better understood that the simulations show a steady growth of incidents over time that can be accommodated by SSAMSS as a product. The tools being used in the development through three-phase systems engineering and layered approach include (1) root-cause assessment, (2) domain development, (3) complex system dynamics, (4) causal loop dynamic flow models, (5) agent-based modeling and linkage and (6) pseudo-random partial model analysis. Continuing research and development of a Smart Sensing Surveillance System that is cost effective, easily deployable,

and intelligent is a process supporting the need for material safeguarding. A phase-development layered approach that encompasses an enterprise program product is required. The finalization of the Situational Strategic Awareness Monitoring Surveillance System (SSAMSS) enterprise program [7] may be employed as an architectural road map to creating a smart surveillance global enterprise overseeing sensitive materials through a global network [8]. At a reduced cost via modifiable-commercial off the shelf (MOTS/COTS) parts integration, SSAMSS can provide specific safety monitoring. A dynamic systems approach is proving to be the best way to assure that the customer's needs, requirements, and prototype development are done with accuracy and precision [1] which covers identified challenges as an issue with Nuclear Information Management and Digital Transformation Support at IAEA. Situational Strategic Awareness Monitoring Surveillance Systems Enterprise (SSAMSS - which is the architecture and hardware system configuration) through Situationally Aware Deployment of Sensing Analytics, Communication, and Knowledge (SAD SACK - the software and hardware protocol) could be employed for, among other applications, humanitarian service to assure a reduction in safety failures such as the material explosion that occurred in 2020 Beirut [2] or a potential dirty bomb incident [3]. Most systems regarding material surveillance safeguarding are stand-alone and expensive – e.g., Geiger counters, radiation dose/activity system doors – in addition to lacking intelligence/sensors/video adaptability. In comparison to China's surveillance ecosystem [4], which is a state-run tool costing an estimated \$20 Billion dollars in 2018 [5], SAD SACK-like systems are designed to be inexpensive, comprehensively scalable, and modular. A historical review providing relevant background and root cause issues is provided in Section Introduction to Chapter 3 and History-Root Cause Problem Continues. In the Section Approach details regarding case studies that feed into the SSAMMS/SAD SACK

approach are discussed. This provides background information for the dynamic system product development approach. Sections Lessons Learned from Past Events, Developed Domains Coupled with Complex Systems Dynamics and Transcending Connectivity in System Engineering detail the processes used to quality product development (from a past, present, and future perspective, respectively). Section Causal Loop details the depth of the initial Causal Loop Diagram detailing relationships, communication, data, and measures. Section Opportunity Through Identification and Partial Simulation details the product connectivity for certain identifiable laws by visually shown potential linkage between those identified laws and/or constraints including a portion of Moore's law linked as a Partial-Model Analysis. Section Projected Development of the Causal Loop Diagram and Connecting the Complex Pieces Through Complicated Relationships reflect the applicability of agent-based models to situationally aware sensing. In Sections Complex System Dynamics Model, Stock & Flow Dynamic Models and Causal Model – Butterflies, the models are identified which will be used to analyze the enterprise systems. These models are run through analysis procedures which display results that are used to identify customer and product demand per incident on a global scale. Section Sensory Data makes SSAMSS Matter details the need for root cause issues of global materials safeguarding, along with their data requirements. In Section SAD SACK Protocol, there is an introduction to a protocol for combined hardware and software to assure appropriate linkage development. Finally, Section Chapter 3 Conclusion concludes the research description, detailing the results and specifying suggested next steps.

History-Root Cause Problem Continues

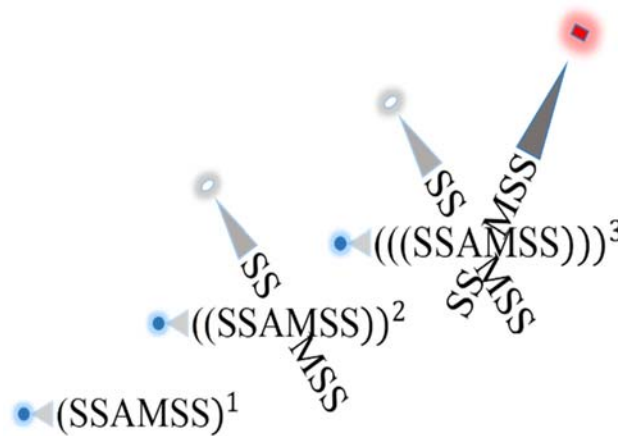


Figure 18: Three-phased & Layered Product Development Approach

Initial articles and research have shined a light on several challenges that were identified from previous assessments [1, 7 and 8]. Those assessments brought attention to (1) monitoring, controlling, and safeguarding radioactive-hazardous materials, (2) verifying that past explosive and nuclear fissile materials have been controlled and disposed of properly, and (3) safeguarding and securing energy materials. All three of these require the development of modern tools with real-time data capability to control subsurface energy materials [6].

Continual research has led to furthering the physical development of the initial aspect of the overall system dynamics regarding SSAMSS as a product. In particular, the selection of Modifiable or Commercial off the Shelf components (MOTS/COTS) e.g., Raspberry Pi and initial hardware configurations, have led to a recommendation for a dynamic systems model [7 and 8]. Furthering the development is the continuance through a three-phased layered approach as referenced in Figure 18. This includes the methodology to address the overall systems relationship, hardware and software linkages, and system dynamic connectivity through initial model analysis, along with models encompassing the product-system enterprise and architecture.

## Approach

As detailed in Section History-Root Cause Problem Continues, previous research has been built up in a phased and layered approach. Initial prioritization over customer needs, requirements, and marketplace helps identify the parts and components that can keep product development competitive in the global market. After that assessment, a hardware cluster component configuration was completed to assure optimal system and subsystem selection. This included an initial byproduct as detailed in the domain diagram tool as shown in Figure 30. Another critical tool was the complex loop diagram which included important measurements, developed as shown in Figure 32. These initial tools are a starting point for combining of all the pieces of the overall dynamic SSAMSS product. The mathematical model incorporates a simple system dynamics model as shown in Figure 27 that was created to incorporate critical perspectives related to area domains reflecting value-added measures important to the customer. This was directly derived from the initial domain assessment as shown in Figure 30. This provided insight specifically to SSAMSS products that potentially would be measured as a baseline to be compared against. The following connection between the two models is Equation 4, which links the two perspectives together providing measurable and specific design proofs [7and 8]. SSAMSS initial and future product design objectives are relative by comparing complexity vs complication, capability vs performance, and functionality vs behavioral perspectives. Every part, component, subsystem, and system are coupled together to make an overall synergistic accumulation to meet design driven objectives and desires. The complication is developing a way to connect all perspectives together that can result in gaps and/or gray/black box spaces. That is where the domains and initial complex systems dynamic

modeling tools come together to create a more measurable model with simulation capabilities. The coupling of models can run simulations that are in turn analyzed by producing data for subsequent analytics. This domain development is a graphical representation of critical details that provides an opportunity to create a measurable simulation with an initial outline as shown in Figure 28. Figure 37 Additionally, a dashboard is simulated as shown in Figure 29 through the analysis portion of the model. Beginning steps would first be to assure that the pieces and layers are properly developed, then placed together against the initial complex loop model-diagram layer to provide confidence that the SSAMSS enterprise up to this point has been developed with sufficient quality, as shown in Figure 27. This study will include a deep consideration of the items that feed into the initial causal loop diagram, as shown in Figure 31. Through an initial assessment, identifiable gaps within the pillars are made clear as the structure starts to take shape as shown in Figure 36. That structure is reinforced by relatable laws as shown in Figure 35, and connected by equations similarly to Equation 6, and Equation 7. The development of SSAMSS as an enterprise is intended to incorporate Agent Model-Based (AMB) diagrams, such as shown in Figure 38, Figure 39, Figure 41 and Figure 42. Furthering the development of future assessment of causal loop diagram is shown in Figure 37. Dynamic relationships regarding the SSAMSS product enterprise are used to show direct and indirect relationships that will support further complex system dynamics. Modeling that is supported by other laws, equations and at this point partial analyses are shown in Figure 42 and simple system dynamics model as shown in Figure 27 have been created to incorporate critical perspectives related to area domains reflecting value-added measures important to the customer. This was directly derived from the initial domain assessment as shown in Figure 30. This provided insight specifically to SSAMSS products that potentially would be measured as a

baseline to be compared against. The following connection between the two models is Equation 7, which links the two perspectives together providing measurable and specific design proofs [7 and 8]. SSAMSS initial and future product design objectives are relatively ranked by comparing complexity vs complication, capability vs performance, and functionality vs behavioral perspectives. Every part, component, subsystem, and system are coupled together to make an overall synergistic accumulation to meet design driven objectives and desires. The complication is developing a way to connect all perspectives together that can result in gaps and/or gray/black box spaces. That is where the domains and initial complex systems dynamic modeling tools come together to create a more measurable model with simulation capabilities. The coupling of models can run simulations that are in turn analyzed by producing analytics. This domain development is a graphical representation of critical details that provides opportunity. The stock and flow complex model show how this tool should work as shown in

Figure 43. The overall, relatively complex system diagram is the actual model that will eventually be used to run simulations of the whole dynamic system, as shown in Figure 44 .

The SSAMSS architecture entails several parts on a local and global scale requiring production of a protocol assuring a connection between the hardware and software together including the satellite CubeSat systems as shown in Figure 53, Figure 54 and finalized in Figure 55.

Lessons Learned from Past Events

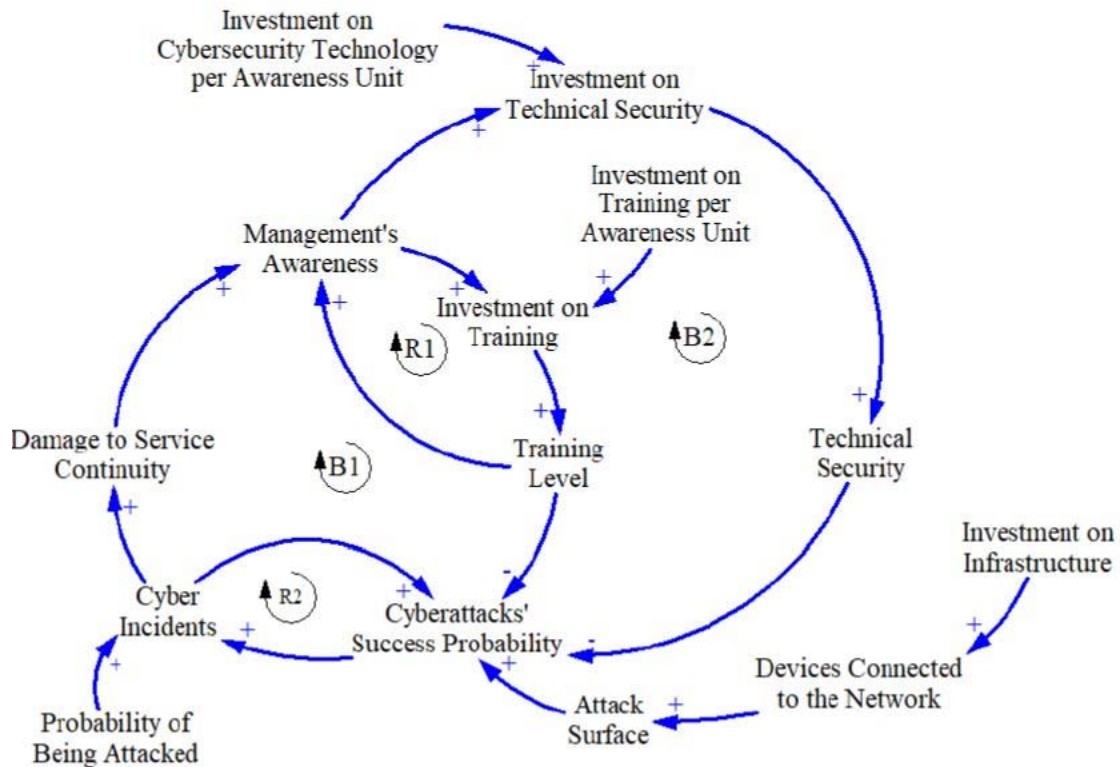


Figure 19: Casual Loop Diagram - Cyber Security Baseline [10]

SSAMSS is developed to encompass an enterprise product-synergistic idea built upon a multitude of baselines that can create a clear perspective regarding requirements and

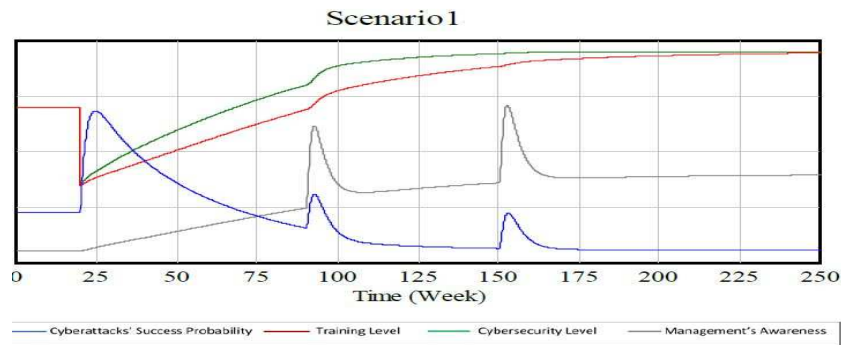


Figure 20: Scenario Graphics Baseline [10]

capabilities. Baselines lead to refined product development in promising directions of future opportunities and help to assure future products are not stuck in outdated approaches. The article [10]

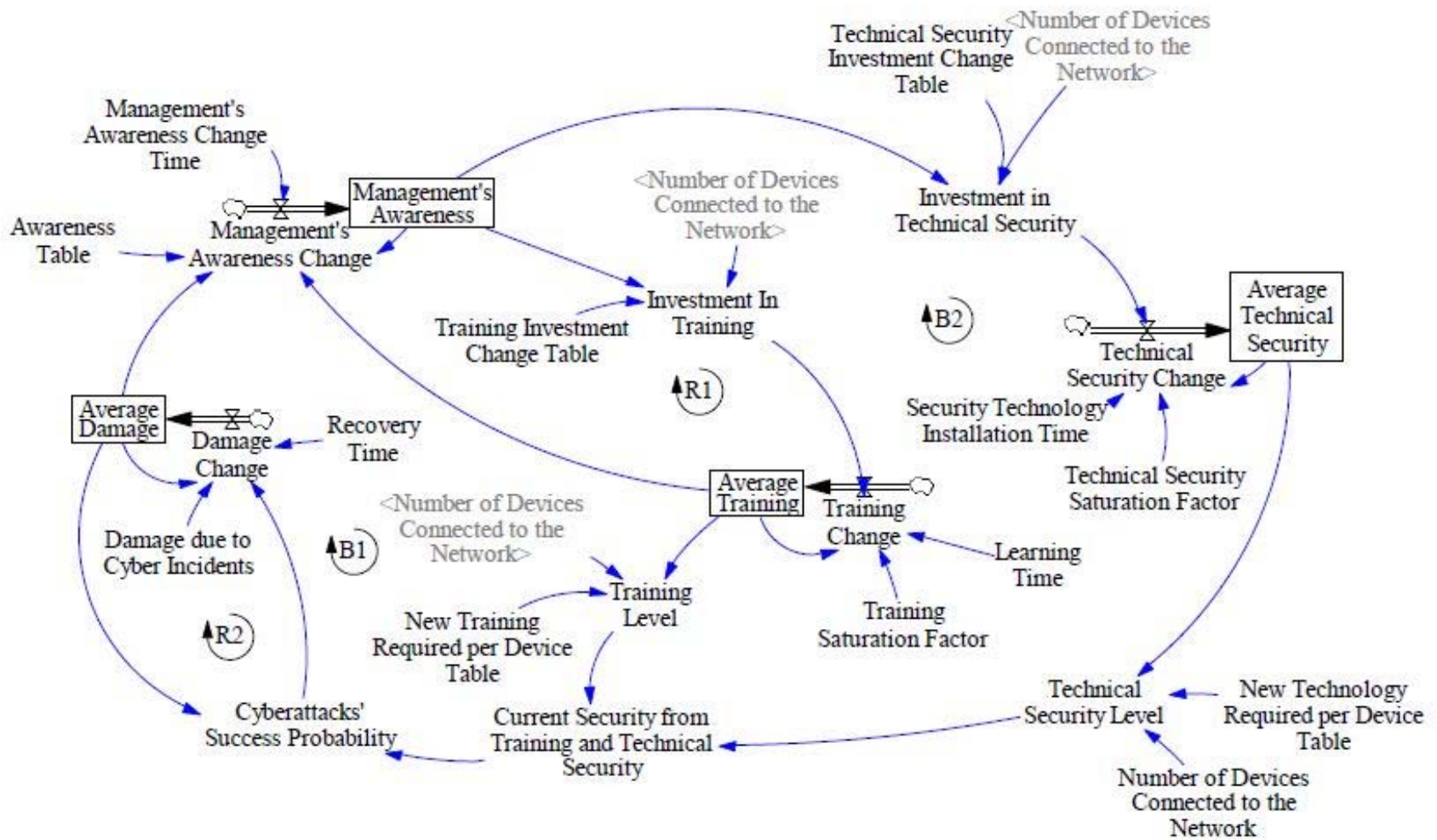


Figure 21: Stock-n-Flow Diagram - Cyber Security Baseline [10]

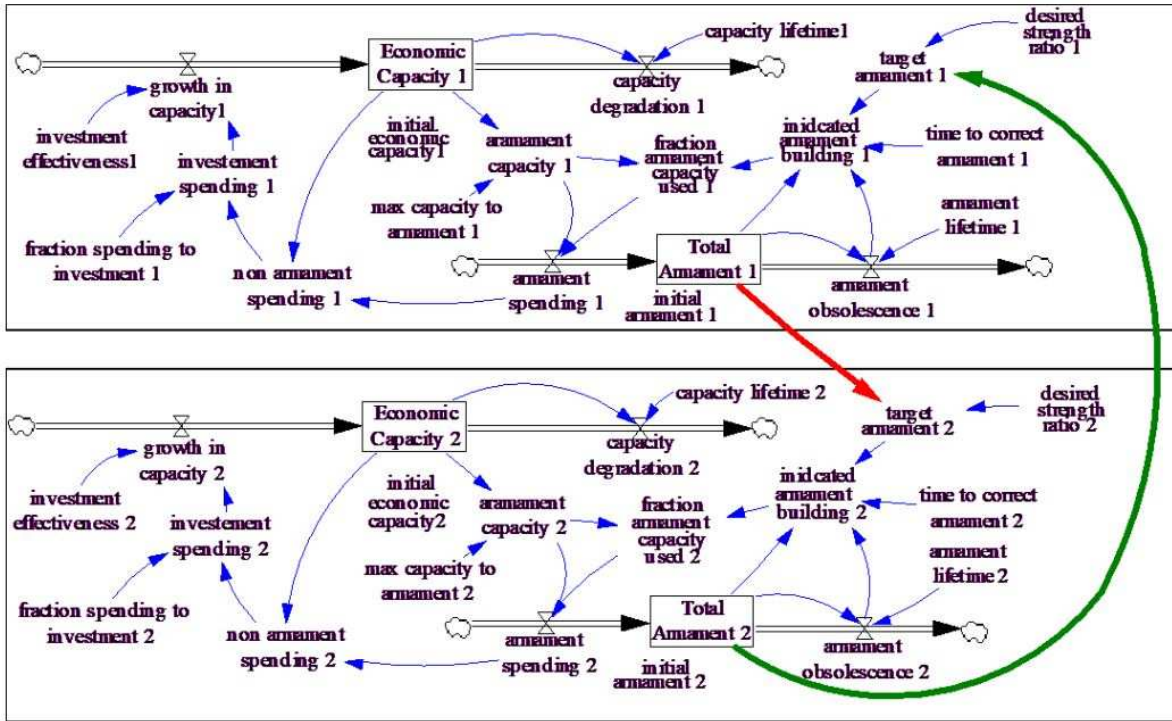


Figure 22: Vensim Arms Race Example Model [11]

uses several tools coupled with Systems Engineering practices to assure that the operations have value-added development initially and in the future. The first baseline as shown in Figure

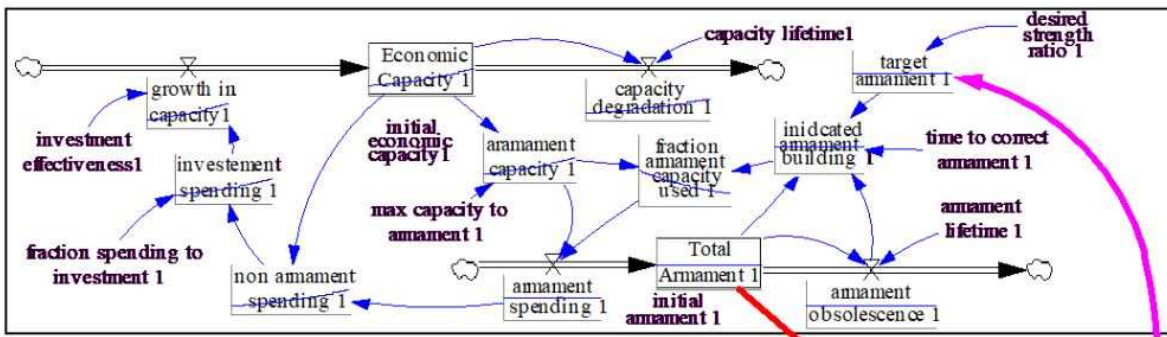
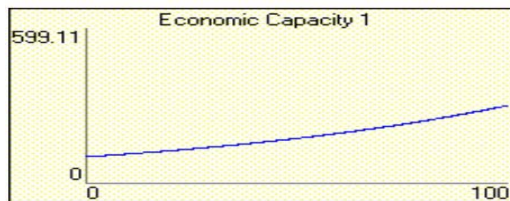


Figure 23: Vensim Entire Simulation -Variable per Arms Model [11]

19 shows the development of a Resilient Cyber Security Technology Strategy [10] through a



Causal Loop Diagram. That Diagram feeds into a Stock and Flow Diagram as shown in Figure

Figure 24: Vensim Arms Economical [11]

21 that results in several scenarios (Figure 20). The approach baseline has similarities to the

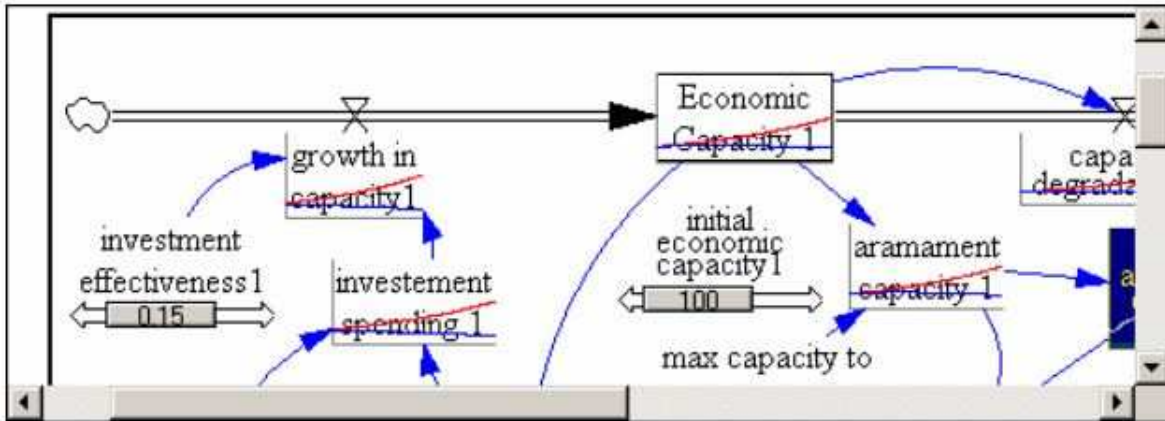


Figure 25: Vensim Arms Comparison Simulation per Variable [11]

SSAMSS initial approach but details further development of the models to create in-depth analysis opportunities regarding the example. As shown in Figure 22, Figure 23, and Figure 24, the Arms Race models reflects costs and armament growth against two competing competitors reflective in Figure 23 and reflects singular simulations, system behaviors and graphical

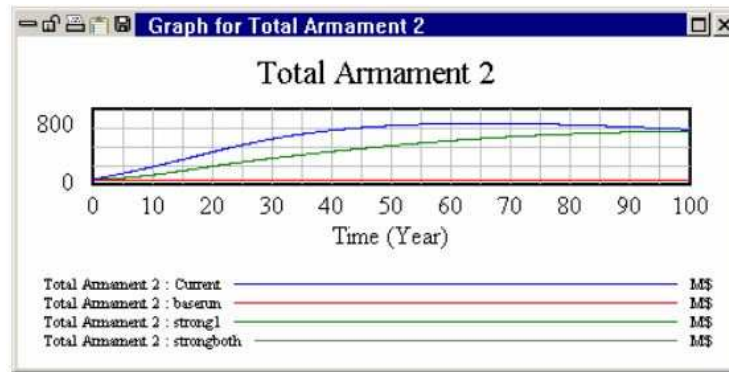


Figure 26: Vensim Arms Graphical Comparison Simulation per Variable [11]

dynamic relationships (Economic Capacity) over a span of time. This reflects a simple complete system like SSAMSS, but not the same as the system of systems-complexity such as the SSAMSS enterprise product. Simulation experiments can run several scenarios like Figure 26 and Figure 25 to collect analytics. This could essentially be used as a baseline to strengthen

the SSAMSS Enterprise through the optimization of multiple variables, singular relationships, components and/or other opportunities in the system dynamic models [11].

Operational Equipment Effectiveness (OEE):

- Eq:  $OEE = [(Availability) * (Performance) * (Quality)]$

Availability:

- Eq:  $Availability \% = [(Actual Production Time) / (Potential Production Time)]$

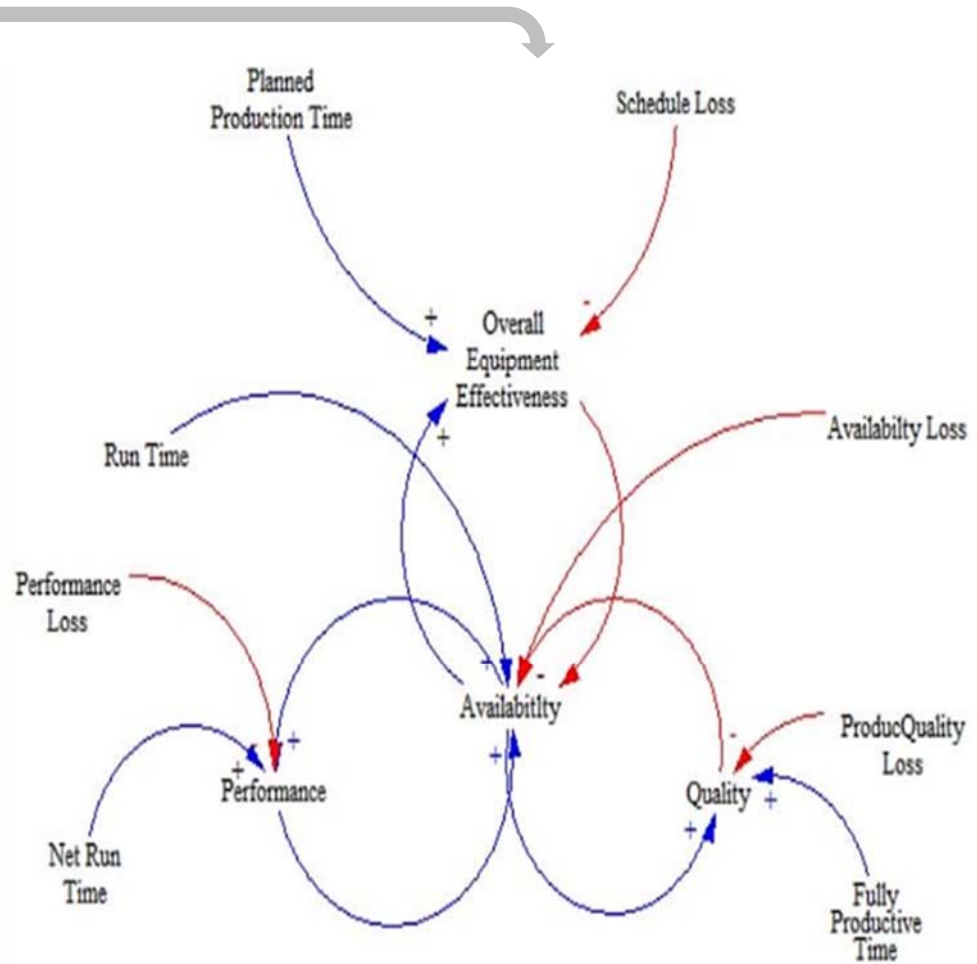
Performance:

- Eq:  $Performance \% = [(Actual Output) / (Theoretical Output)]$

Quality:

- Eq:  $Quality \% = [(Good Output) / (Actual Output)]$

*Equation 4: Operational Equipment Effectiveness, Availability, Performance and Quality formulas [8]*



*Figure 27: Initial Complex Loop Diagram with Detailed Variables [7]*

## Developed Domains Coupled with Complex Systems Dynamics

Simple system dynamics model as shown in Figure 27 have been created to incorporate critical perspectives related to area domains reflecting value-added measures important to the customer. This was directly derived from the initial domain assessment as shown in Figure 30. This provided insight specifically to SSAMSS products that potentially would be measured as a baseline to be compared against. The following connection between the two models is Equation 6, which links the two perspectives together providing measurable and specific design proofs [7and 8]. SSAMSS initial and future product design objectives are ranked by comparing complexity vs complication, capability vs performance, and functionality vs behavioral perspectives. Every part, component, subsystem, and system are coupled together to make an overall synergistic accumulation to meet design driven objectives and desires. The complication is developing a way to connect all perspectives together that can result in gaps and/or gray/black box spaces. That is where the domains and initial complex systems dynamic modeling tools come together to create a more measurable model with simulation capabilities. The coupling of models can run simulations that are in turn analyzed by producing analytics. This domain development is a graphical representation of critical details that provides opportunity. That opportunity is using the tools to create a quantitative way to gauge qualitative parameters that SSAMSS needs to be able to compete, compare and be measured against. This qualitative approach uses the domains to find ways to create mathematical models that have simulatability. That data from those simulations provide evidence and/or proof of what

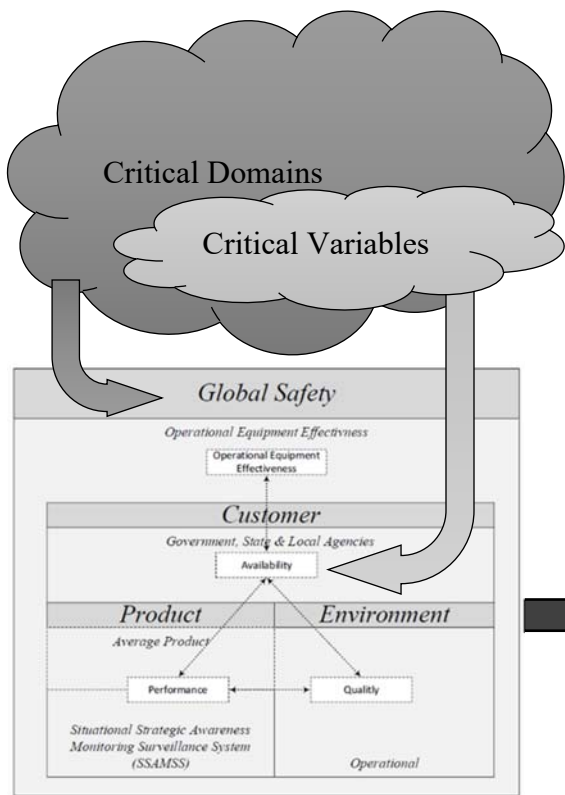


Figure 30: Domain Area Diagram with Variable Assessment (7)

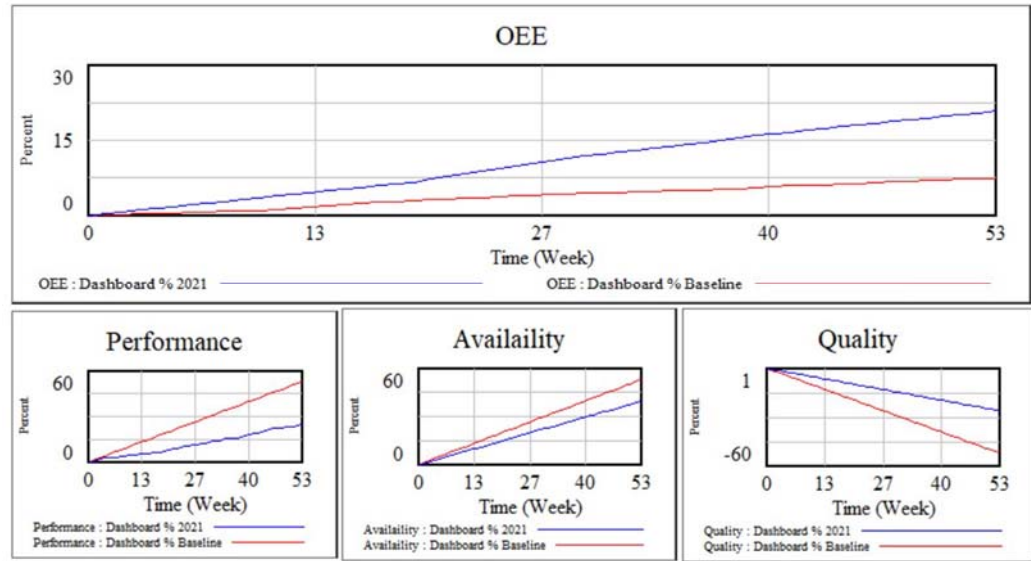


Figure 29: Partial Pseudo-random Dashboard for SSAMSS [9]

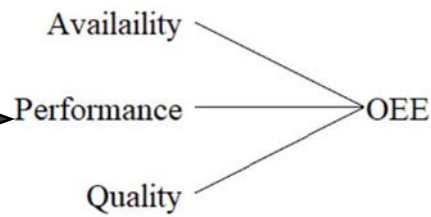


Figure 28: Visual Mathematical Relationship Diagram

SSAMSS as a product can provide. This creates an opportunity for the optimization of SSAMSS as a product against the current standards. Baselines and standards collected from competing products are added to the models and diagrams can then be utilized to interject points of interests to collect statistical numerical values. These values help assure a controlled development of more complex and dynamic systems while integrating a measurable feedback loop approach through phase and iterative development over time. This controlled collection of data points referencing Figure 28 shows measurable values that are utilized for future system development, optimization, or risk reduction. Initially, this will be achieved through the creation of dashboards that will integrate into SSAMSS driven by the customer, product optimization and future development collected through critical Technical Performance Measures (TPM) and Key Performance Indicators (KPIs) as shown in Figure 29 [9]. How SSAMSS as a product communicates its cause-and-effect relationships is a further deep dive into the initial system dynamic models. This initial overlapping perspective provides pillars that can be used like binoculars to look at specific variables being used to assure a non-biased development of the overall product. This perspective also provides rich information on what may still be needed to develop future simulation, models, or details.

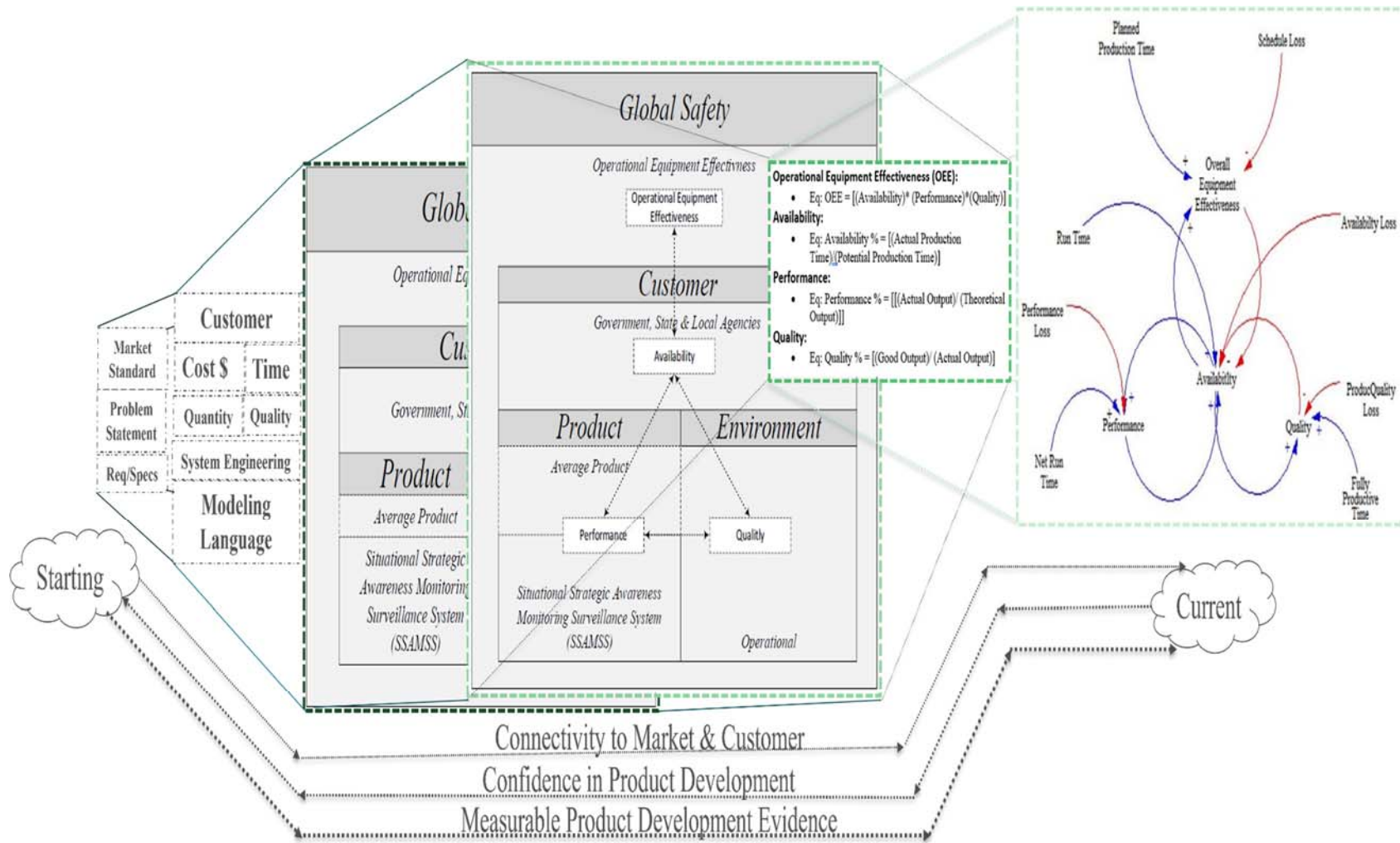


Figure 31: System Engineering Initial-starting to Current Transcending Perspective Diagram

## Transcending Connectivity in System Engineering

Systems engineering as an approach acts as a driver for the system causal loop diagram as referenced in Figure 27. Connectivity and transcending are relative in general as a perspective to the customer, the market, and SSAMSS as an overall competitive enterprise. Figure 31 details initial through current perspectives of the overall product development. That development uses mathematical inputs that act as the glue between the domains and the complex causal system diagram providing critical measurable details: (1.) connectivity to market and customer, (2.) confidence in product development, and (3.) measurable product development used as verifiable evidence between the slices of the initial product through the current development. The cause-and-effect relationships in Figure 32 are used to create additional diagrams and models. Those will simulate specific relationships such as SSAMSS enterprise as a whole and SAD SACK protocols which are further detailed in Sections 7, 8 and 9. These are used to further develop the initial causal loop diagram, described next.

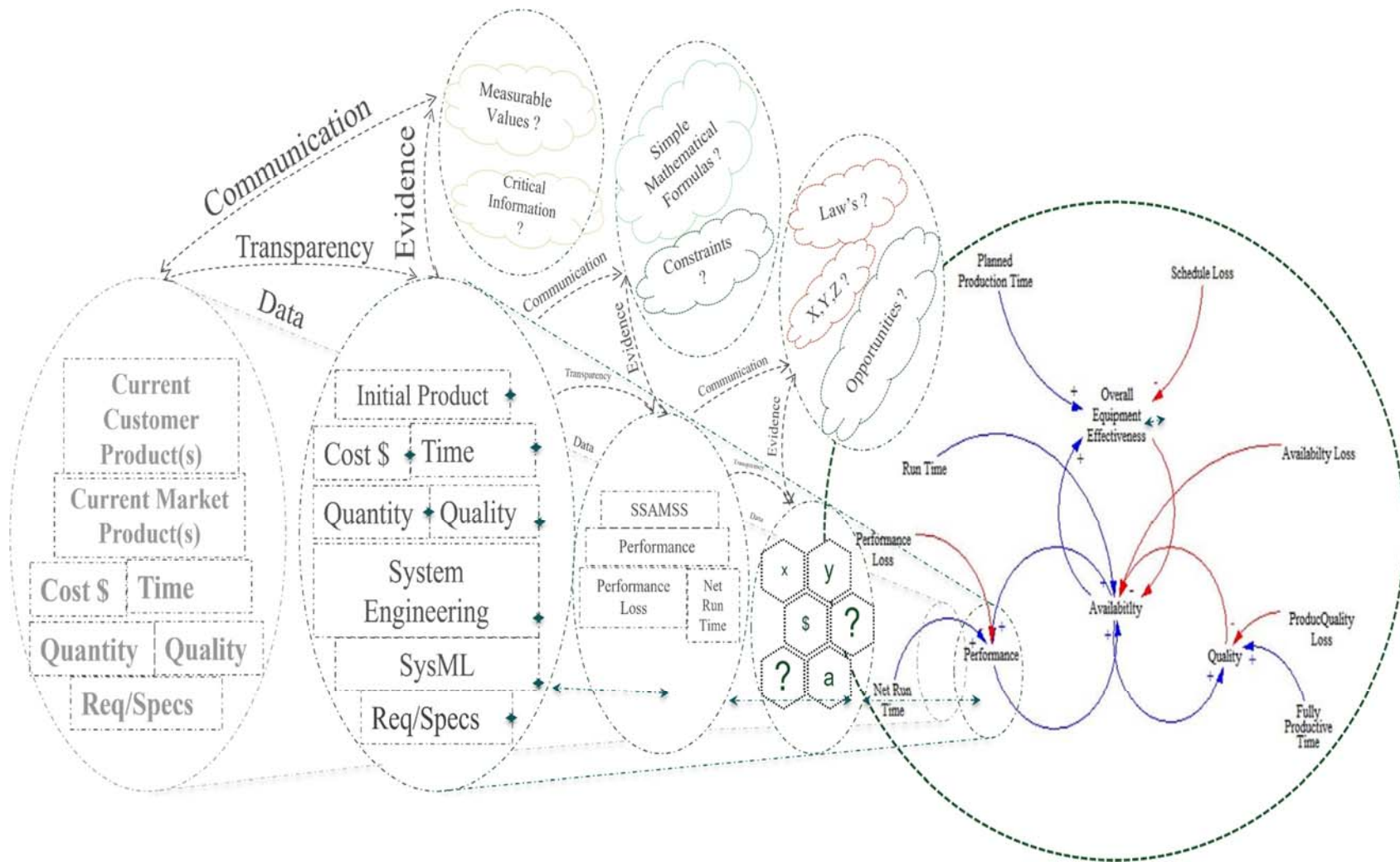


Figure 32: Initial Casual Loop Diagram Explaining Measures, Relationships, Inputs, Variables and Pillar Assessment with Control Loops details.

## Causal Loop Diagram

The initial causal loop diagram reflects pillar-slices of development while providing confidence through the transitional phases. As each variable, input, and output continues to be assessed through the current and future causal loop diagram it becomes fortified as a valuable tool. The tool continues to detail and add critical information in later sections. The starting development feeds into a causal loop diagram while considering control loops that represent the initial product placement. Through the assessment, an overlapping approach was used to further develop pillar-slice placement representing connectivity between the control loop variables, inputs, and outputs. As represented in Figure 32, the overlapping pillar-slices take into consideration several markers. These considerations create confidence with the customer regarding SSAMSS as a product. That confidence is created by connecting communication, transparency, and evidence (control loops) between the customer's initial product development and current product development down to specific variables (causal loop diagram). That connectivity relates to data between the pillar-slices that can be used as a type of binocular view while zooming in and out between the layers and slices. This binocular capability gives a reinforcement of details relating back to increased confidence in product development. Another critical aspect is being able to assess the pillar-slices as they look for any potential opportunities and/or gaps to optimize or correct any areas that may be lacking per control loop variable assessments of the dynamic surveillance system. Those critical variables represent customer needs, requirements, strengths, weaknesses and at some pillar-slice levels laws that impact SSAMSS overall product-customer relationships. These details are further discussed in sections

Opportunity Through Identification and Partial Simulation, Connecting the Complex Pieces Through Complicated Relationships and Projected Development of the Causal Loop Diagram. Above all these tools are used to connect the starting perspectives to the initial causal loop diagram to assist in creating a competitive edge now and through the future.

Opportunity Through Identification and Partial Simulation

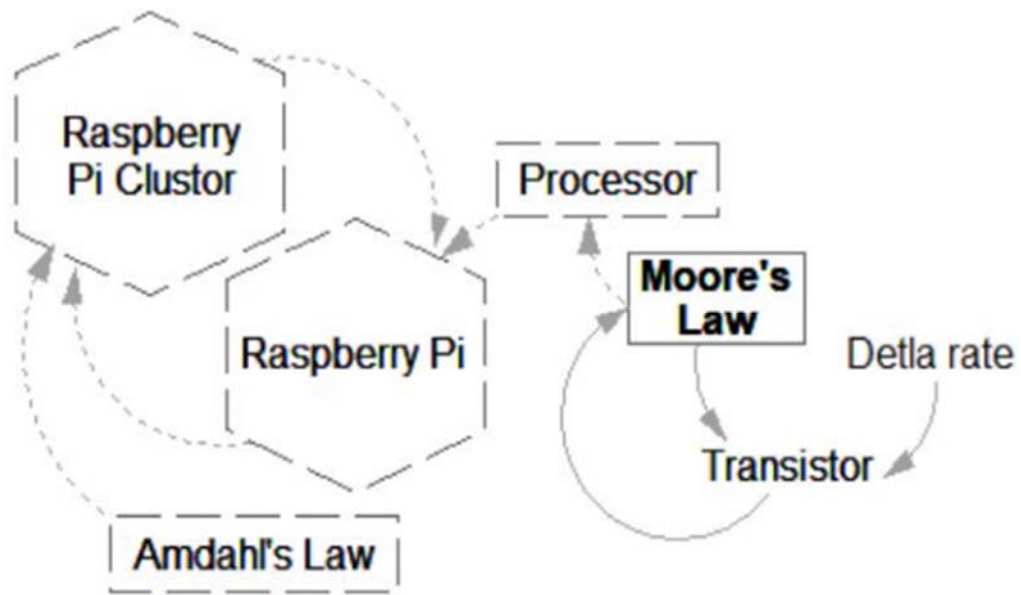


Figure 33: Partial-Sim Analysis-Moore's Law

As the initial causal loop diagram is initiated (Figure 33), gaps, constraints, opportunities, and laws that may impact product development overtime as detailed in the previous sections become clear. A partial simulation can be analyzed as it runs baseline and comparative simulations. Another portion of the model is used only to connect two components that would ultimately be used in SSAMSS product development i.e., Raspberry Pi processors and/or Raspberry Pi clusters including associated costs that will be utilized for future simulation-analysis. As shown in Figure 34, Moore's law [13] is used as a simulation baseline vs comparative baseline to an Intel processor over time as shown in Equation 5 and mathematically modelled in Equation 6. Regarding future development, simulation, and

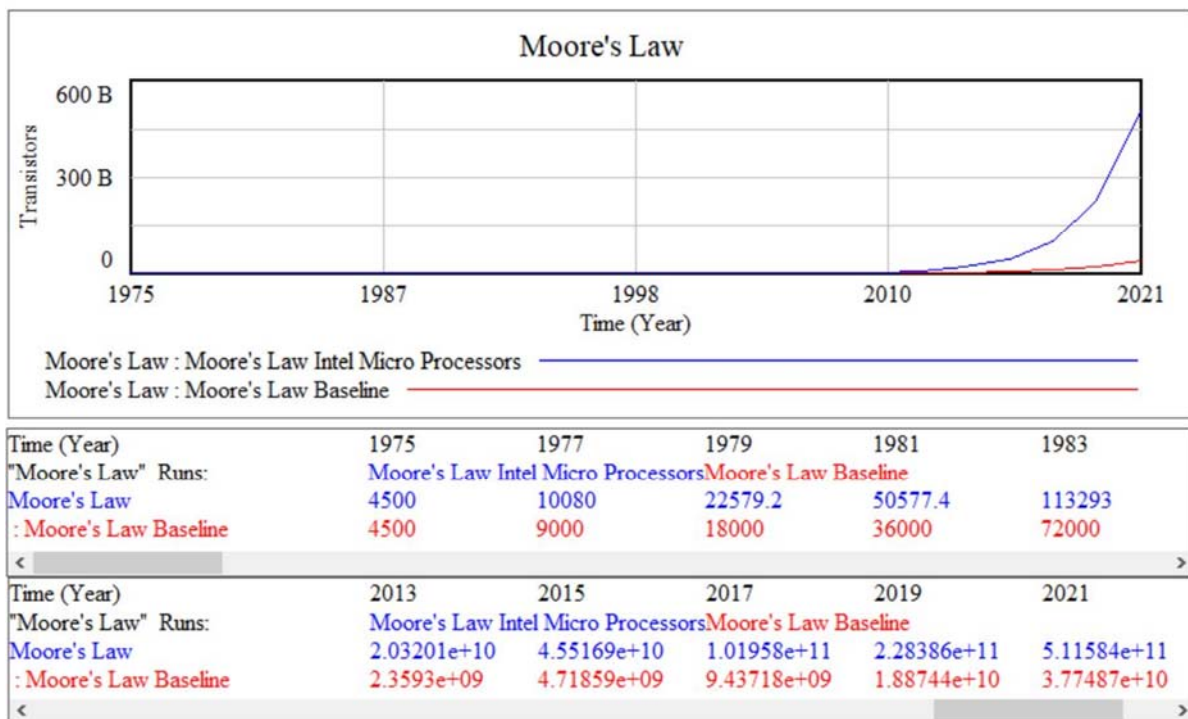


Figure 34: Moore's Law Partial Model Simulation Baseline vs Intel

analysis the model will be able to incorporate additional components, costs, relationships, and laws that may impact or constrain SSAMSS as a complex dynamic system. The model portion that can be simulated is run as a reflection of the pillar-slice developed in the prior sections that

feeds the causal loop model. Selected portions of SSAMSS production and configuration specifically variables, laws, and/or inputs feed the simulator: p these include Moore's law, Delta rates and transistors. Equation 5 is specific to baselining Moore's law (Delta rate = 0.5) from 1975 up until 2022 comparing an Intel microprocessor baseline (Delta rate = 0.62) over the same duration of time. This growth curve starts with 4500 transistors, doubling over the span of every two years. The pillar development initially came from previous inputs such as initial cost, operational costs, maintainability, reliability, and intelligence. That criticality regarding observable laws has an impact on the development of SSAMSS as a current and future product. Again, Moore's law through the assessment is clearly turning up as an input regarding SSAMSS development and should be further understood as a model and as a mathematical formula as referenced Equation 6 [13].

- |  |  |
|--|--|
| <p>(01) Delta rate=<br/>0.62<br/>Units: 1/Year</p>                                       | <p>(05) Processor = A FUNCTION OF( Moore's Law)<br/>Units: **undefined**</p>                       |
| <p>(02) FINAL TIME = 2022<br/>Units: Year<br/>The final time for the simulation.</p>     | <p>(06) Raspberry Pi = A FUNCTION OF( Processor)<br/>Units: **undefined**</p>                      |
| <p>(03) INITIAL TIME = 1975<br/>Units: Year<br/>The initial time for the simulation.</p> | <p>(07) SAVEPER =<br/>TIME STEP<br/>Units: Year<br/>The frequency with which output is stored.</p> |
| <p>(04) Moore's Law= INTEG (<br/>Transistor,<br/>4500)<br/>Units: Transistors</p>        | <p>(08) TIME STEP = 2<br/>Units: Year<br/>The time step for the simulation.</p>                    |
|  | <p>(09) Transistor=<br/>Moore's Law * Delta rate<br/>Units: Transistors/Year</p>                   |

$$n_i = n_0 2^{(y_i - y_0) / T_2}$$

Equation 5: Moore's Law Code Baseline (rate = 0.5) vs Intel (Rate = 0.62)

Where

- $n_0$  is the number of transistors in some reference year,

- $y_0$ , and  $T_2 = 2$  is the number of years taken to double this number.
- Since the data cover 40 years, the values of  $n_i$  span many orders of magnitude and it is convenient to apply Moore's Law to its logarithm, which shows a linear dependence on  $y$ ”

$$\log_{10} n_i = \log_{10} n_0 + \frac{y_i - y_0}{T_2} \log_{10} 2$$

Equation 6: Moore's Law as a mathematical formula [13]

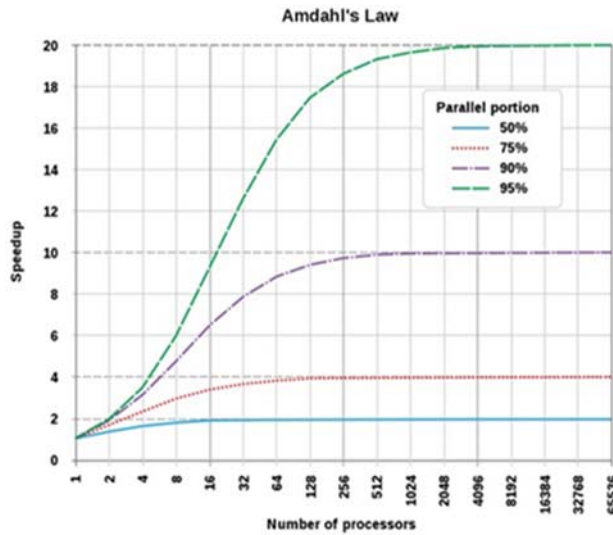


Figure 35: Graphical Example of Amdahl's [14]

An additional law that was identified to have an impact was Amdahl's law. Amdahl's law is represented in a portion of the causal loop model but was not simulated during this partial analysis as represented in Figure 35. Unlike Moore's law which impacts transistors, costs and rates overtime Amdahl's law impacts parallel processing, number of processors and speed which would be a consideration regarding the SSAMSS Pi cluster configuration. As this potentially could be a bottleneck, constraint, and/or opportunity regarding processing power the law needs to be considered. A graphical representation is shown in Figure 35 and mathematical equation referenced an Equation 7 has been collected to better understand the law eventually integrating into the simulator.

$$S_{latency} = \frac{1}{(1 - p) + p/s}$$

where

- S latency is the theoretical speedup of the execution of the whole task.
- s is the speedup of the part of the task that benefits from improved system resources.
- p is the proportion of execution time that the part benefiting from improved resources originally occupied.

$$\begin{cases} S_{Latency}(s) \leq \frac{1}{1-p} \\ \lim_{s \rightarrow \infty} S_{Latency}(s) = \frac{1}{1-p} \end{cases}$$

Equation 7: Amdahl's Law as a mathematical formula [14]

### Projected Development of the Causal Loop Diagram

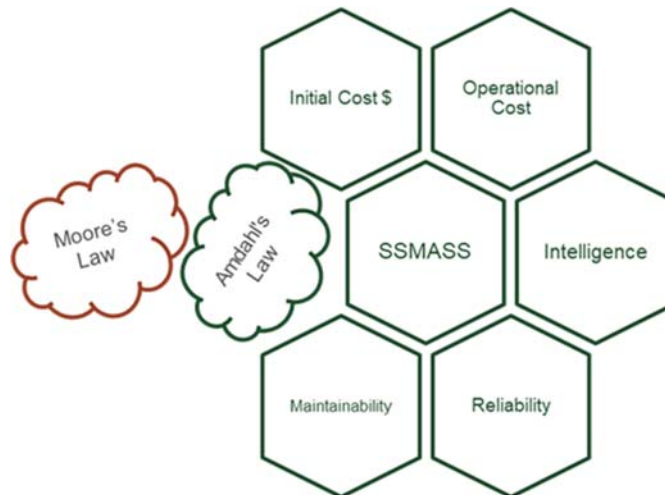


Figure 36: Pillar Slice of Laws, requirements

An in-depth understanding of the cross sections between initial, current, and future pillar-slices is performed at the start of the causal loop diagrams which are used to create models reflective of requirements similarly to SSAMSS as a product. The verifiable areas are identified by connecting customer demands and requirements as well as identifying gaps. As assessed in the previous section those gaps initially identified potential laws that impact SSAMSS through the product life cycle while regarding its development as shown in Figure 36. Those understandings are developed from the starting through the future pillar-slice details. For SSAMSS to maintain a competitive edge a projected insight into other views is developed that

incorporates the initial causal loop diagram as referenced in Figure 37. This projected insight provides a global perspective of SSAMSS potential growth as a product now and in the future. This intertwining of previous tools i.e., complex system diagram, causal loop system models, starting (trust, predictability, and analytics), current (measures and KPIs) and future (confidence, dashboard, and metrics) pillar-slice to show connectivity between product states (by data). That can be intertwined into other tools assuring a competitive edge while still under development as a product that is able to be simulated similarly to Moore's law which was analyzed in the previous section. Although there are differences between the systems engineering methodology V diagram and the future causal loop diagram there is still somewhat of a V shaped perspective that helps feed the pillar-slices, layers, phases, and states of product development. Incorporating through a controlled approach all these tools, models, simulations, and analysis create a perspective of behavior, functionality, and capabilities as reflected in Figure 37.

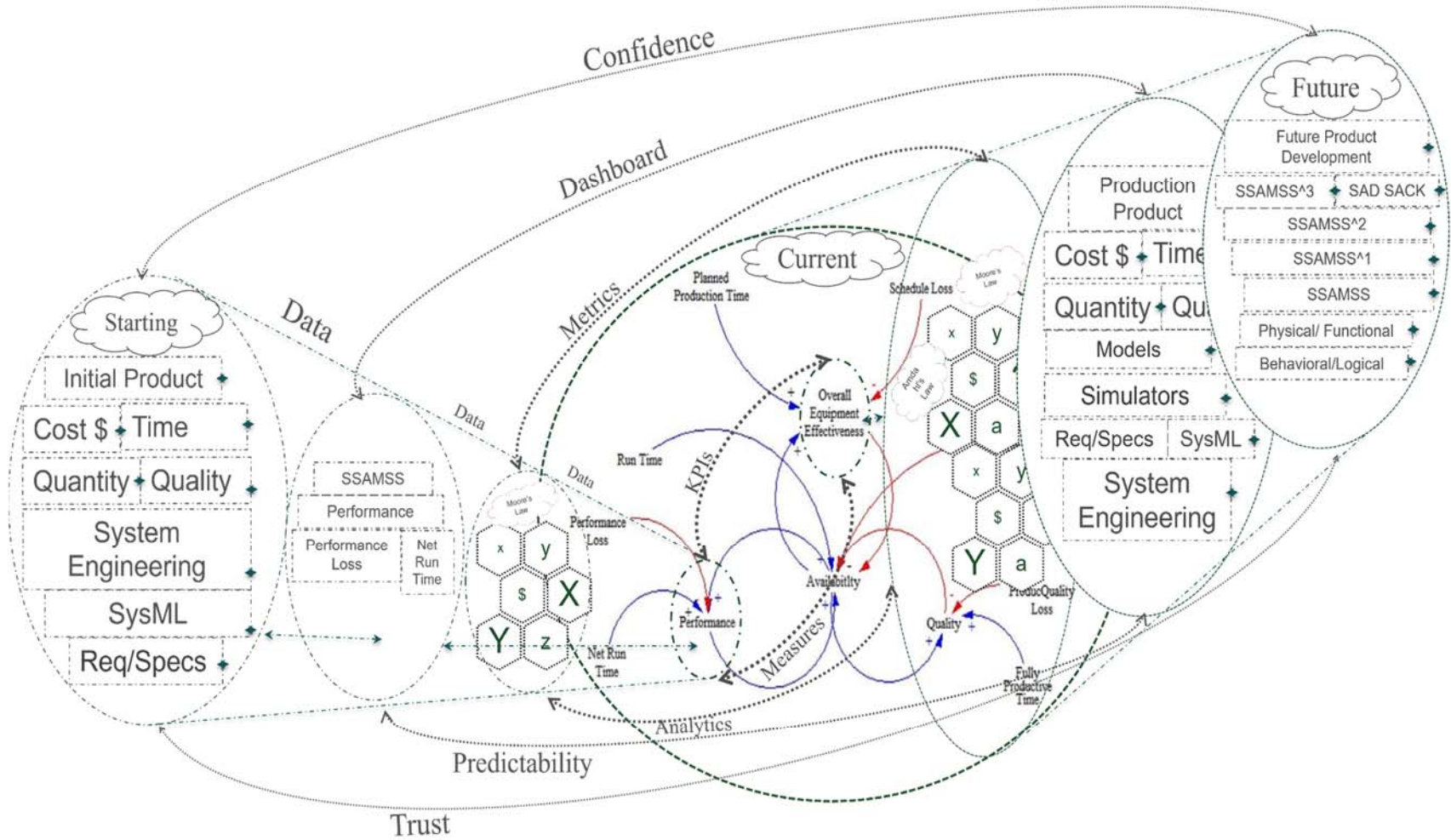
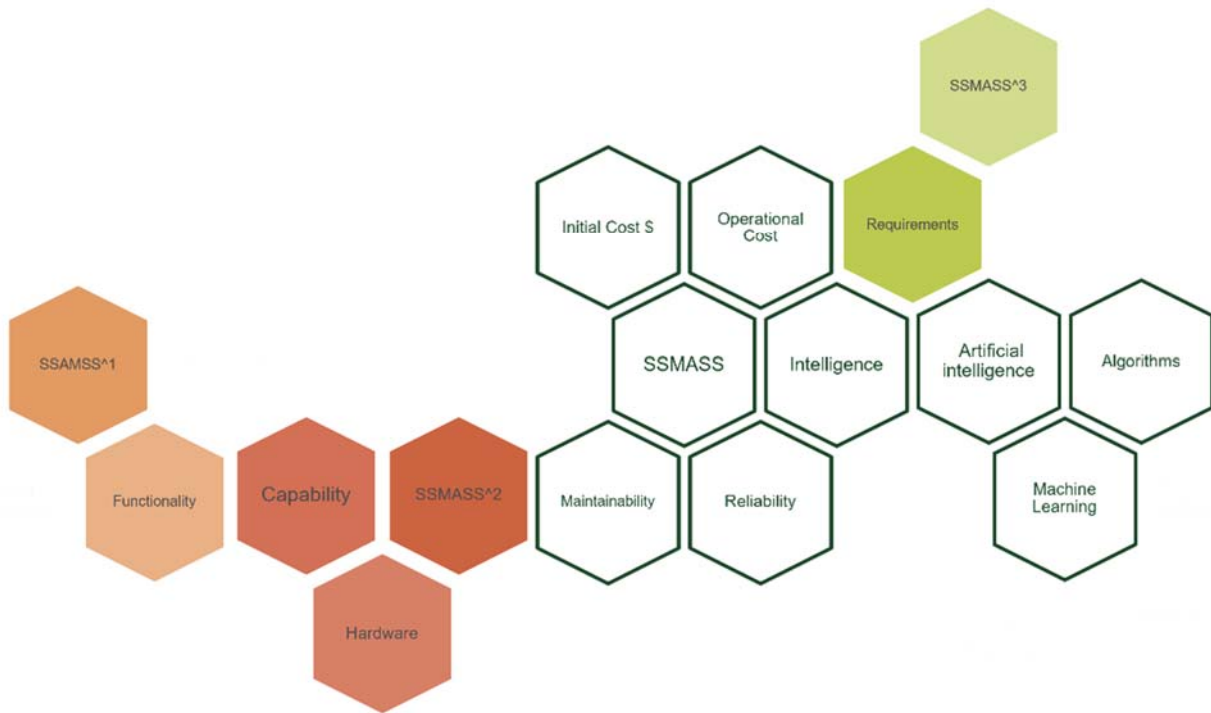


Figure 37: Starting-Initial, Current and Future Views of SSAMSS

## Connecting the Complex Pieces Through Complicated Relationships



*Figure 38: SSAMSS<sup>1</sup> - SSAMSS<sup>3</sup> Initial Agent Model Based Model (ABM)*

As the complexity of SSAMSS starts to take shape, furthering those connected nodes becomes critical to assuring that there is not any unnecessary deviation, and that relationships, interactions, linkages, and interfaces stay connected between all aspects and tools. From the initial building blocks which were developed under simple requirements to more complicated types of requirements e.g., operational, functional, performance, interfaces, etc., a clear picture starts to take form of the products direction and magnitude. Agent-Based Modeling (ABM) through the pillar-slice perspective can have significant utilization through this specific tool. As shown in Figure 38 the ABM tool provides a lot of perspective and insight to any areas that connect SSAMSS as a product and an enterprise by showing the complicated network of nodes

and complex relationships. As shown in the next Figure 39 SSAMSS starts taking directions regarding potential developments such as gap assessments that naturally start to progress. These gaps, opportunities or constraints are identified

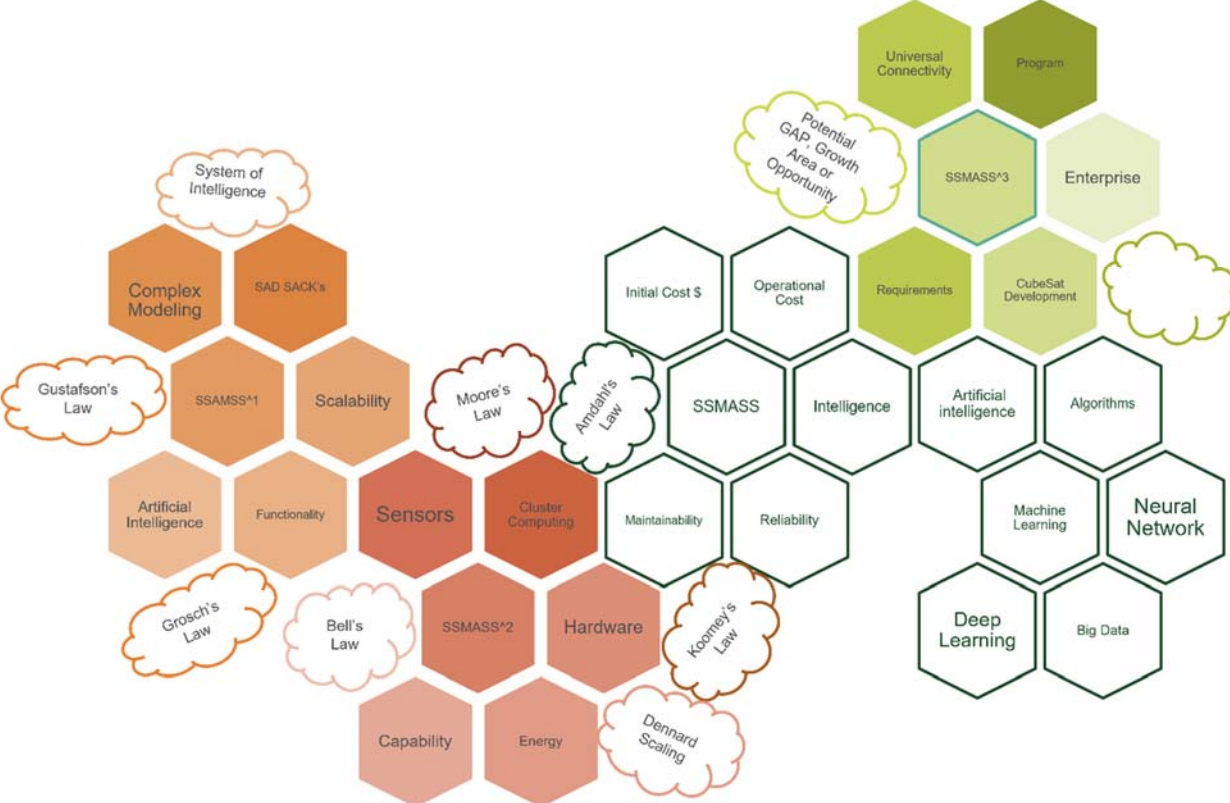


Figure 39: SSAMSS<sup>1</sup> - SSAMSS<sup>3</sup> ABM Current Development Programs, Models and Additional Nodal Connections v

as potential laws, technologies, software, or other types of inputs/outputs that feed into the ABM tool. Utilization of the ABM tool instead of just pillar-slices become more appropriate when perceived as nodal relationships. These nodes are intertwined as hexagonal shapes that identify complicated relationships and gaps which are shown in Figure 39. There are areas that are examined but not identified currently in the ABM as they are not critical to SSAMSS. The following Figure 41 continues to grow on these ideas as visibly showing the nodal relationships connected by a link providing magnitude and direction. These complexities are critical in understanding that these relationships are direct or indirect between the nodes. This

identification can be simplified to formulate further understanding-mathematically of any opportunities in developing the product through simulations and analyses. The ABM model from the nodal perspective provides the ability to see with clarity in turn identifying another opportunity and/or constraint i.e., Gustafson’s law. In this section, the law is not integrated into the simulation or the model, but it is collected with intentions of integrating into the simulation and running under analysis in the future. Gustafson’s law as shown graphically in Figure 40 or mathematically in Equation 8 could be a critical simulation factor in the future.

$$\begin{aligned}
 S &= s + p \times N \\
 &= s + (1 - s) \times N \\
 &= N + (1 - N) \times s
 \end{aligned}$$

Where

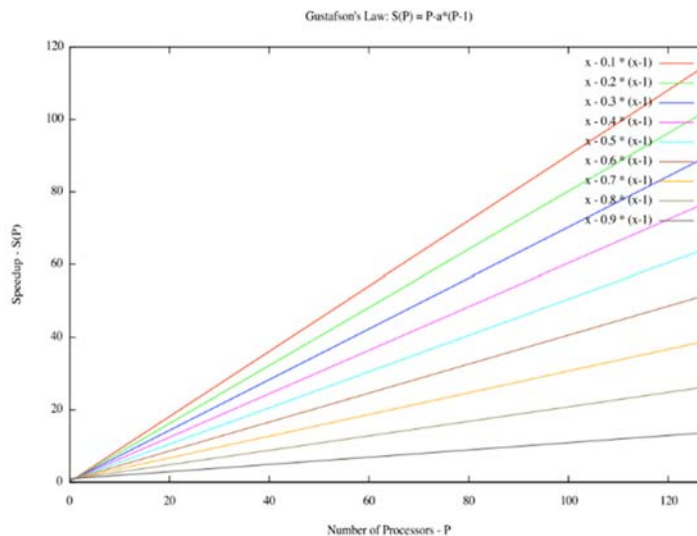
S is the theoretical speedup of the program with parallelism (scaled speedup).

N is the number of processors.

s and p are the fractions of time spent executing the serial parts and the parallel parts of

*Equation 8: Gustafson’s law*

the program on the parallel system, where  $s + p = 1$ ;



*Figure 40: Gustafson’s Law as a mathematical formula [16]*

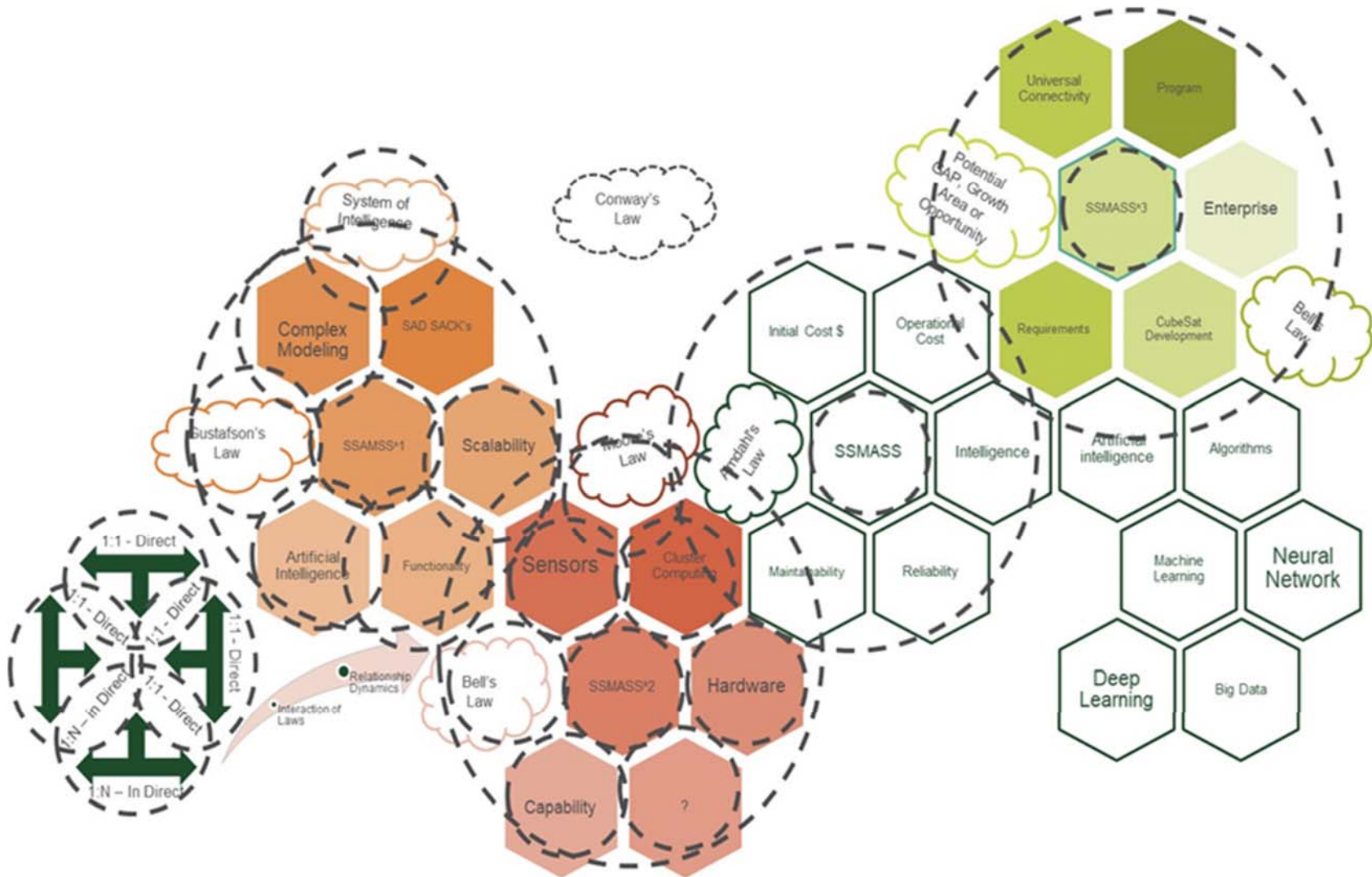


Figure 41: SSAMSS¹ - SSAMSS³ Enterprise: Current ABM including Dynamic Relationships, Interactions, Gaps, Opportunities, Constraints

## Complex System Dynamics Model

The concept of SSAMSS, although not complex, is complicated due to the multitude of informative layers intertwined between the overall development of the product levels as a whole system-of-system. The complexity comes from the overarching process of controlling and assuring that there has been proper assessment of why certain choices were made in the development of the sensor surveillance system resulting in a complex systems dynamic model regarding the products rippling effects. Analysis paralysis is overcome by a value-added approach at this critical point of the product development using the complex systems dynamic analytics model to further understand critical details. As a complex systems dynamic model starts to take shape you can see the relationships-connectivity between the domains, inputs, outputs, equations, formulas, and variables connecting as shown in Figure 42.

Through the initial causal loop model a reflective complex system dynamic model is created representative of SSAMSS as a product that interacts with several domains. Those domains interact between the systems-of-system levels and by creating a complex model the whole product can simulate estimated measurable and mathematical relationships between the domains, variables, constants, indirect and/or direct relationships that can simulate outputs. The visual display of connectivity from Domains, measures-mathematical model, and parameter-ed portion of the complex systems dynamic that are intertwined with the hardware and software reflecting the impacts of the sensing surveillance system in relation to the environment. Figure 42 displays hypothesize environmental relationships that impact the SSAMSS products, systems, components,

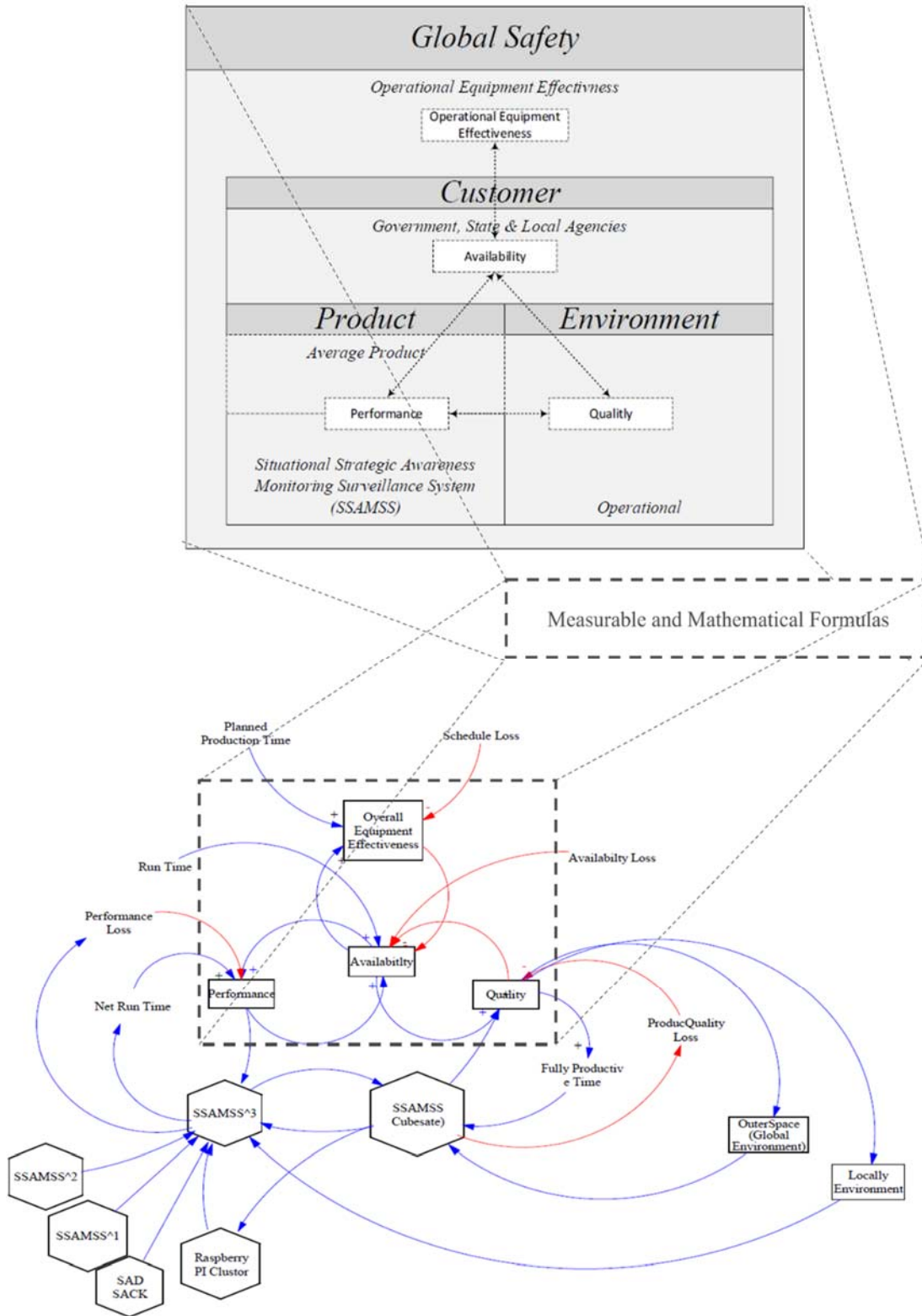


Figure 42: SSAMSS<sup>1</sup> - SSAMSS<sup>3</sup> – Complex Systems Dynamic Model Associated to Domains/Parameter Diagram parts, and variables in a butterfly ripple effect i.e., cause-and-effect. The cause-and-effect

relationships in the model can run some simulation-able portions providing evidence of correct linkages between relationships and variables shown as indirect ('-') or direct ('+') relationships between distinct types of variables. This shows the not so obvious global layered connectivity between all the systems through the domains relating back to 1. Performance, 2. Availability, 3. Quality and Overall Equipment Effectiveness.

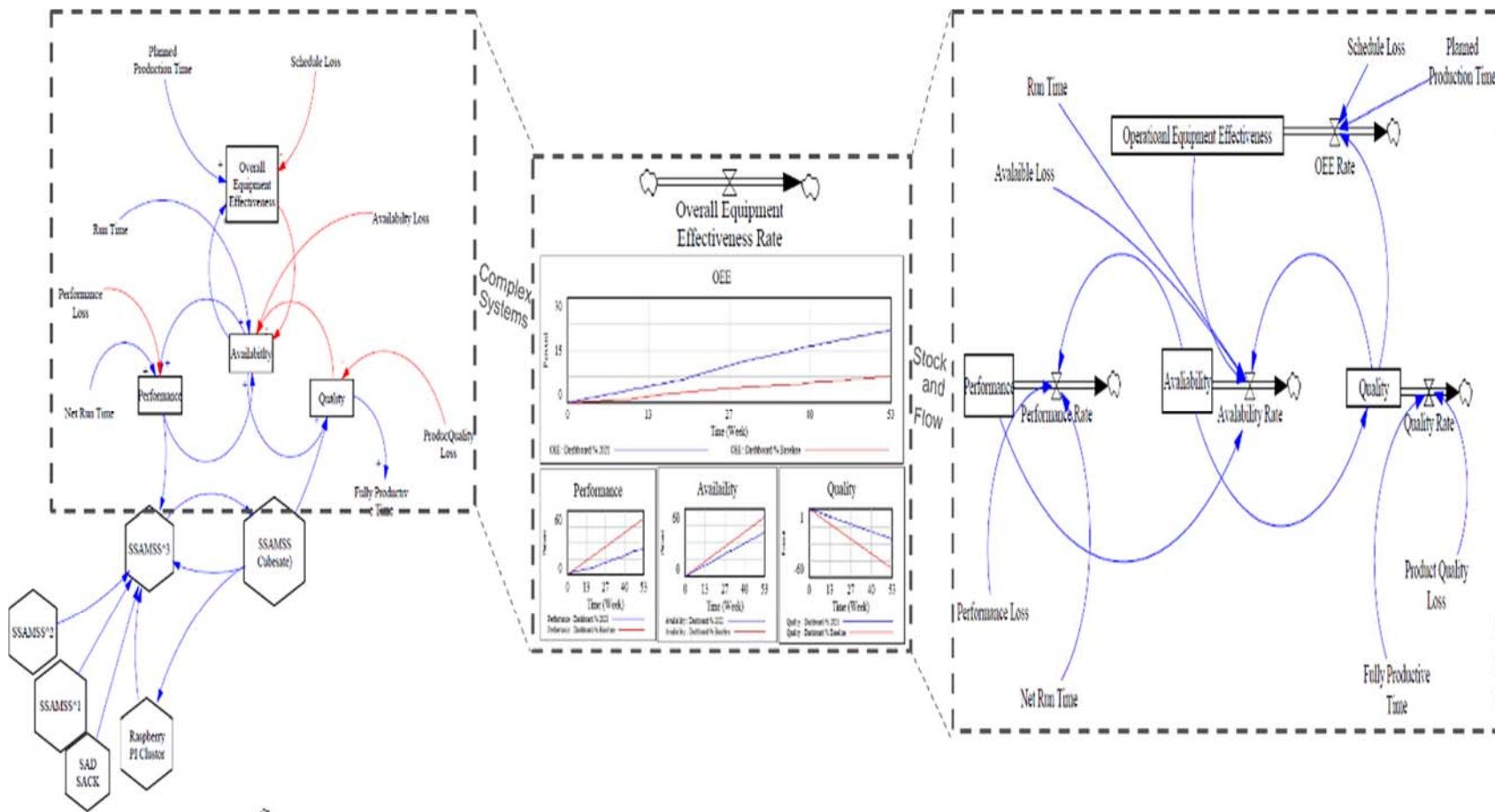


Figure 43: Stock & Flow Model of Current Complex Model

## Stock & Flow Dynamic Models

Figure 43 the transparency is incorporated into an estimated (hypotheses via pseudo-random normal distribution placed in the Vensim simulator) simulated view of the type of data that will be collected from the model showing baselined and projected against variable information, OEE, availability, performance, and quality. This feeds into the Stock and Flow diagrams model which can be used to run discrete and/or continued simulation in this case resulting in analytical data outputs. These models can be used to show rates between key parameters associated with SSAMSS through the enterprise proving that the products are meeting its desired numerical values to assure market and customer confidence, validation, and verification. This processing of the analytical-simulation tools can be used to support funding and/or further evidence of the development when comparing SSAMSS and SAD SACK. As shown in

Figure 43 a comparable baseline vs projected rates dashboard is simulated against the hypothesized complex and stock-n-flow models.

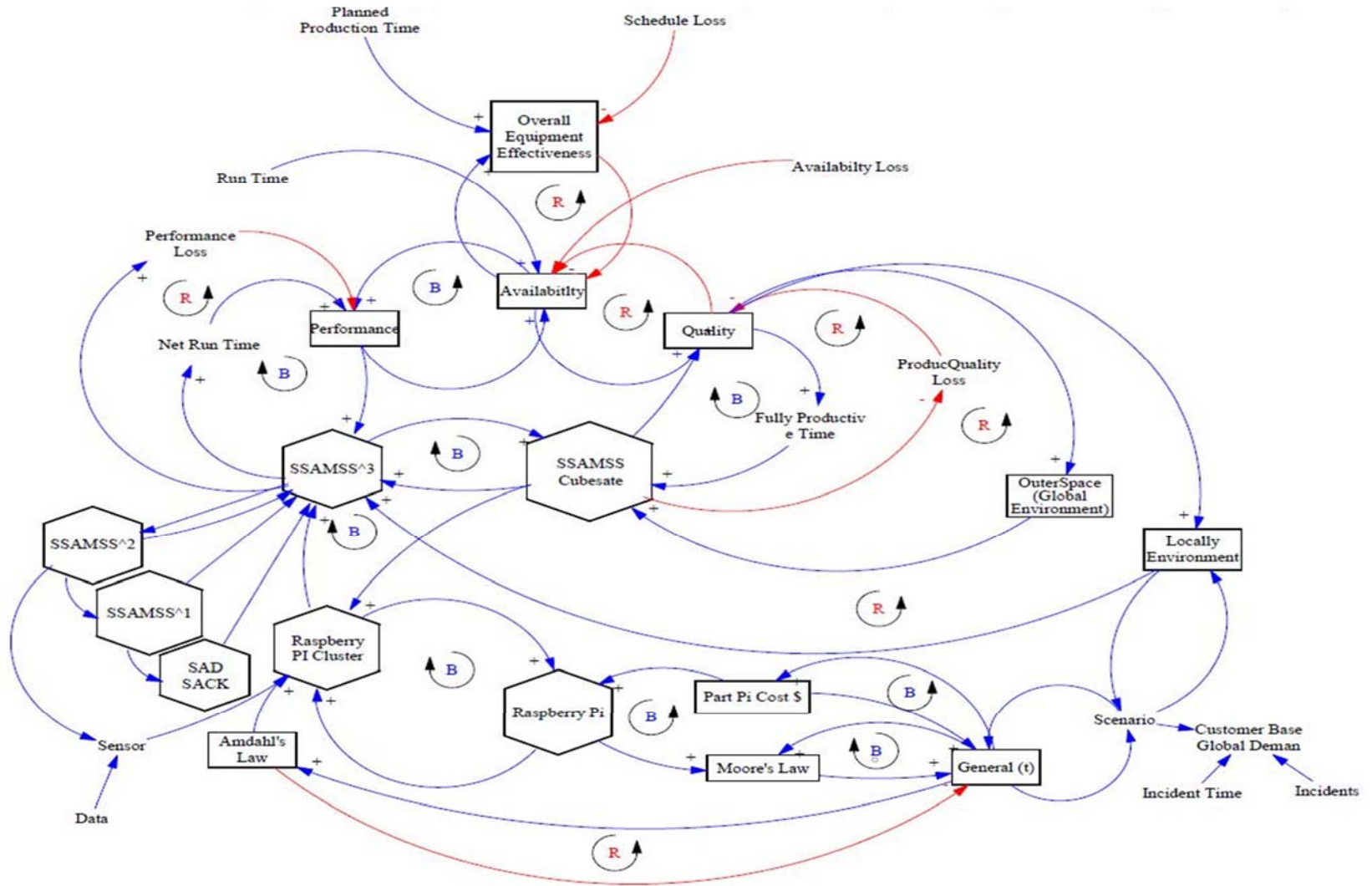







Figure 44: Full Current Complex System Diagram Model - + =; -, R, B, Rate with Partial Model Analyses

## Causal Model – Butterflies

Table 14: Legend for Casual and Stock and Flow Diagrams [18]

	Read as W causes Z with +ve link polarity or mathematically as $(\partial Z/\partial W > 0)$ . If the cause increases, the effect increases above what it would otherwise have been.
	Read as A causes B with -ve link polarity or mathematically as $(\partial B/\partial A < 0)$ . If the cause increases, the effect decreases below what it would otherwise have been.
	Read as X causes Y with +ve link polarity but only after some delay.
	Label to indicate a balancing feedback loop.
	Label to indicate a reinforcing feedback loop.

Systems Engineering is an available tool to create perspective to the remote sensing surveillance systems. That clarity of the SSAMSS as a product is reflected by a simulate-able model detailing everything including any updated relationships as shown in Figure 44. This up-to-date fully developed complex system model provides a focus view of balancing (B = Balance) and equilibrium (Reinforcement) loops throughout the dynamic relationships. Further in-depth understanding of these relationships is developed to show positive and negative loops as diagrammed in figure 29 and described in Table 14. A principal element to all these tools is linking them together as an entirety creating a graphical representation that is dynamical simulate-able per global and nodal (variables) relationships. The creation of a complex systems dynamic model related to SSAMSS provides value as the simulated vs collected data will change as it starts being collected over time controlling the butterfly effects. The analytical data through the hypothesized relationships initially will be collected in portions, partial-analysis, pseudo-random normal distribution i.e., simulating Moore's law as a portioned-out portion. A pseudo-random number generator created in MATLAB produces estimated capabilities of global incidents comparable to

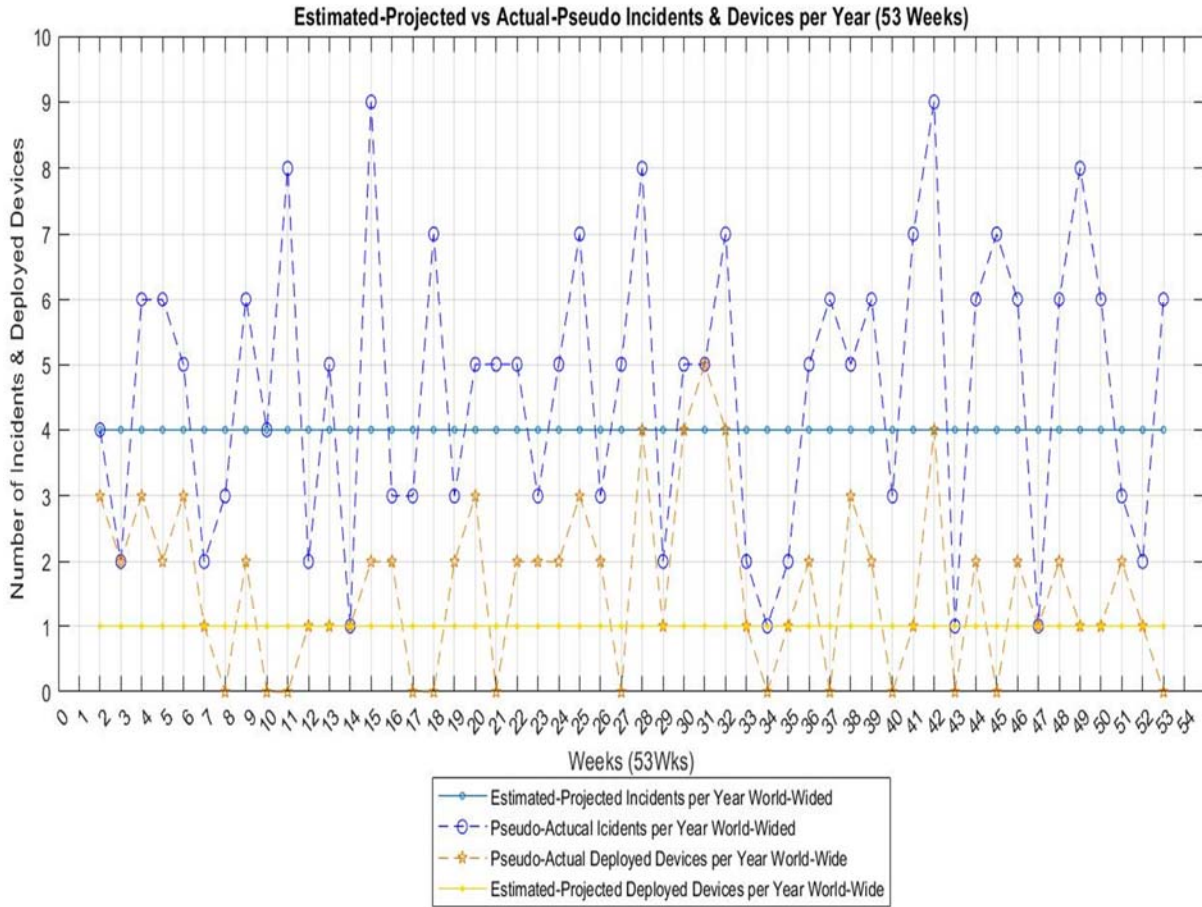


Figure 45: MATLAB pseudo-random number generated incidents and demand [6]

customer demand over a span of one year (53 weeks) as shown in Figure 45. The data sets take actual incident information collected from IAEA reports at random generation an expected incident resulting in an average over the span of one year [6]. As the product is developed into a smart surveillance system that is capable of remote sensing and mobile imaging with optional sensory data capabilities. This mobile configurable product has applications that could have been used to safeguard sensitive materials referencing an incident that happened in Lebanon with the explosion of fertilizer-ammonium nitrate. For our case study, the incidents of depleted uranium and depleted materials that go missing globally pose a risk which will be used to feed our simulate-able model. The studies from IAEA estimated an average of 200 incidents per year globally, 2013-2018 [6]. Incidents on a global scale are compared against as SSAMSS being a deployable product

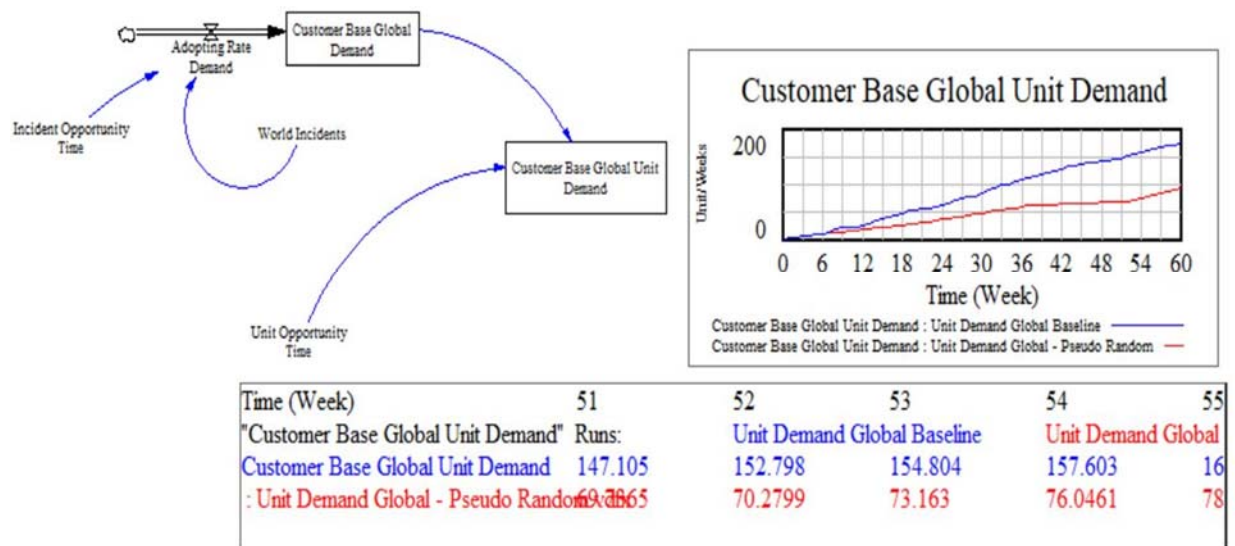


Figure 46: Partial-analysis Pseudo-random Analyses of Projected Unit Demand vs Actual Unit Demand

can counteract in an actual vs projected global incidents vs deployable SSAMSS units reflective of a supply and demand simulation. The starting MATLAB simulation analytics showed that there are roughly 200 incidents globally with an average of 4 incidents per week based on the IAEA data when run against the pseudo-random number generator over the span of 1 year (53 weeks) as shown in Figure 45. Assessment of the demand rate actual vs projected unit product to meet incidents will be needed to assure accommodation per week. A rough estimate of one unit per week was simulated against the globe incident values. The pseudo-random number generator is random (simulation script range: Min=0 between Max=6) being anywhere from 0 to 6 units per week when compared against Figure 45 values. As shown in the complex dynamics model portions of the model are incorporated to help initiate a feeding process of the overall model as shown in Figure 46. Although just a part of this model can be simulated it can replicate what was initially assessed through MATLAB generator by verifying and validating similarity in values after several simulations. Feeding SSAMSS model is a scenario that will provide additional insight and create further depth of understanding between the customer, market environments and SSAMSS

capabilities. As completion of a portion of the complex model provides the ability to run pseudo-random uniform distribution in a selected portion of the model as shown in Figure 47. As you can see the world incidents is reflected of the MATLAB model with 208 projected (167) incidents/53 weeks or roughly 4 (3.15) incidents per week which could be coupled with a Monte Carlo analysis for refined values.

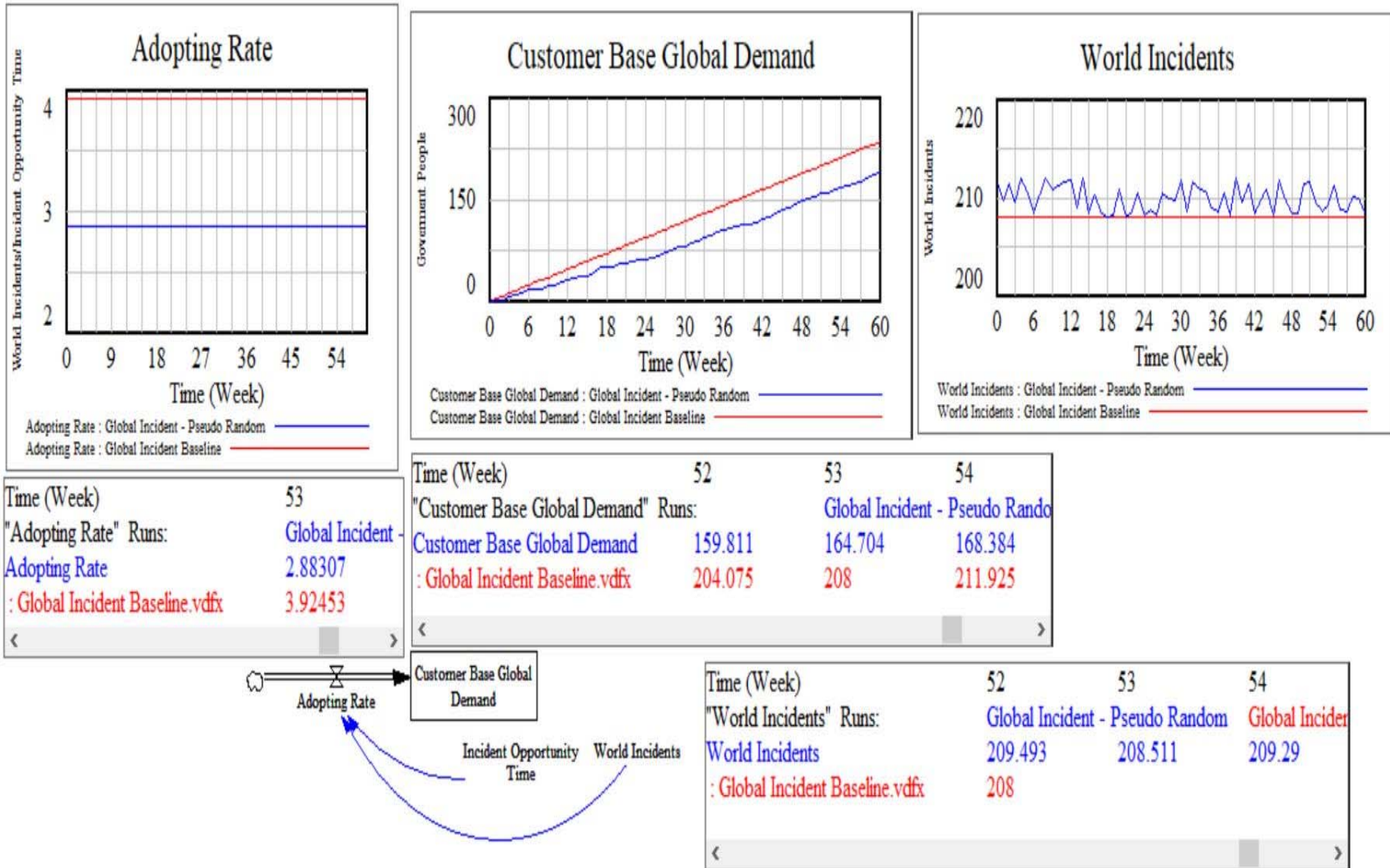


Figure 47: SSAMSS Partial-analysis Pseudo-random Analyses of Actual Projected Incidents and Actual vs Projected Customer

## Sensory Data makes SSAMSS Matter



*Figure 48: Beirut explosion of Ammonium Nitrate Investigation [19]*

Through statistical process control-partial analysis provides numerical data with the ability to identify quantitatively where the units need to be deployed throughout the globe at a local level.



*Figure 49: Beirut Explosion*

As a smart surveillance system with remote sensing and mobile imaging capabilities simulated

scenarios as shown in Figure 46 provide environmental interactions with unit demand regarding deployment responses. The simulator provides analytical perspectives comparable to SSAMSS as a deployable product vs customer base global demand. Through the estimated data there may



*Figure 50: Pi Temperature Sensor*

be as high as 200 incidents globally (Figure 47) as predicted by the MATLAB simulator within the span of 1-year (53 weeks) when compared to the Vensim simulator the stock-n-flow model projected an estimated 155 incidents (global unit demand)/53 weeks (Figure 46). With coverage of units simulated to be roughly 155 incidents per year an estimated 74 SSAMSS units would be able to be deployed that first year (Figure 46). SSAMSS is a product needed in order to safeguard the steady growth of predicted scenario of incidents per year as hazardous materials continue to become and issues throughout the world in regard to surveillance, monitoring and controlling. As a critical product it can help to protect humanity, hazardous materials and reduce incidents that may relate to exposure or explosions i.e., Beirut explosion of Ammonium nitrate [19 and 20] and/or potential risks of dirty bombs. This is where SSAMSS mobile imaging and remote sensing capabilities at cost come consideration as a potential product to assist in hazardous material safeguarding and surveillance. As shown in Figure 48 there is ammonium



Figure 51: Pi Thermal Camera

nitrate left unguarded-unprotected while in an unmaintained storage facility. SSAMSS would be able to be a product helping oversee hazardous materials in similar situation throughout the globe to increase a proactive response to assure that incidents of unsafeguarded materials similarly to the situation in Beirut are constantly monitored effectivity and at cost. In Figure 50 a

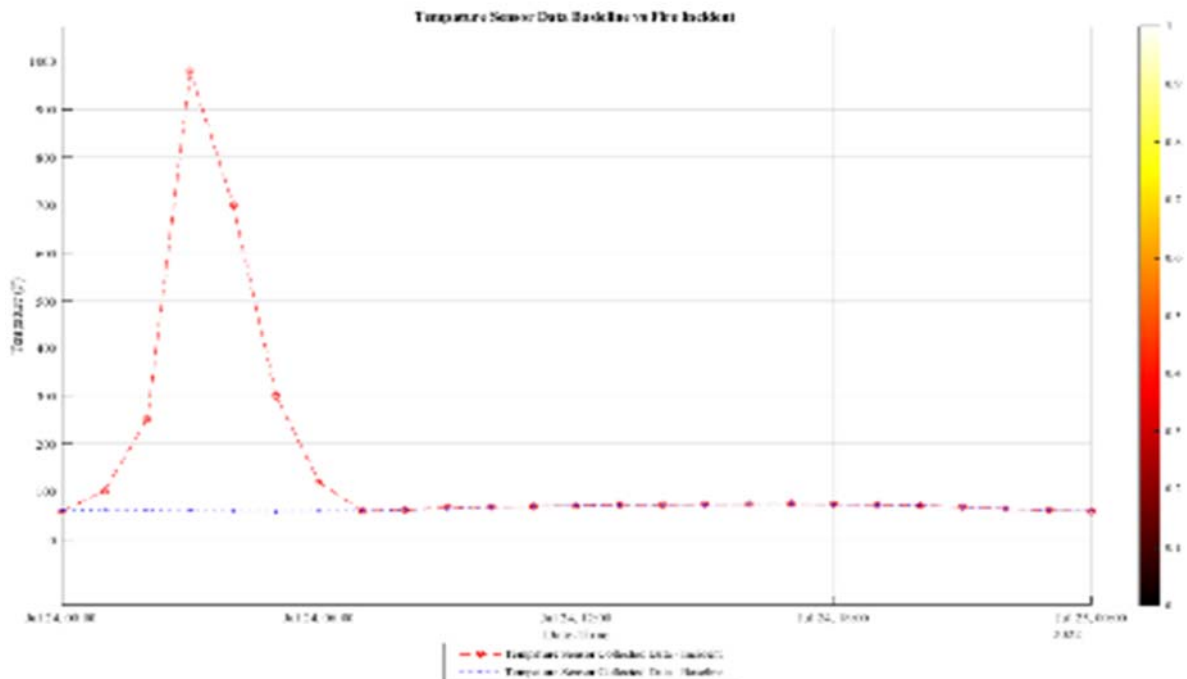


Figure 52: Pi Temperature Sensor Collected Data Baseline vs Incident.

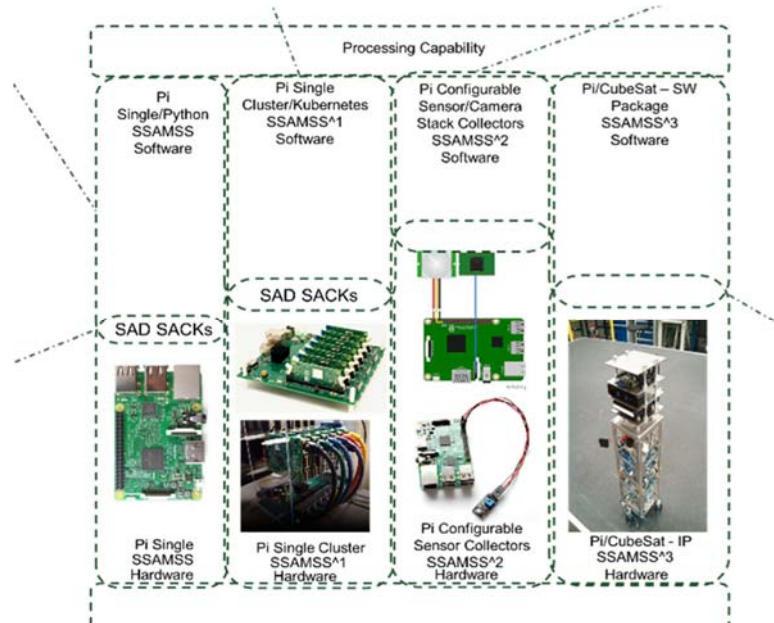


Figure 53: SAD SACKs Protocol Initiative

low-cost thermal sensor could collect temperature data when integrated into a Raspberry Pi Collector (Raspberry Pi per unit cost \$8.00 – \$35.00/ unit) that would be linked to a SSAMSS cluster. SSAMSS enterprise which is a cluster of Raspberry Pi's and collectors of data in real-time would be graphed, processed, and respond to the sensor data. The spike in the graph showing a delta in temperature-fire change that increased quickly as shown in Figure 51. Continuing to support the remote sensing and mobile imaging capabilities of SSAMSS you can see a thermal camera coupled into the collector gathering image data as shown in Figure 51 and Figure 54. An example of thermal data of people and a fire has been shown and processed as if SSAMSS was collecting and processing the data. SSSAMS coupled with a thermal sensor and a thermal imaging data could notify command and control quickly to react and respond to any potential incidents regarding hazardous materials such as overseeing ammonium nitrate or depleted uranium as shown in Figure 54. At a low-cost thermal temperature and imaging sensors start collecting data as shown in Figure 52 and Figure 54. SSAMSS enterprise specifically SSAMSS square and the CubeSat technologies starts processing the data that is collected. The

data been collected locally in turn becomes information and transmitted globally back to command and control to assure reducing any potential incidents. Those potential incidents are now observed as they occurred in a proactive and real time approach as shown in Figure 53. That information would need some sort of coupling to assure that the hardware, software, and information is distributed appropriately to command and control requiring the development of a protocol specific to SSAMSS as a unit which is further discussed in Section SAD SACK Protocol.

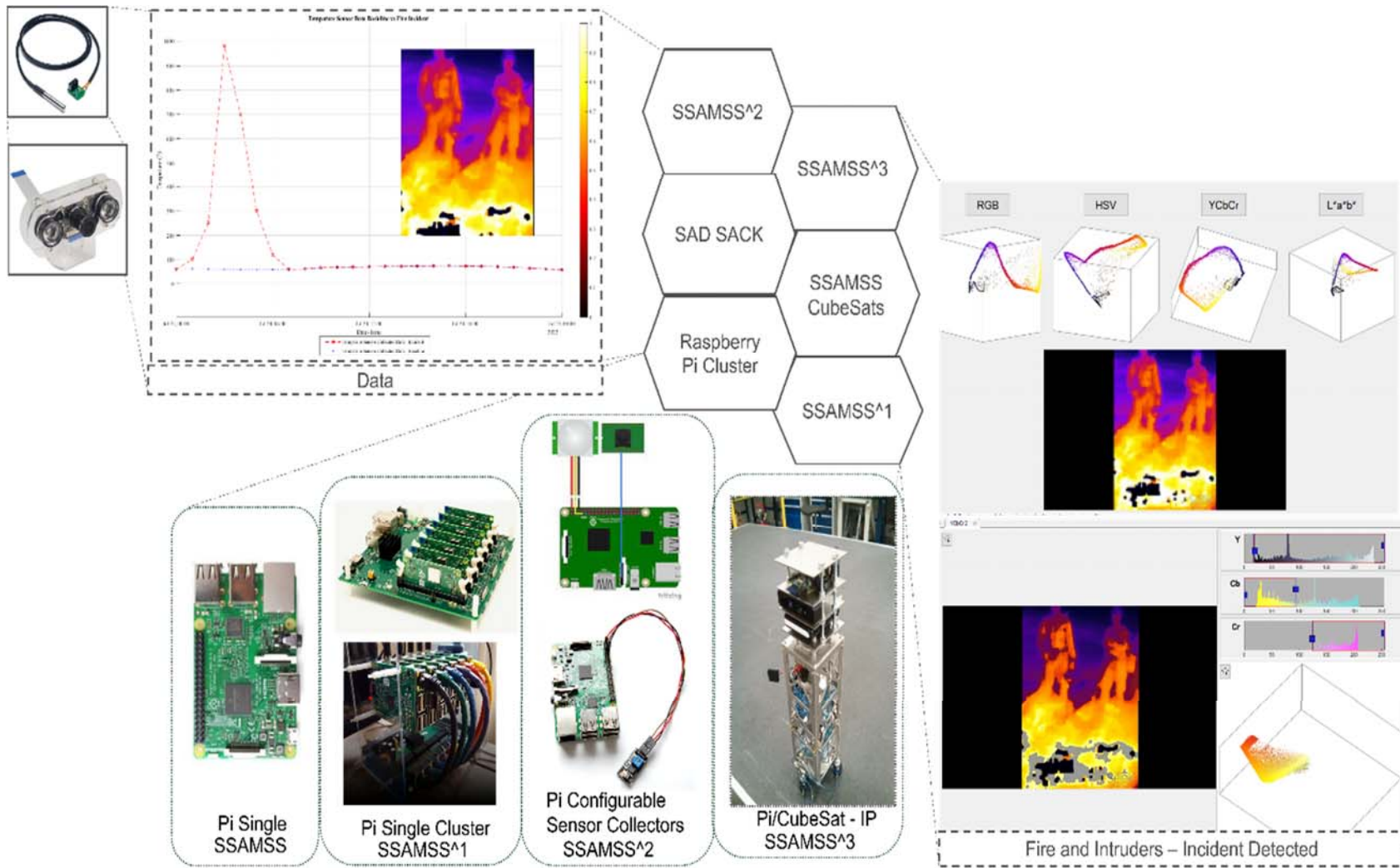


Figure 54: SAD SACK Protocol Initiative- SSAMSS Sensor Types, Sensor Data, Clusters and CubeSat and Processing information

## SAD SACK Protocol

The complexity of a smart monitoring surveillance product such as SSAMSS uses a cohesiveness of parts, components, subsystems, systems, and that eventually come together as a system-of-systems i.e., enterprise. The tool sets used to identify and develop the product and enterprise of this complex system are used to communicate, guide and proof that the capabilities are going in the right direction i.e., ABM, complex system dynamics models, complex causal loop models and diagrams. This tool set align throughout the system engineering model reinforcing through assurance that functionality, capability, and requirements satisfy the customer through a connectivity between the hardware and software relative to systems, subsystems and components and parts through a protocol called Situationally Aware Deployment of Sensing Analytics, Communication, and Knowledge (SAD SACK). This protocol that is being introduced will assure interactions between the hardware, software, and transportation of the data-information between SSAMSS as an entire product i.e., Sensors, Clusters through CubeSats as shown in Figure 55. As a in between approach the SAD SACK protocol will act as a medial handling the software and hardware though the product levels. SAD SACKs initiative is primarily a set of rules and regulations that governing, dictated and guide the exchange, transmission, and transfer of data, information, command, telemetry between devices, sensors, and clusters. With additional considerations to other hardware and software driven systems, subsystems, components, and parts reflecting Energy, Data, Signals, Sensing, Sensors, and Materials

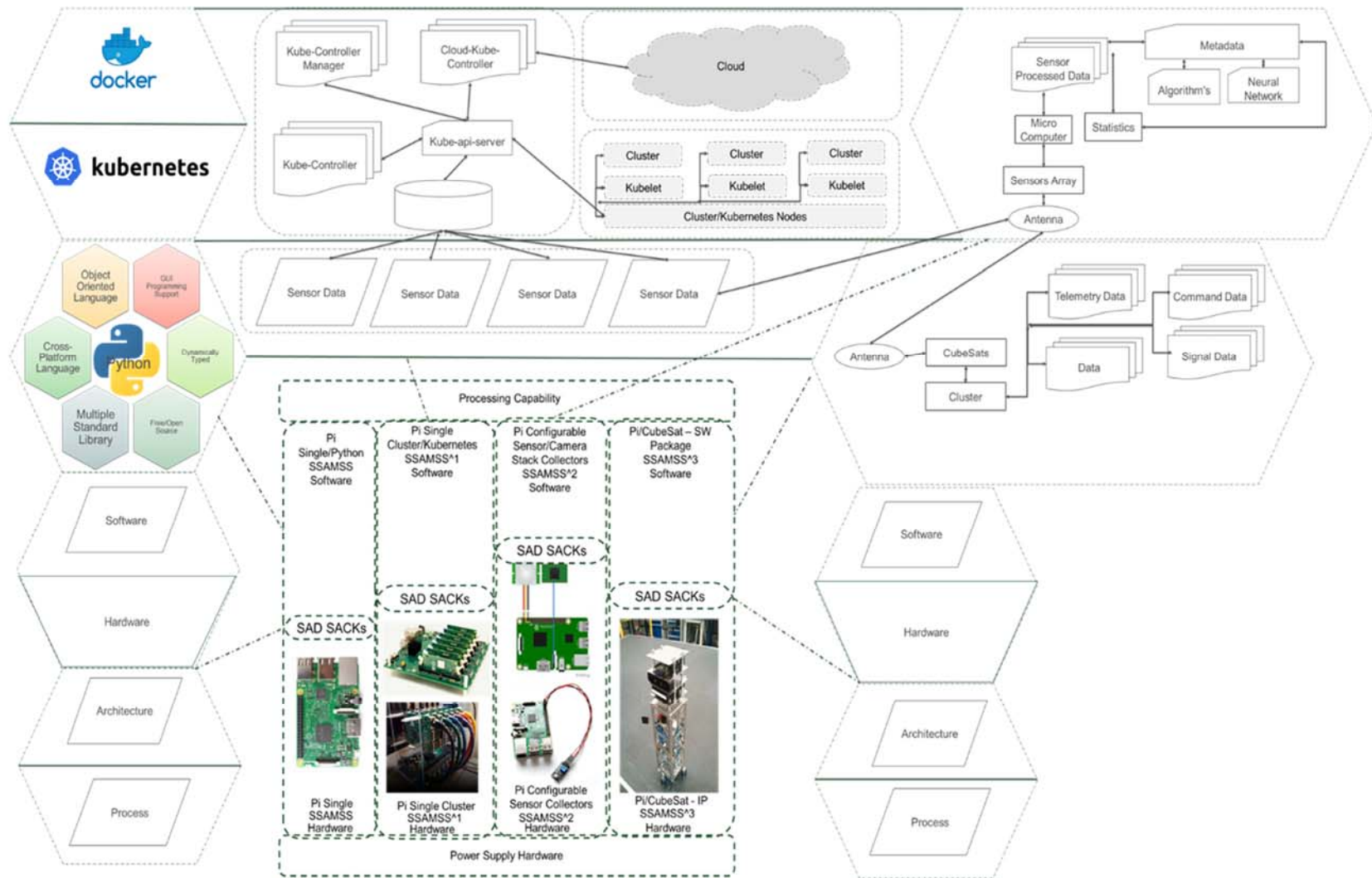


Figure 55: SAD SACK Full Protocol Implementation; Software, Hardware, and Logistic

## Chapter 3 Conclusion

It has been shown through the complex systems dynamics model and the stock and flow model that there are advantages capabilities of pulling out measurements collected through simulated formulas and relationships reflecting portions of SSAMSS as a product. Through careful vetting specific scenarios are developed through real event data. That data feeds into the model reflecting actual environmental and incidents that project supply and demand situations that SSAMSS as a product would encounter through a quasi-random simulation.

- Data Demand: Assessment of actual incidents provided by IAEA it was estimated that there were roughly 200 incidents globally per year (roughly 4 incidents per week per 53 weeks).

The results will be discussed starting with the actual statistical data used to start the simulation or initial needs analysis through MATLAB simulation. To assure that SSAMSS as a product is needed, supply and demand, a pseudo-random number generator calculated demand.

- MATLAB Demand: Pseudo-random number generator simulated demand roughly 208 incidents globally per year (roughly 4 incidents per 53 weeks)
- MATLAB Supply: Simulated Supply roughly Random Distribution Command product supply SSAMSS at 90 units per 53 weeks.
  - This simulation does not calculate any queuing of units that may feedback and/or decommissioned in-out of the supply chain which in the future will be considered.

Through the quasi-random MATLAB simulation, a scenario is created that will feed the complex system dynamic model that would also feed our stock and flow model to see if we are able to

replicate the collected data in a Vensim simulator. Replication between MATLAB and Vensim data was produced and comparable with the complex system dynamic model:

- Comparison between data vs MATLAB vs Vensim demand
  - This was done to assure similarity in results when compared across actual data vs MATLAB Simulations vs Vensim Simulations to assure simulation is reasonable.
- Vensim Demand projected: Demand simulated calculated supplying that demand with SSAMSS at 164.70 units per 53 weeks (roughly 3 units deployed per 53 weeks) based on government customer demand.

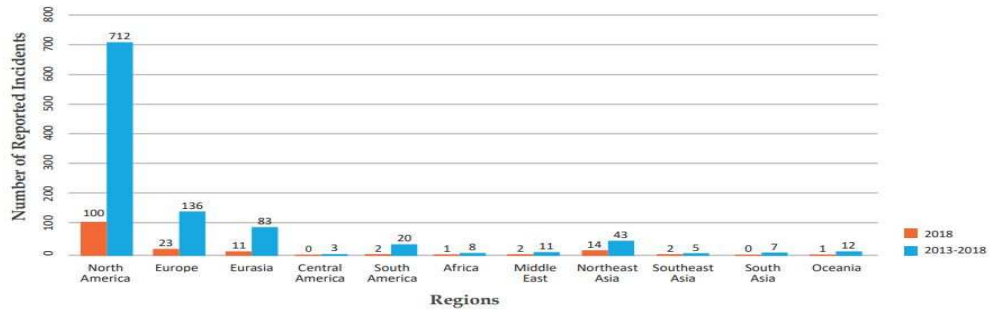
We then ran another simulation showing actual customer global unit demand 157. 603 vs actual demand of 76.153 units which matched the initial MATLAB values. The scenarios fed the SSAMSS complex systems dynamic model and ultimately started another portion Moore's law which showed a baseline vs intel transistors per year capability.

- Vensim Demand: Demand simulated calculated supplying that demand with SSAMSS at 164.70 units per 53 weeks (roughly 3 units deployed per 53 weeks) based on government customer demand.

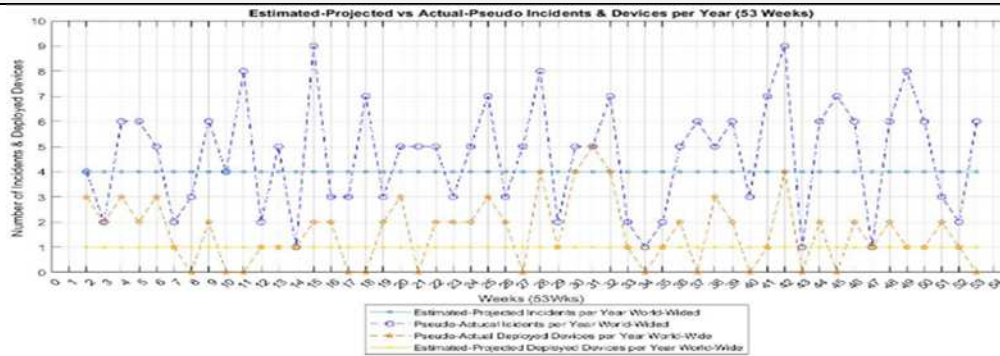
This is a great start as we will be able to tie the costs per Raspberry Pi to a comparable product per microprocessor as detailed in table 2. Bring a system from initial need to prototype consists of a multitude of tools, process, approached and models. The Agent-Based Model is a qualitative tool. The quantitatively tool could be used to integrate mathematical formulas i.e.,

## Collected Data by AIEA

Figure 3. Reported Incidents by Region



## Pseudo-random number generated data via MATLAB



## Pseudo-random generated data via Vensim

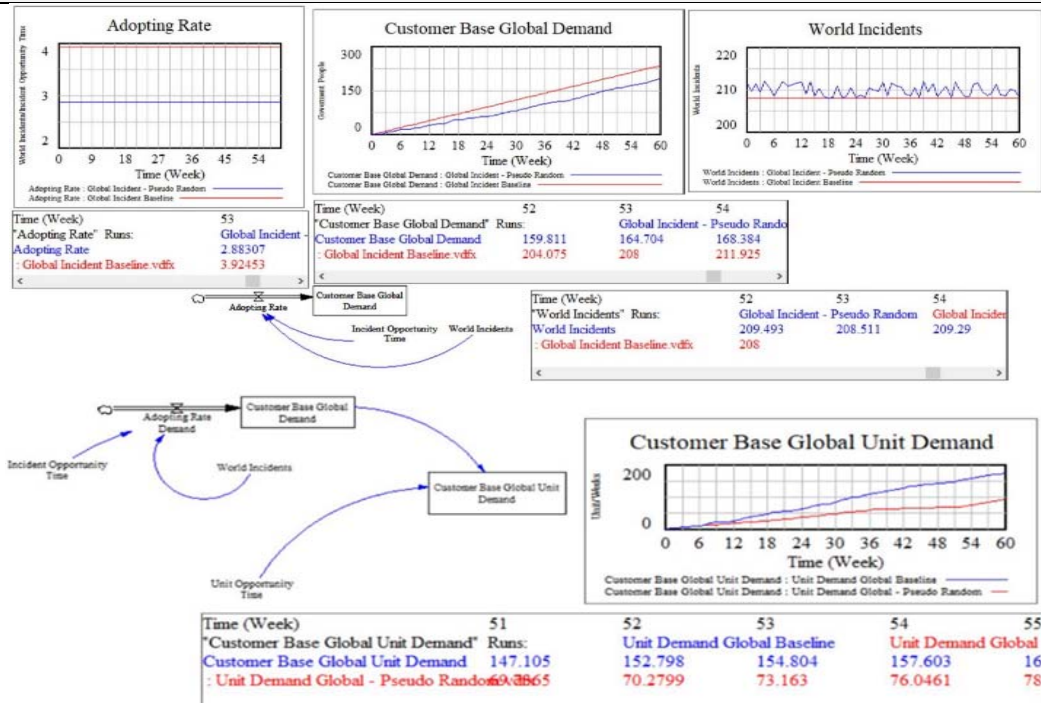


Figure 56: Collective comparison between actual vs projected

Moore's, Amdahl's, Gustafson's, and even Bell's into a mathematical model. That model could calculate two critical variables; 1. Pi Part Cost \$ and General (t) which are represented in the Complex. Causal Loop Diagram model.

That tool while complex it show relationships and provides quantities vs components perspectives by indirect and direct relationships (providing indirect/direct and discrete and continuous modeling potential). Stock and Flow models that show variables, components, and rates between those parts of the model and a deeper perspective of the current Complex model. Above all this development has provided deeper understand and confidence in why and how SSAMSS should be develop along with current incite to Functional, Technical, Behavior, Performance, Capabilities, Interfaces and eventually tying them to associated costs. Those two relationships would be coupled with the Pi Cluster to optimize processing power and cost. This association are impacting eventually be applied to the dynamic models. Also providing current and possibly future development of areas of interest with SSAMSS<sup>1</sup> - SSAMSS<sup>3</sup> and the new idea SAD SACKs. Assuring that there's a need for a new system in a practical and economical way. The singular approach with lack of utilization of technology coupled with economic factors. SSAMSS is developed as a system of systems to assist safeguarding sensitive materials with intelligence technology and economical. The system concept meets primary characteristics that are balances, beneficial and economical by utilizing 1. Systems Engineering, 2. Model Based Systems Engineering, 3. Complex System Dynamic Models, 4. Causal Loop Diagrams, 5. Stock and Flow Models. These tools support the development of SSAMSS<sup>1</sup> - SSAMSS<sup>3</sup> and SAD SACKs as shown Figure 56. SAD SACKs ties Python, Docker/Kubernetes [21], process and logics, hardware, and software.

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## CHAPTER 4

Conclusion – Is SSAMSS Worth creating as an Engineered Model when compared against the conceptual system designed?

## Introduction to Chapter 4

The principal objective of this chapter is to finalize a decision whether SSAMSS as a conceptually designed product and enterprise should be considered as a viable option that should be physically engineered resulting in potential future manufacturing. As a smart, cost effective, and materials safeguarding product. Through the systems engineering approach-methodology will be detailing the last portions of research and if the product should ultimately become an engineered model. The engineering model will not be built but will be available for future students to continue, build and fully architect. Reviewing the last required portions of the systems engineering life cycle as references to in Figure 57 to provide a closing decision. A final assessment of sensor and configuration options estimated data-packets and sizes, AI-

TinyML, additional physical model details, suggested testing, validation, verification, and projected retirement-decommission approaches [1].

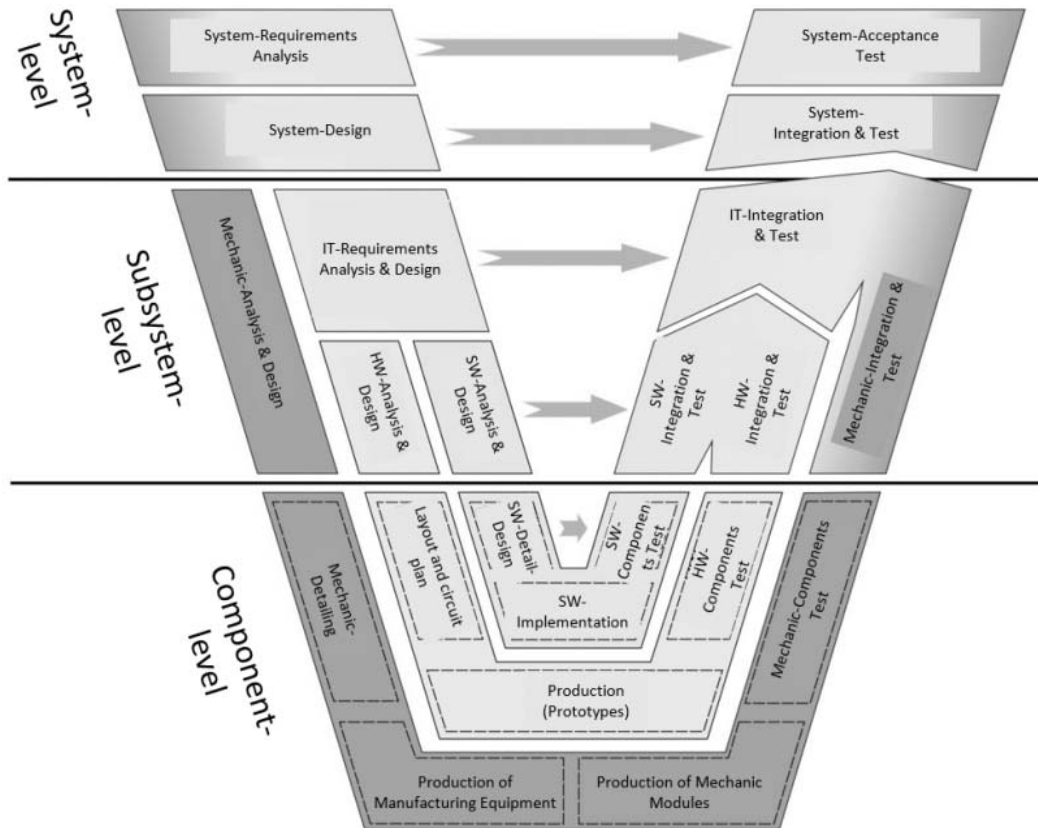


Figure 57: V-model by Bender [3]

Background

Through the referenced [2] system engineering life cycle the next portion needing to be reviewed are sensors. This initial sensor selection per category will assess the data produced from those sensors and sensor configuration options. A full complex model reflecting data points, documents, personal resources, and engineered physical model as references [3] will be developed conceptually. The V-models referenced in Figure 57 and Figure 58 are shown to

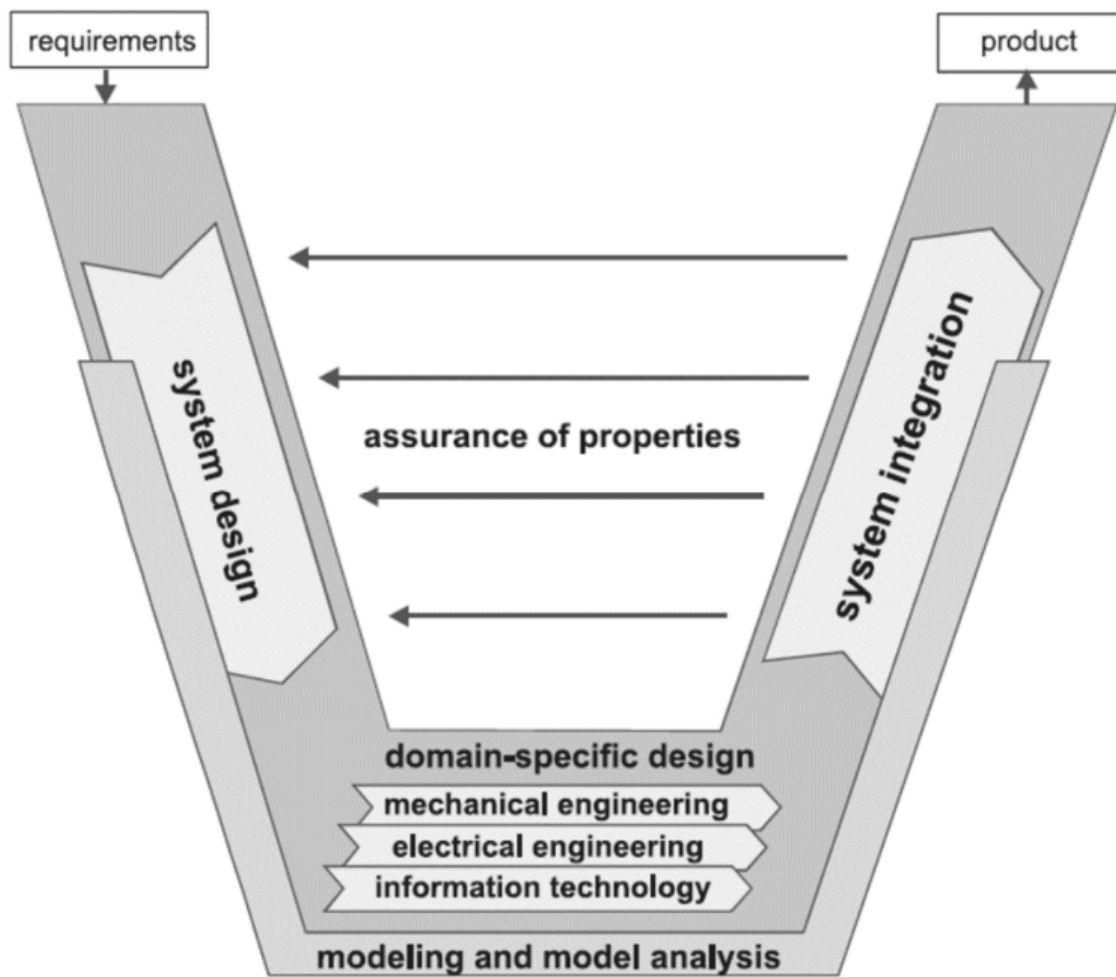


Figure 58: V-model by Bender [3]

provide a map detailing the product development. Assuring that the product is meeting its requirements by being developed appropriately to meet market and customer needs

competitively. The tools used throughout this research relate to portions of the V-model as a point of communication that is translated to the appropriate groups. It is also piecemealed between MBSE, SysML, V-diagram but with an overall focused approach regarding Systems Engineering approaches. To be able to create accurate models that use quasi-random simulations sequence mission statements had to be created closely relating to active vs standby incidents. The Mission Operational Scenario Statement and Sequence Table 15 was developed:

Table 15: Sequence of Events per State vs Detection Scenario description Summary


Scenario	Sequence of Events	State	Detection	Scenario description
<i>Mission Operational Scenario</i>	<ol style="list-style-type: none"> <li>1. SSAMSS Collector Detects</li> <li>2. Specific Sensors are activated.</li> <li>3. Activated Sensor starts collecting Data.</li> <li>4. SSAMSS Collector data is transmitted to SSAMSS Cluster</li> <li>5. SSAMSS Cluster processes SSAMSS Collector data using TinyML – Machine Learning, AI, Neural Networks and Algorithms</li> <li>6. Processes data become incident information.</li> <li>7. SSAMSS Cluster Transmits/receives to SSAMSS CubeSat</li> <li>8. CubeSat Communicates with global and local command and control.</li> <li>9. CubeSat uses micro telescope to image SSAMSS deployed unit</li> </ol>	Mission Operational	Active Incident	Mission operational scenario is when an active intruder and/or dangerous real-time event is happening around the SSAMSS enterprise (Maximum effort of the system communicating incident while collecting, processing, and informing command and control).
<i>Stand-by Scenario</i>	<ol style="list-style-type: none"> <li>1. SSAMSS Collector has no detection.</li> </ol>	Normal-Baseline	Non-Incident	Normal scenario is when a





	<ol style="list-style-type: none"> <li>2. Specific sensor is not activated.</li> <li>3. Sensors occasionally sends out pulse data.</li> <li>4. SSAMSS Collector pulse data is transmitted to SSAMSS Cluster</li> <li>5. SSAMSS Cluster processes SSAMSS collector data to assure there are not hardware failures.</li> <li>6. Processes data become hardware information.</li> <li>7. SSAMSS Cluster Transmits/receives to SSAMSS CubeSat</li> <li>8. CubeSat Communicates with global and local command and control if there is a hardware issue otherwise occasionally sending hardware status updates.</li> <li>9. CubeSat uses micro telescope to image SSAMSS deployed unit if there is a hardware-software issue that may need maintenance.</li> </ol>			<p>minimal to none actives are happening in real time around SSAMSS enterprise (basically pulse and generic data assuring system as an enterprise is functioning normally with no hardware-software issue).</p>
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## Product Sensors


Sensor configuration, sensor types, data types and data sizes are critical details needed to assure SSAMSS as a product can compete against its marketplace competitive systems. This information is critical to the overall system-of-system design which in turn effects the cost, processor needs, projected power consumption demand, and data transfer between SSAMSS clusters, SSAMSS Collectors, CubeSat systems and SAD SACKs protocols. Table 16 below lists primary and add-on sensors which will be assessed for product development. In order to build and develop an optimal SSAMSS Collector Sensor configuration option that is cost effective and viable to provide required material surveillance sensing safeguard measures. Additional information is collected to compile competitive sensors against each other. This will assure that the mission ops scenario is being met according to the best sensor selection through vetting of sensor details in a matrix that will coincide with the SSAMSS cluster.

*Table 16: SSAMSS Collector Sensor Selection Table*

Sensor Type	Visual of Sensor	Cost \$ per unit	Purpose of sensor (operating parameters)?	Primary configuration (critical to primary mission and/or scenarios)	Redundant, Add-on to configuration (Special case missions and/or scenarios)
Video/Camera					
1. Dorhea Raspberry Pi 4 Camera IR-CUT Night Vision		\$18.99	Video Camera – IR/Night/Day	Primary	Redundant

Camera Module					
2. Dorhea for Raspberry Pi Switching Day/Night Vision Video Module Adjustable Focus		\$16.99	Video Camera – Night/Day	NA	Redundant
3. MLX90640 Thermal Camera Breakout		\$65.45	Thermal Camera - -40 to 300°C detection with approximately 1°C accuracy	NA	Add-on
Other					
4. Gowoops 2pcs DHT22 / AM2302 Digital Temp Humidity Gauge Monitor		\$10.56	Temperature range: -40 °C ~ 80 °C, Humidity measuring range: 0~100%RH, Humidity measurement	Primary	Redundant
5. Diymore 10pcs DS18B20 18B20 TO-92 3 Pins Wire Digital Thermometer Temperature IC Sensor		\$8.99	Sensor Temperature: -55°C ~ +125°C	NA	Redundant

<p>6. BONATEC H 9 in 1 MQ Sensor Modules Kit Project Super Starter Kits for Gas Detection</p>		<p>\$20.99</p>	<p>Package Includes: MQ-2 Smoke Sensor, MQ-3 Alcohol Sensor, MQ-4 Methane Sensor, MQ-5 LPG Natural Gas City Gas Sensor, MQ-6 isobutane propane sensor, MQ-7 Carbon Monoxide Sensor</p>	<p>NA</p>	<p>Add-on</p>
<p>7. EPLZON HC-SR04 Ultrasonic Module</p>		<p>\$12.99</p>	<p>Detect and pick up audio</p>	<p>Primary</p>	<p>NA</p>
<p>8. Vibration Switch Sensor</p>		<p>\$7.05</p>	<p>Vibration sensor</p>	<p>NA</p>	<p>Add-on</p>
<p>9. HiLetgo HC-SR501 PIR Infrared Motion</p>		<p>\$8.49</p>	<p>Motion Sensor</p>	<p>NA</p>	<p>Redundant</p>
<p>10. Clock</p>		<p>\$8.99</p>		<p>Primary</p>	<p>Redundant</p>
<p>11. Radiation sensor – Geiger Cointer</p>		<p>\$40.36</p>	<p>Detection of 20mR/h ~ 120mR/h of gamma rays and 100 ~</p>	<p>Primary</p>	<p>Add-on</p>

			1800 off variables / points of the soft beta ray. The maximum count rate: 25 times / min		
12.GPS: HiLetgo GY- NEO6MV2 NEO-6M GPS Flight Controller Module 3V- 5V with Super Strong Ceramic Antenna		\$8.99	Tracks: Time, lat, long, alt, speed, heading, climb, err	Primary	NA

This will provide the best sensor type selection while provide valuable information regarding costs, data, information, and usage of the sensors. The sensor information needs to be understood in order to optimize SSAMSS Collector system as shown in Table 17. This will then be fed into another Decision Matrix (Pugh Matrix) that will assure the best configuration selection between the sensors.

Table 17: SSAMSS Sensor Collector Additional Details Table

Sensor Type	Data Type	Min Peak time Stand-by (lowest Data consumption per min)	Max Peak time Operations (Operational data consumption per min)	Max power Consumption (when Operational)	Weight per Unit	Max Operational (Incident in a 24hr period)
Video/Camera						

1	1080p	200 bytes	2048576 bytes	3.3V	1.12 ounces	20 min
2	1080p	200 bytes	2048576 bytes	3.3V	1.12 ounces	20 min
3		200 bytes				
Other						
4.	text file	200 bytes	200 bytes	3V~5.5V	0.5 ounces	20 min
5.	text file	200 bytes	200 bytes	3V~5.5V	0.1 ounces	20 min
6.	text file	200 bytes	200 bytes	~5.5V	3.21 ounces	20 min
7.	Audio Wave	200 bytes	1048576 bytes	3.3V	1.5 ounces	20 min
8.	text file	200 bytes	200 bytes	3V	0.8 ounces	20 min
9.	text file	200 bytes	200 bytes	3V	0.6 ounces	20 min
10.	text file	200 bytes	200 bytes	3V	0.9 ounces	20 min
11.	text file	200 bytes	200 bytes	~80V	5.9 ounce	20 min
12.	text file	200 bytes	200 bytes	~5.5V	0.704 ounces	20 min

As the additional sensor details are assessed it provides insight to which sensors to selection. This selection will be considered as a general configuration that is chosen to meet the primary operational mission of safeguarding sensitive materials with high contaminants and thermal consideration depending upon its environmental properties. General primary mission operations are any radioactive (radioactive waste materials is an unavoidable by-product of the use of radioactive materials – Plutonium, Uranium-235, Uranium-235 and Irradiated fuel) and/or potentially explosive materials i.e., fertilizer ammonium nitrate that are hazardous to human, animal and/or the environment. This scenario is our primary and generic mission operations that SSAMSS as a produce is developed to surveil and safeguard. As the sensors are identified through a weighted decision matrix the mission operation primary scenario will select the

primary and redundant configuration of the SSAMSS collector as shown in Table 18. As the questions vet out which sensor is best for the SSAMSS Collector it derives the desired parts needed to meet the primary mission objectives. Although this doesn't fully configure the sensors it does provide which components are needed to meet customer needs and full fill a testable mission scenario shown at the bottom of Table 18. The parts i.e., sensors are also defined by showing if they need to share and/or require their own Raspberry Pi microcomputer (shared or individual processor) to function as it acquires data from the threat environment while operating.

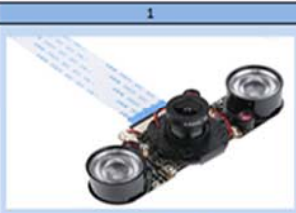





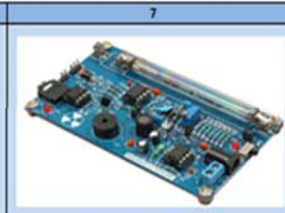




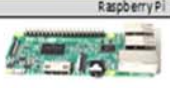


Table 18:SSAMSS CollectorSensor Matrix Table and Sensor selection

Category Rating by important (7 = Critical Value, 5 = Somewhat Critical Value, 1 = minimal Critical value)	7	5	3	7	5	7	5	7	Score indicates capability to meet mission and requirements needs	Score indicates if sensor is needed and dictates optimal configuration option
Sensor Options	Does this sensor meet Primary Mission Operation needs?	Does this sensor meet Redundant Mission Operation needs?	Does this sensor meet Add-on Mission Operation needs?	Is the sensor information of value in regards to the mission ?	Is the sensor data of critical value in regards to the mission ?	Is the sensor reasonably priced when compared to other competing systems \$?	Is operating the sensor a reasonable price other competing systems\$?	Does the sensor need a Microcomputer - Pi or can it share a board?		
1	5	5	0	5	5	5	5	1	153	153
2	3	5	0	5	5	5	5	1	139	
3	1	1	5	5	5	5	5	1	110	110
4	5	5	0	5	5	5	3	3	145	145
5	3	5	0	3	3	5	5	3	137	
6	0	0	5	3	3	5	5	5	98	98
7	5	3	1	5	5	5	3	5	138	138
8	1	3	5	1	1	3	3	5	92	
9	3	5	1	3	3	3	3	5	116	
10	5	5	0	5	5	5	5	1	153	153
11	5	0	5	5	5	3	5	1	119	119
12	5	5	0	5	5	5	5	5	157	157

5 - Critical to mission success - Critical Value add	5 - Critical to mission success - Critical Value add	5 - Critical to mission success - Critical Value add	5 - Critical to mission success - Critical Value add	5 - Critical to mission success - Critical Value add	5 - Critical to mission success - Critical Value add	5 - Critical to meeting requirements	5 - Critical to meeting requirements	5 - Can Share a board
3 - Accommodates mission success - major value add	3 - Accommodates mission success - major value add	3 - Accommodates mission success - major value add	3 - Accommodates mission success - major value add	3 - Accommodates mission success - major value add	3 - Accommodates mission success - major value add	3 - Accommodates meeting requirements	3 - Accommodates meeting requirements	3 - Requires a microcontroller
1 - Considered mission success - minor value add	1 - Considered mission success - minor value add	1 - Considered mission success - minor value add	1 - Considered mission success - minor value add	1 - Considered mission success - minor value add	1 - Considered mission success - minor value add	1 minor meeting requirements	1 minor meeting requirements	1 - Requires a Board
0 - No value add	0 - No value add	0 - No value add	0 - No value add	0 - No value add	0 - No value add	0 - Does not meet requirements	0 - Does not meet requirements	0 - NA

1	2	3	4	5	6	7	8
							
Raspberry Pi Zero W	Raspberry Pi Zero W	Raspberry Pi Zero W	Raspberry Pi B+			Raspberry Pi Zero W	Raspberry Pi B+
							

## Engineered Model and Simulation – Testing

There are four critical systems to SSAMSS, 1. SSMAS Cluster, 2. SSAMSS Collector, 3. SSAMSS CubeSat and 4. SAD SACKs Protocol. These systems together compile a systems-of-system and are considered SSAMSS overall enterprise as detailed in Table 19. At this point through the V-model diagram coupled with simulation, analysis, and case studies several of the systems are capable of meeting market and customer needs while satisfying requirements. All the systems have had in-depth research and detailed reviews, but the two primary systems that have been simulated and/or optimized to be considered for future engineering model are the SSAMSS Cluster and SSAMSS Collector. As a continuation of the research SSAMSS Collector is finalized through sensor and data analysis of incident and non-incident scenarios.

*Table 19: SSAMSS Enterprise Description Table*

SSAMSS Enterprise			
SAD SACKS	SSAMSS^1	SSAMSS^2	SSAMSS^3
Hardware-Software Protocol	SSAMSS Cluster	SSAMSS Collector	SSAMSS CubeSat
Acts similar to the nervous systems while connecting all the systems together.	Acts similar to a local lower brain of the systems by making assessments, reporting and decisions.	Acts similar to all the senses i.e., hearing, smelling, seeing, etc. while observing locally.	Acts like the higher brain and eyes while communicating to command and control.

There is an assessment of the sensor’s selection as parts to assure they are configuring the parts, components, and subsystems together to assure proper mission scenario i.e., worst case vs baseline normal scenario. Through Table 20 it shows how the configuration of the sensors data in bytes over the span of a 24-hour period is collected via quasi-random number simulation.

The data in the scenario shows how the SSAMSS Collator Sensors works together to collect critical data during an incident and use pulse data to assure that there are no hardware failures in the non-incident table. The sensor data has been identified to show data types i.e., text of media which will have different sizes as show in the previous Table 17 . In turn that data is used as a pseudo-random number generator to simulate sensor collected data as shown in Table 20 that is simulated an incident vs non-incident scenario. The first sensor collects data showing that between the hours of 5 (400AM) and 6 (500AM) the camera data goes up to MBs showing an active incident graphicly by the SSAMSS Collector Camera as shown in Table 20.

Table 20: SSAMSS Collector Sensor - Quasi random sensor data for Incident (Ops) and non-Incident (stand-by baseline)

24 hr duration		Operational Data - Incident Scenario								Hours	Stand-by Data - No Incident								
Date	Time	1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8	
Wednesday, April 5, 2023	11:00:00 PM	5640	2940	2940	3600	5700	4440	2760	6180	0	5640	2940	2940	3600	5700	4440	2760	6180	
Thursday, April 6, 2023	12:00:00 AM	4380	5820	3000	4860	4080	5940	5940	4440	1	4380	5820	3000	4860	4080	5940	5940	4440	
Thursday, April 6, 2023	1:00:00 AM	4200	6300	2760	3480	3780	5100	4080	4860	2	4200	6300	2760	3480	3780	5100	4080	4860	
Thursday, April 6, 2023	2:00:00 AM	5820	4080	4800	5460	3600	3480	4920	3840	3	5820	4080	4800	5460	3600	3480	4920	3840	
Thursday, April 6, 2023	3:00:00 AM	2940	3060	5700	3600	4500	4620	5940	2820	4	2940	3060	5700	3600	4500	4620	5940	2820	
Thursday, April 6, 2023	4:00:00 AM	5280	2820	4200	4860	4860	3600	5640	2940	5	5280	2820	4200	4860	4860	3600	5640	2940	
Incident Scenario - Someone trying to break into a SSASS controlled Door (10 min incident that triggers night Camera, thermal Camera, sound sensor). Rest of the sensors are take a standard reading but don't initiate due to not sensing - programmed any triggering traps)	Thursday, April 6, 2023	4:10:00 AM	1616211	1292112	10140	7890	10020	9120	10080	7200	5.1	4020	3960	3300	3660	3840	5280	3720	2880
	Thursday, April 6, 2023	4:21:00 AM	1522172	1145991	9240	11580	10650	11820	7800	7680	5.2	3120	6300	4860	4620	3240	5580	3240	5040
	Thursday, April 6, 2023	4:22:00 AM	1634316	1158420	10500	8100	8940	6660	6540	6480	5.3	3900	5400	3240	4440	3120	4680	2700	3420
	Thursday, April 6, 2023	4:23:00 AM	1966117	1903538	9180	7740	11820	11880	8280	10020	5.4	2760	2880	3960	5520	4560	5160	4020	4260
	Thursday, April 6, 2023	4:24:00 AM	1725615	1189566	6420	7500	10650	10980	10740	10620	5.5	6300	2940	3840	3540	5400	3360	5100	5640
	Thursday, April 6, 2023	4:25:00 AM	1436397	1128385	8460	7380	10440	8260	6660	9060	5.6	4860	2700	5100	5520	2820	4980	3480	4080
	Thursday, April 6, 2023	4:26:00 AM	1739621	1327515	8160	9840	7560	7140	9780	10440	5.7	4620	5820	4680	5520	4800	5880	4740	4920
	Thursday, April 6, 2023	4:27:00 AM	1888223	1397394	7740	10500	7500	10800	7380	9840	5.8	4560	3780	5220	3060	3300	6180	2880	4260
	Thursday, April 6, 2023	4:28:00 AM	1444948	1346783	11520	9900	7380	10920	6780	11940	5.9	3840	5700	5520	5160	4200	6120	5700	2940
	Thursday, April 6, 2023	5:00:00 AM	2820	4860	4320	3840	6060	6240	4740	5820	6	2820	4860	4320	3840	6060	6240	4740	5820
Thursday, April 6, 2023	6:00:00 AM	4620	4140	4260	4920	4620	3960	4260	3840	7	4620	4140	4260	4920	4620	3960	4260	3840	
Thursday, April 6, 2023	7:00:00 AM	5460	3300	8060	4560	3660	4320	4500	4920	8	5460	3300	8060	4560	3660	4320	4500	4920	
Thursday, April 6, 2023	8:00:00 AM	5160	6300	2820	3360	5040	4500	5040	5040	9	5160	6300	2820	3360	5040	4500	5040	5040	
Thursday, April 6, 2023	9:00:00 AM	2820	5280	3240	3540	4920	4320	2700	4980	10	2820	5280	3240	3540	4920	4320	2700	4980	
Thursday, April 6, 2023	10:00:00 AM	5220	4200	3120	6240	5160	4740	5460	4020	11	5220	4200	3120	6240	5160	4740	5460	4020	
Thursday, April 6, 2023	11:00:00 AM	4920	2760	4560	4860	4440	5700	3300	5340	12	4920	2760	4560	4860	4440	5700	3300	5340	
Thursday, April 6, 2023	12:00:00 PM	4980	6120	5580	4680	3360	6300	5640	3420	13	4980	6120	5580	4680	3360	6300	5640	3420	
Thursday, April 6, 2023	1:00:00 PM	2700	3120	5160	3060	5640	4740	5100	4680	14	2700	3120	5160	3060	5640	4740	5100	4680	
Thursday, April 6, 2023	2:00:00 PM	3540	4920	5820	5820	4440	2820	2940	5340	15	3540	4920	5820	5820	4440	2820	2940	5340	
Thursday, April 6, 2023	3:00:00 PM	3900	3960	6240	4560	2760	2820	2880	2760	16	3900	3960	6240	4560	2760	2820	2880	2760	
Thursday, April 6, 2023	4:00:00 PM	5580	4920	4740	3720	5340	4700	5340	2820	17	5580	4920	4740	3720	5340	4700	5340	2820	
Thursday, April 6, 2023	5:00:00 PM	2940	3900	6180	3900	5160	4500	2820	6300	18	2940	3900	6180	3900	5160	4500	2820	6300	
Thursday, April 6, 2023	6:00:00 PM	6300	3540	4920	4800	4260	3240	4200	4740	19	6300	3540	4920	4800	4260	3240	4200	4740	
Thursday, April 6, 2023	7:00:00 PM	4740	3540	5700	4800	4440	3600	4080	4200	20	4740	3540	5700	4800	4440	3600	4080	4200	
Thursday, April 6, 2023	8:00:00 PM	6060	3300	3120	3780	4620	4260	3660	4440	21	6060	3300	3120	3780	4620	4260	3660	4440	
Thursday, April 6, 2023	9:00:00 PM	4980	3720	5460	3600	3900	5460	5820	5520	22	4980	3720	5460	3600	3900	5460	5820	5520	
Thursday, April 6, 2023	10:00:00 PM	4080	3780	4080	4980	4500	3360	4500	3180	23	4080	3780	4080	4980	4500	3360	4500	3180	
Thursday, April 6, 2023	11:00:00 PM	5460	3900	5760	5640	2940	5040	3480	4140	24	5460	3900	5760	5640	2940	5040	3480	4140	
Friday, April 7, 2023	12:00:00 AM	3360	5220	5340	4980	2880	6180	4140	5220	25	3360	5220	5340	4980	2880	6180	4140	5220	

The spike in the table when compared to the normal baseline shows how the camera can collect incident data. That data can be collected and transmitted back to the SSAMSS cluster then sent to the CubeSat which will gather additional information while send it back to command and control globally and locally.

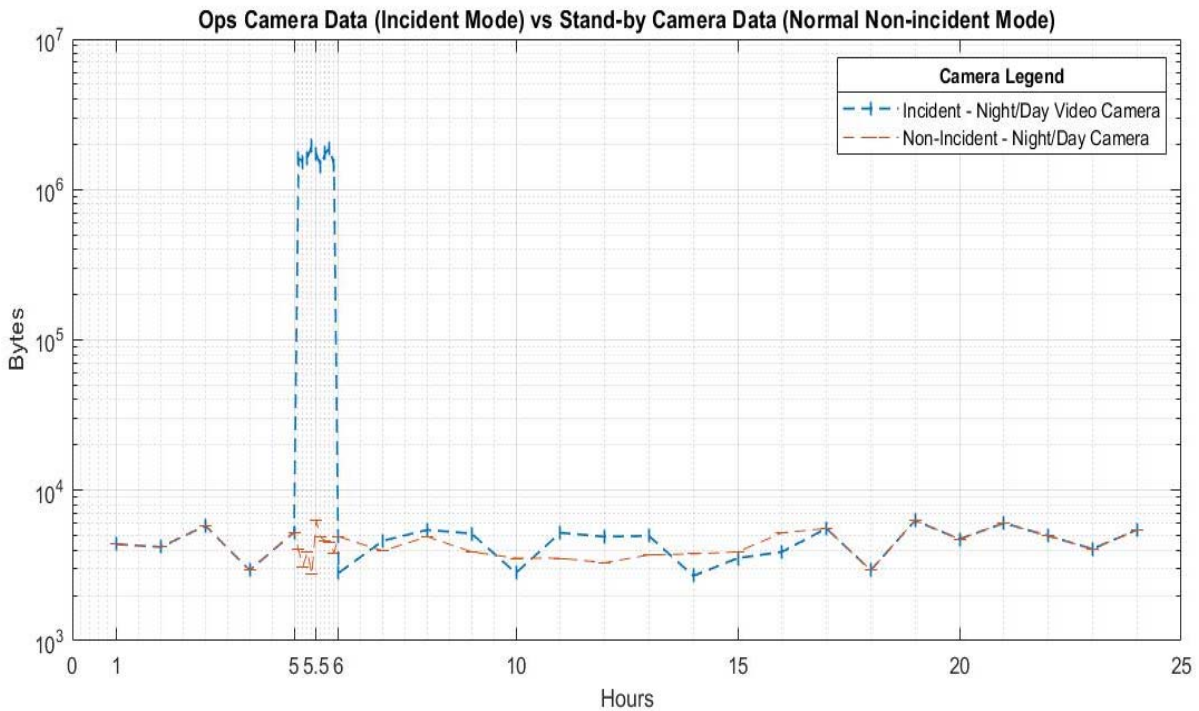


Figure 59: Camera Sensor Incident (Blue)vs Non-Incident (Orange)

The next set of sensor data is placed together as these sets of data create a more impactful meaning whether there is an actual incident or non-incident i.e., Thermal Camera, Temperature- Humidity sensor, and Geiger Counter Sensor to increase identifying incident type as shown in Table 17 and Table 18. The following combination of sensors is placed together on a single Pi to assure processor information is assessed since the data is similar. Again, you can see the incident in the graphs between the hours of 5 (400AM) and 6(500AM). The Geiger

counter doesn't have any impacted data due to it not sensing any sensitive materials i.e., radioactive items of this specific incident.

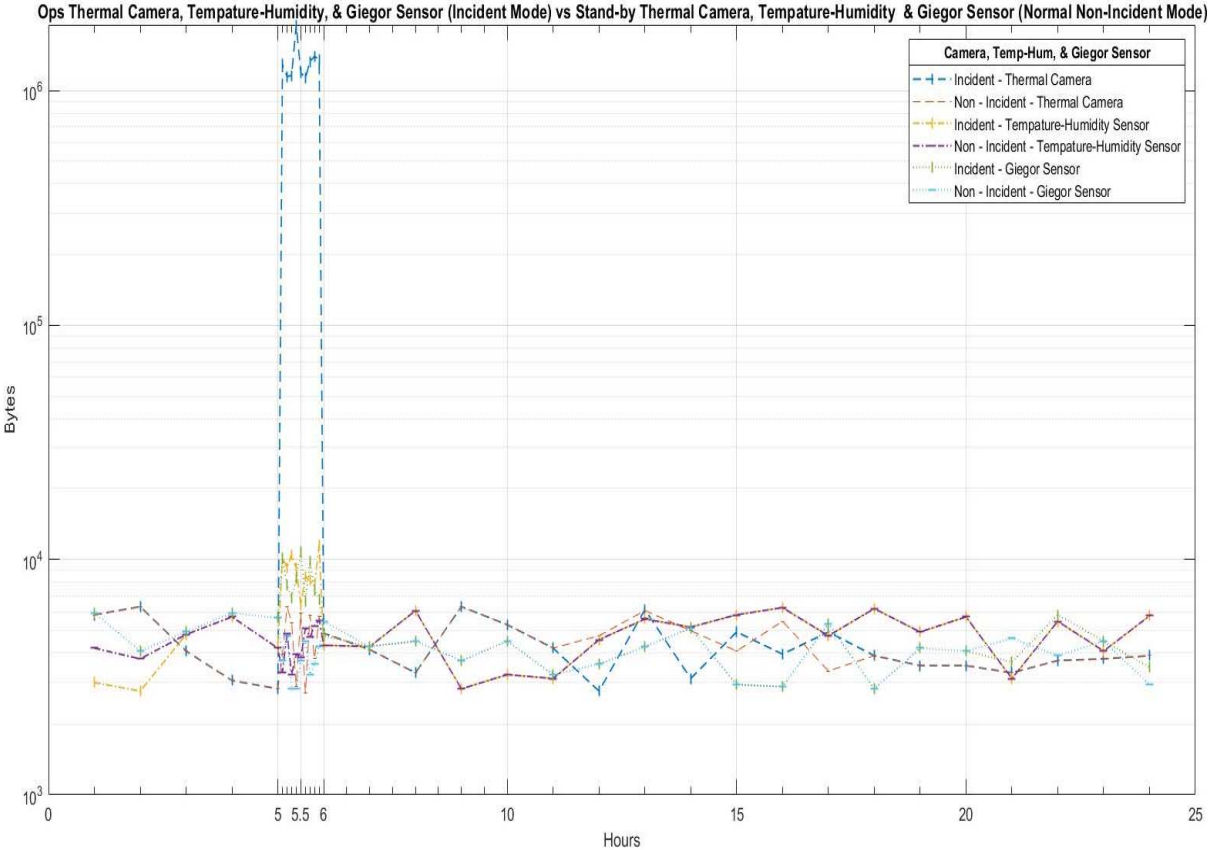


Figure 60: Thermal Camera Sensor Incident (Blue) vs Non-Incident (Orange); Temp-Hum Sensor Incident (Yellow) vs Non-Incident (Purple); Gieger Sensor Incident (Green) vs Non-Incident (Light Blue)

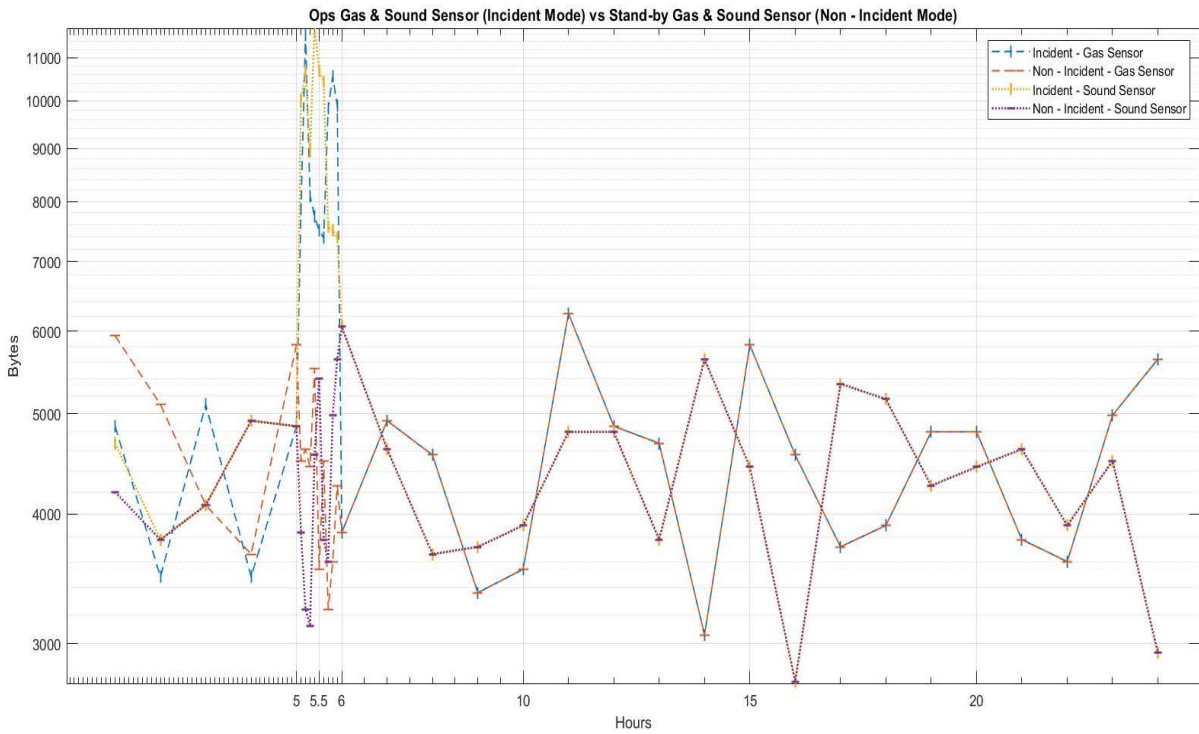


Figure 62: Gas Sensor Incident (Blue) vs Non-Incident (Orange); Sound Sensor Incident (Yellow) vs Non-Incident (Purple)

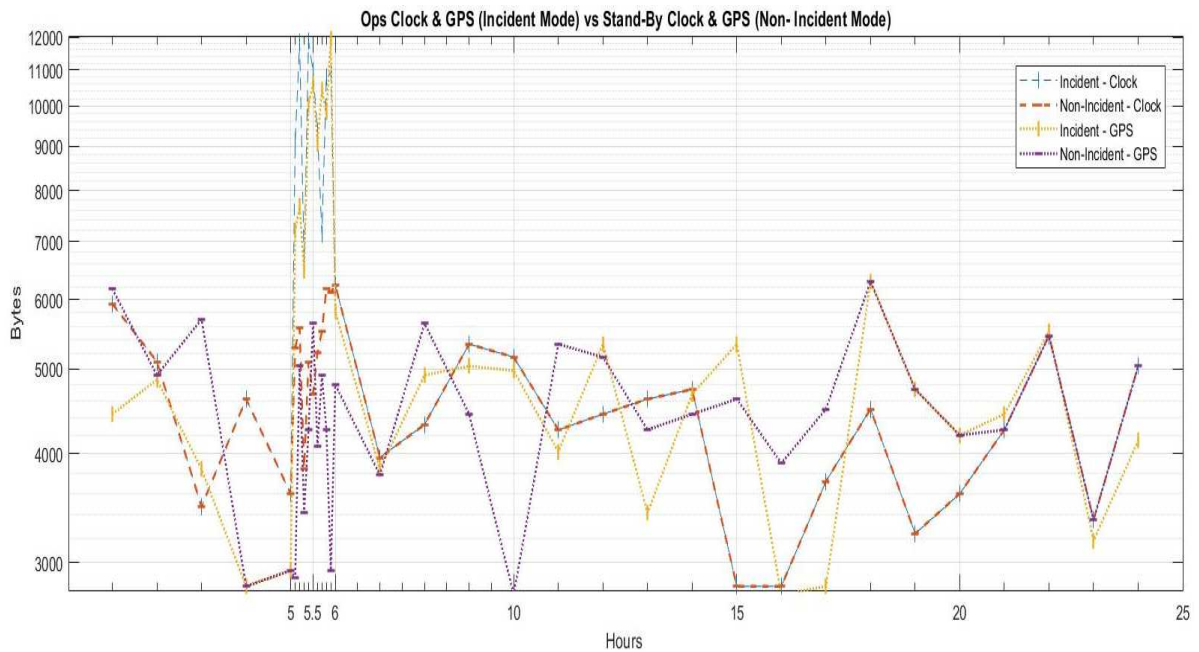


Figure 61: Clock Sensor Incident (Blue) vs Non-Incident (Orange); GPS Incident (Yellow) vs Non-Incident (Purple)

The gas sensor starts collecting higher data at the point of incident not because it has detected anything anomalies. If gas anomalies had been detected, then the sensor data would be that

much higher; especially if it sensed smoke – CO<sub>2</sub> gases. The sound sensor does have a higher spike due to increase of dB activating during the incident resulting in high levels of Bytes of data being collected. As the sensor data continues to be collected the clock and GPS sensor data starts spiking as well. These sensor types provide accurate time and GPS location of the incident and location of the SSAMSS local hardware. All the sensor data is coupled together on a complete compiled graph showing Incidents (Ops) and Non-Incident data (baseline) as showing in Figure 63. The graph shows normal trending data within a 24-hour period with a steady small data rate pining from all the sensor relaying that the hardware is functional-performing. Unlike when there is a spike between 5 (400am) and 6(500am) hrs. the data rates increase significantly. Especially, any sensor picking up activities i.e., Camera, Thermal Camera, Temperature Sensor, Sound Sensor, Clock and GPS. The camera and thermal camera have the highest collection of data when it is detecting and incident with the other sensor having increased data collection but not as large as the video and sound data. This data as its being simulated will reflect test set of data within a 24 hour.

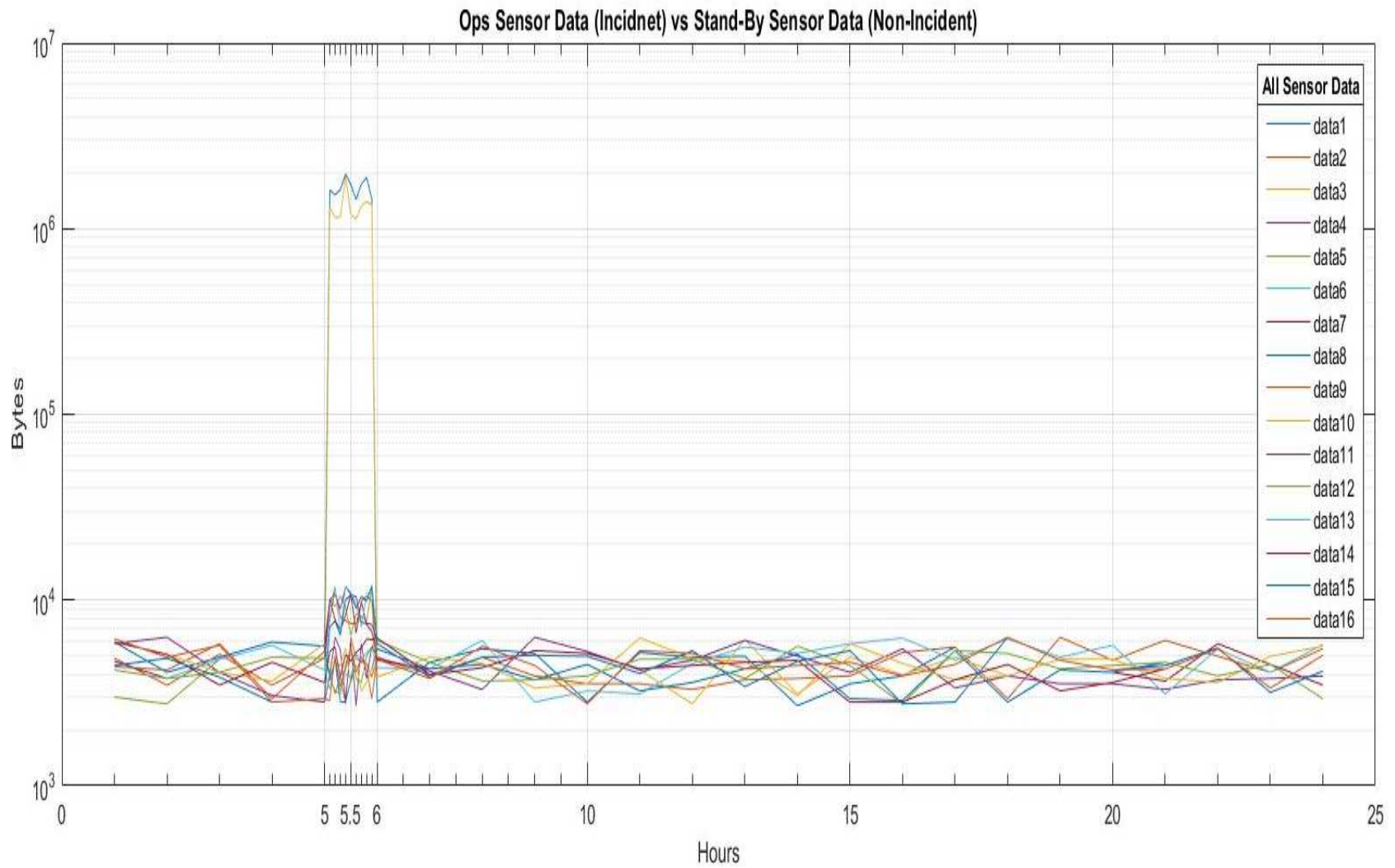


Figure 63: All Sensor Data – Ops (Incident) vs Stand-by Normal (Non-Incident)

period. The simulated data will also be utilized as test data to reflect that SSAMSS as a product can collect critical data to safeguard hazardous materials. The simulated data is not only reflective of test data but how that data may be used to evolve an intelligent sensing surveillance system at a reduced cost. The next assessment of the data is to review incident vs non-incident thorough a box a wishers graphical perspective Figure 64. The baseline data for non-incident data is between a Max of 7000 Bytes to min 2500 Bytes. This simulated test data sets of maxima, average and minimum provide valuable feedback to data package sizes during

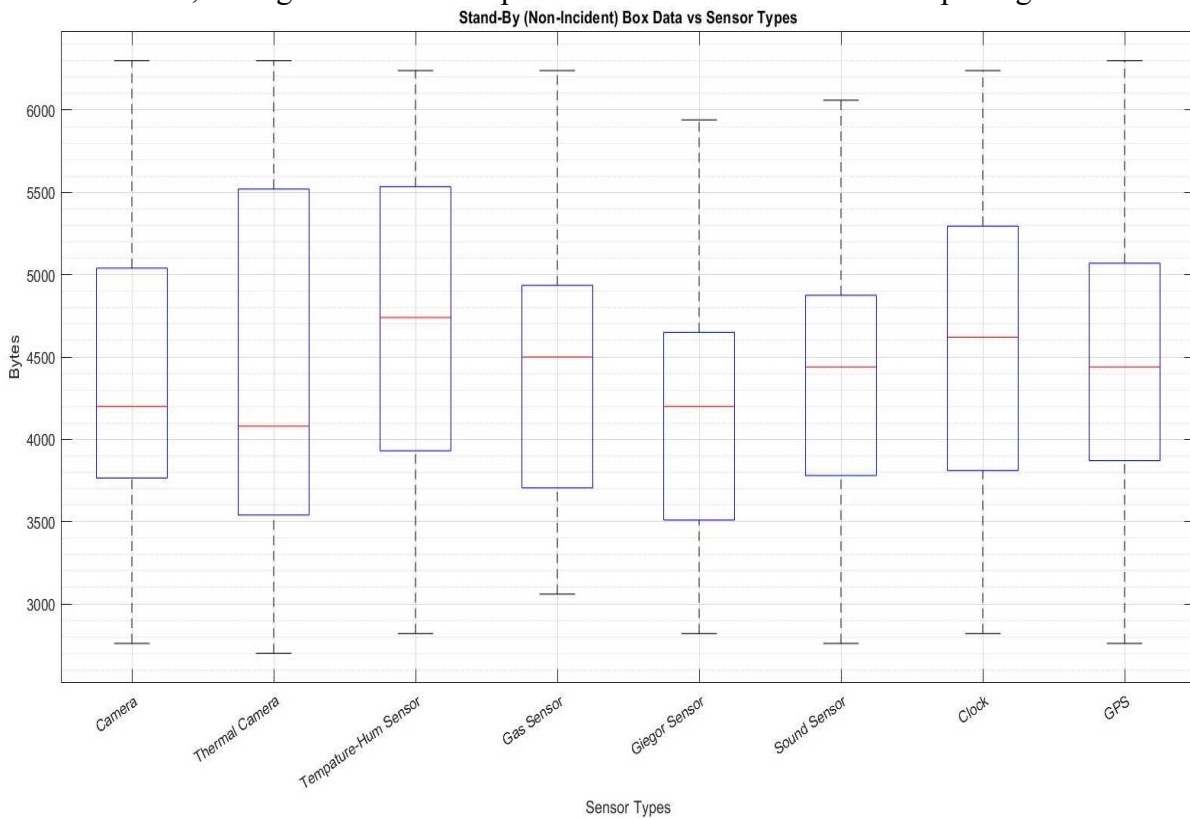


Figure 64: Normal baseline (non-Incident) sensor data

normal hardware operations. The operational scenario which is the incident data is viewed through a box and whiskers perspective related to the sensors with a maximum of 14.38 MB and a minimum of 2000 Bytes as shown in Figure 65. Another critical perspective of the box

and whiskers data is a collective of Ops (Incident) vs Stand-by (non-incident) normal mode

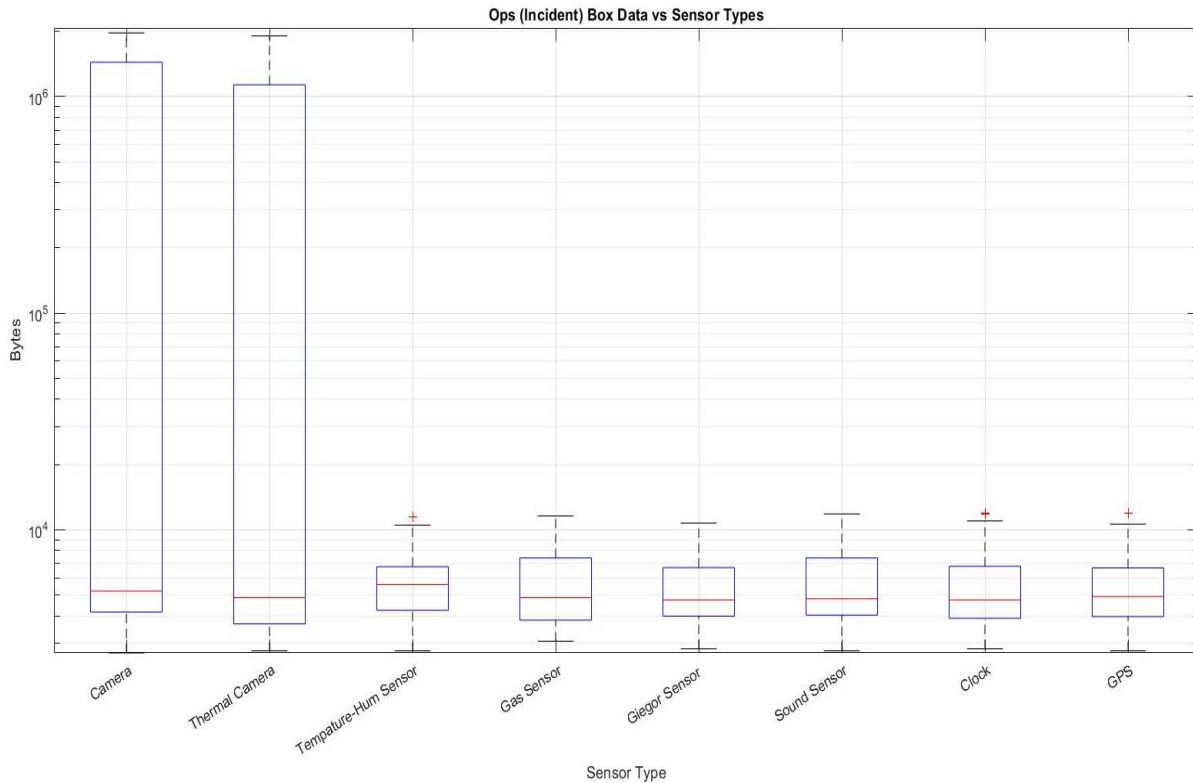


Figure 65:Operational (Incident) Sensor data

between all the sensors as shown in Figure 66. The collected sensor data details the deltas between the two events and/or scenarios. It is clear to see that the two sensors with the most data packets sent during an incident are the night/day camera and the thermal camera. The second sensor with the highest sound sensor and the rest of the sensors fall within the same range. The video sensors have a large increase in data due to its digital video format which is similar to the sound sensor which sends audio data. The rests of the sensors transmit data packets as text based which is a smaller digital footprint then audio or video formats.

Continuing to review the data a cumulation of the overall data sets is collected per sensor. As shown in Table 21 the overall data assesses over the span of 24hrs what the Maximum, Average, Minimum and Standard deviation per incident and non-incident.

Table 21: Ops vs Standby Summary Sensory Data

24 hr duration		Operatioanal Data - Incident Scenerio								Hours	Stand-by Data - No Incident								
Date	Time	1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8	
24 hrs Including Incident - Bytes		15072520	11991744	192960	186900	190680	193320	178500	187680	24 hrs No Incident - Bytes	145440	147000	153540	147480	143340	152160	136800	147000	
24 hrs Including Incident - MB		14.3883263	11.44739736	0.18420088	0.17841596	0.18202438	0.18454454	0.17039727	0.17916056	24 hrs No Incident - MB	0.138838	0.14032716	0.14657029	0.14078537	0.1368333	0.14525293	0.13059018	0.14032716	
Incident - Max, Ave and Min Data Points	Max	1966117	1903538	11520	11580	11820	11880	10740	11940	No Incident - Max, Ave and Min Data Points	6300	6300	6240	6240	6060	6240	5940	6300	
	Ave (Mean)	456743	363386	5847	5664	5778	5858	5409	5687		4407	4455	4653	4469	4344	4611	4145	4455	
	Min	2700	2760	2760	3060	2760	2820	2820	2760		2760	2700	2820	3060	2760	2820	2820	2760	
Standard Deviation		744066	598213	2310	2259	2476	2735	2068	2501	Standard Deviation	968	1126	978	841	799	943	906	960	
Incident Scenerio		Incident Scenerio - Some on trying to break into a SSASS controlled Door (10 min incident that triggers night Camera, thermal Camera, sound sensor). Rest of the sensors are take a standard reading but don't initiat due to not sensing -programmed any triggerring traps or anomial data).								Non - Incident Scenerio		Normal operation through pulse data as the are non- events happening. As the system is only ping to communicate that there are no hardware failure or incidents occurring - baseline data.							

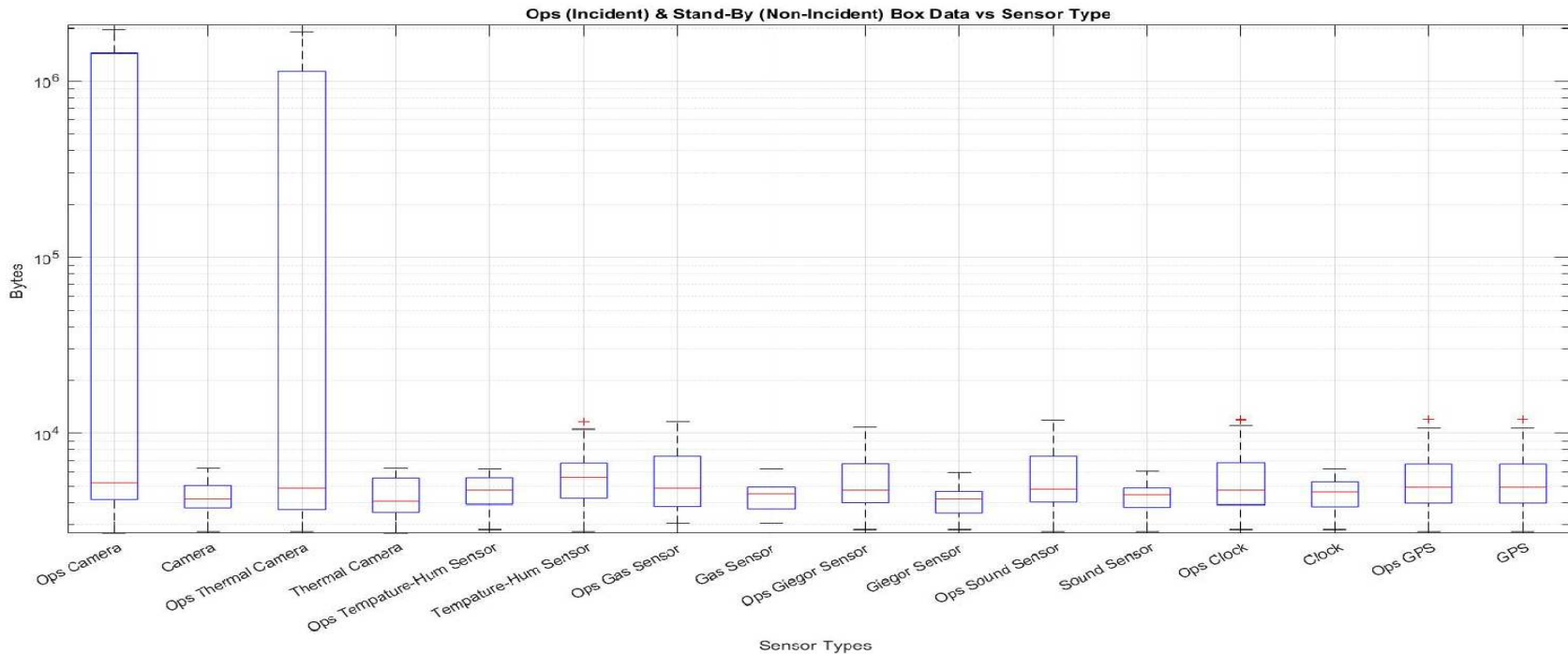


Figure 66: Box and Whiskers Ops vs Standby Sensor Data

The standard deviation as listed in Table 21 uses an equation Equation 9:

- Population Standard Deviation

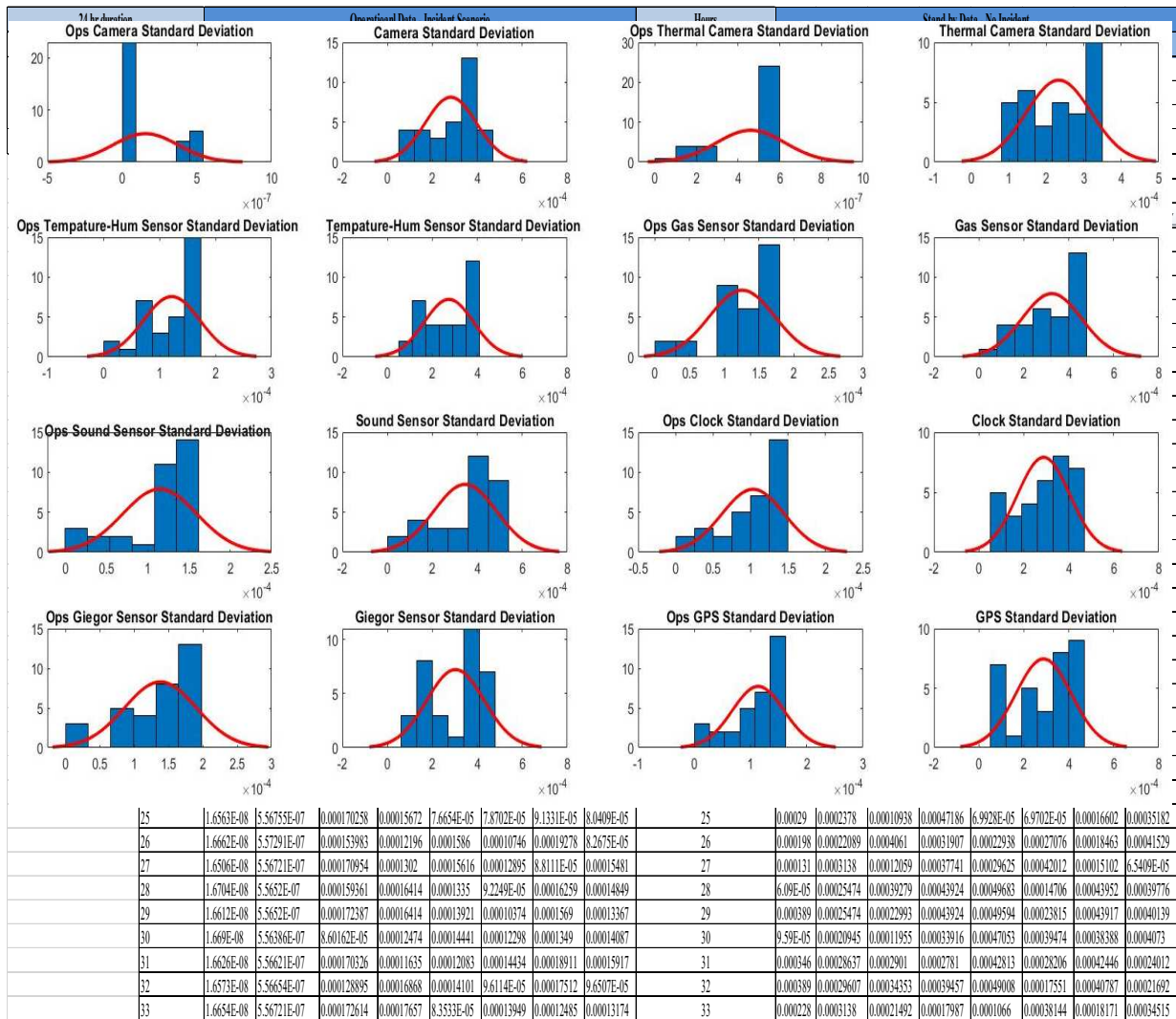
$$\sigma^2 = \frac{\sum(x_i - \mu)^2}{N}$$

- $\mu = \text{Mean (average)}$
- $x_i = \text{each value from the population}$
- $N = \text{Population size}$

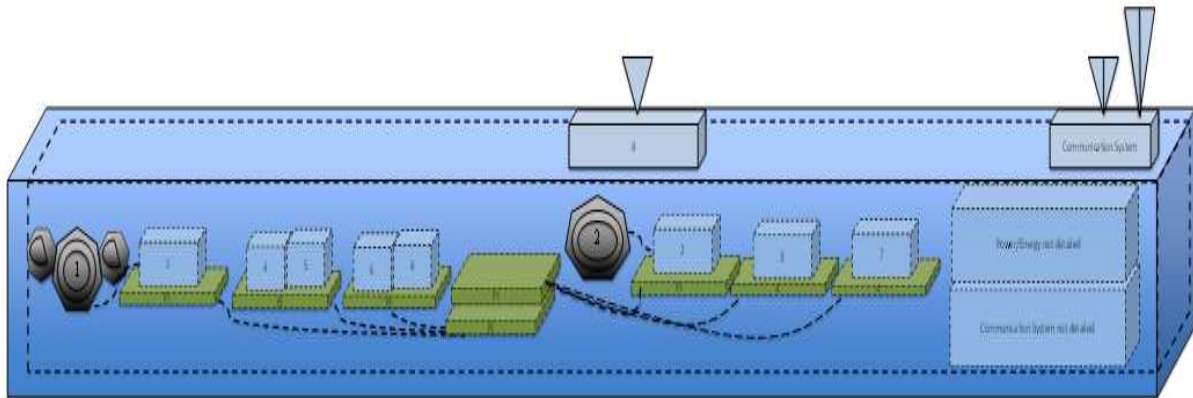
Equation 9: Standard Deviation

After the standard deviation is calculated, it was followed up with the normal distribution of a population as shown in Table 22 detailing the sensor data.

Table 22: Ops vs Standby Summary Data table



As the data is further assessed and vetted, we are able to pull out histogram information



*Figure 67: Ops vs Standby Deviation and Standard Deviation per Sensor Data*

regarding the sensor's incident and non-incident analytics. The histogram data also displays the data in a bar and bell curve format as shown in Figure 67. Again, being able to see the spread with the larger data set such as the camera and thermal camera due to the significant increase in data which flattens out the bell curve when compared to stand by or normal operational mode. These types of data sets would be transmitted by the SSAMSS Collector and processed in the SSAMSS Cluster in turn would transmit to the SSAMSS CubeSat. The artificial intelligent or smart sensing portion of the system would be processed in the SSAMSS cluster. The cluster would take data sets like the box and whispers and histograms and use machine learning and neural network to identify a real-time incident that would be communicated back to global and local command and control personnel. These types of statistical data sets are used to relay information to help assess and predict location behaviors as its being observed. Through the

sensor simulation analysis and assessment, the SSAMSS cluster configuration would be as showing in Figure 70 and Figure 71.

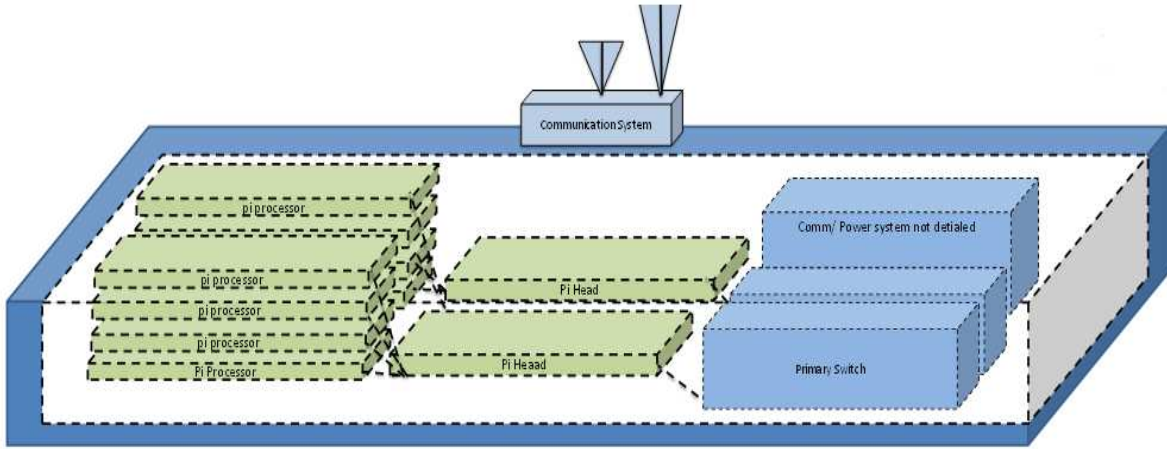


Figure 70:SSAMSS Cluster configuration

Through the decision matrix the best options of sensors were vetted and identified. As it is shown through a simulated test data event, it was identified that these coupling of sensors work

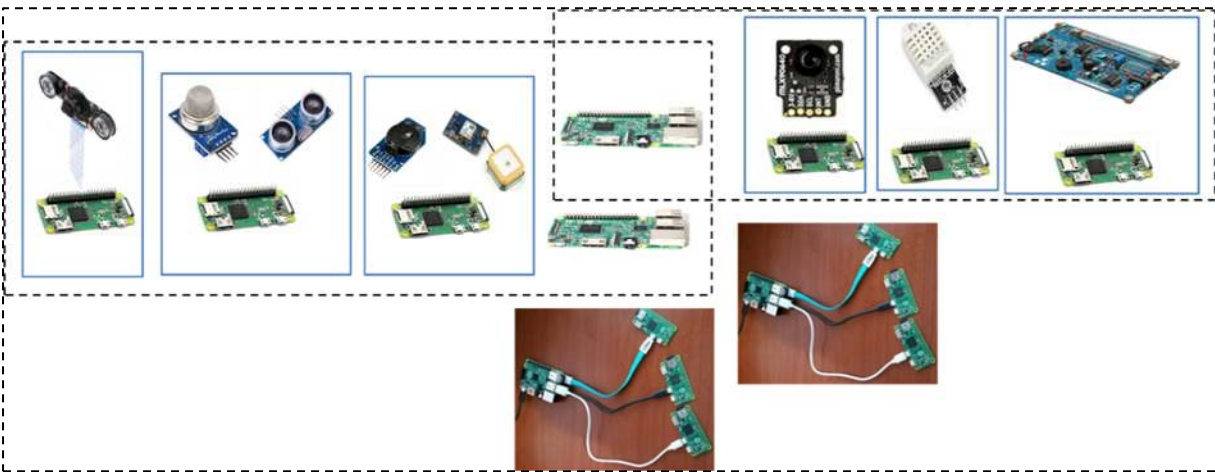


Figure 69: SSAMSS Collector Sensor configuration actual physical display with sensors configuration

best together. The actual physical parts are placed into components and become a system as shown in Figure 69. The other portion of physical system that has been developed is the

SSAMSS Cluster which is ultimately the brains of the actual system. SSAMSS collector acts as the senses of the system and collect data locally communicating what may or may not be happening like intrusion, fires, explosion and thefts when compared to normal every day operational behavior at deployed location. The brains of the processing power are going to be placed in the SSAMSS cluster as shown in Figure 68 and Figure 69. As it is shown that there will be a primary and redundant part of the cluster similar to the left and right side of the brain. The SSAMSS Enterprise is shown in Figure 72 with the entire structure working together per single unit deployment. The display of the local units which have been simulated, analyzed and assessed have proved to be capable of competing

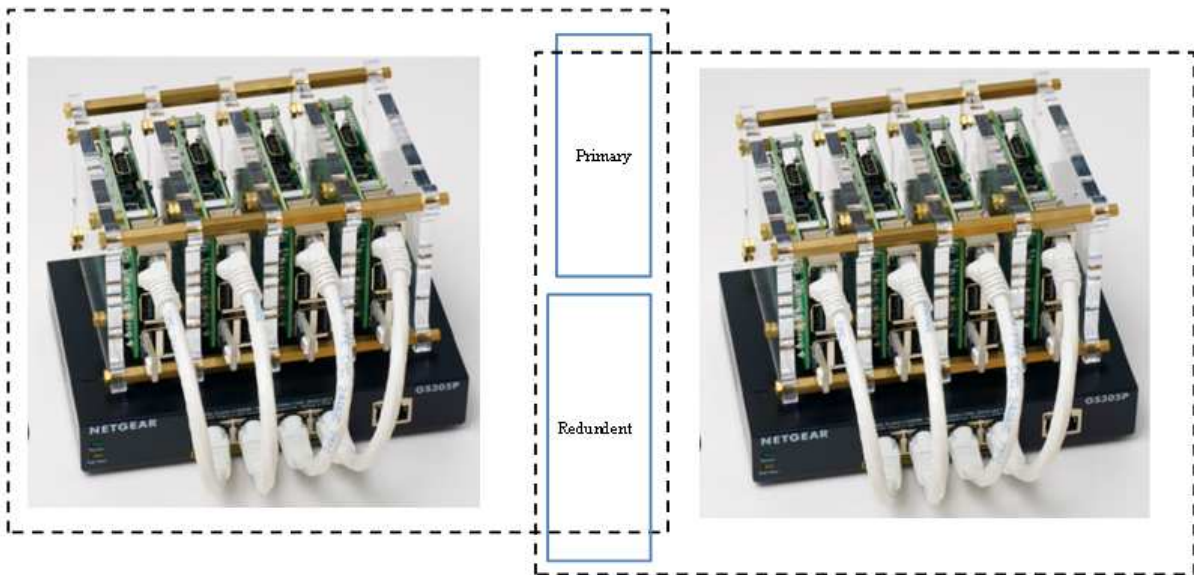


Figure 71: SSAMSS Cluster actual physical components configuration

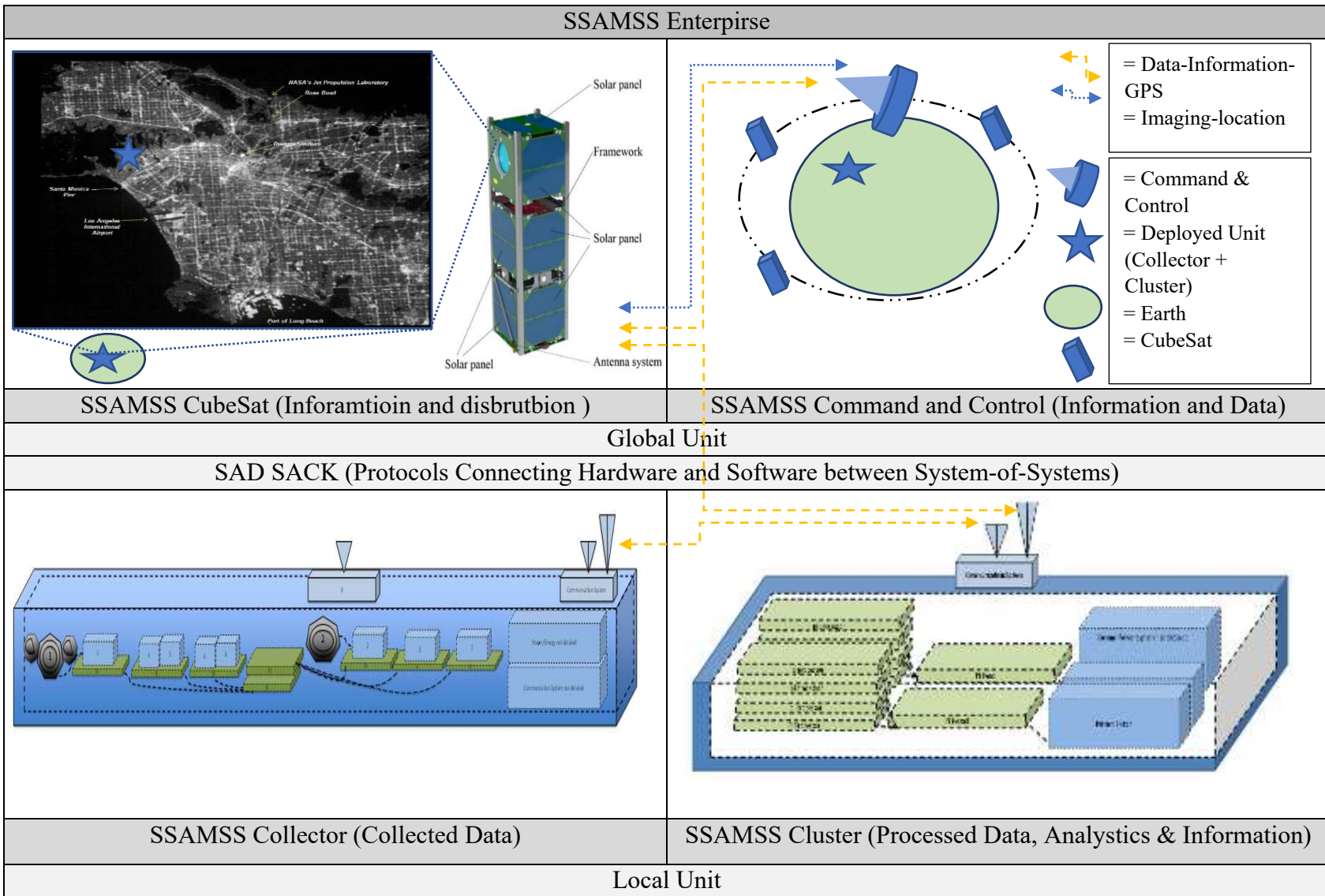


Figure 72: SSAMSS Enterprise

against other material safeguard systems i.e, giegor counter, web services, portable sensor and portable door monitor. In fact the cost of SSAMSS per unit is compararble if not cheaper then most of the modern day singular type systems on the market and/or used by the customer. The majority of the systems have been tested through simulations and would provide confidence in the customer i.e., govermenet againcy proving funding to create an actual engineered model that could ultimitly be placed under production for future usage.

#### Verification and Validation (V & V)

There 6 critical requirements, (1) initial cost \$; (2) operations cost \$; (3) AI, communication, and intelligence; (4) reliability; (5) maintainability; and (6) scalability are initially validated. The validation came from the initial assessment of the customer, market, and comparable system analysis against SSAMSS as a product [verification]. As the requirements flow down into the system, subsystem, components, and parts every selection was done with the following requirements and considered as a “shall statement.” These shall statement where able to be through a targeted selection of microcomputer and sensors that utilized cost effective Commercial off the self (COTS) parts i.e., Raspberry Pi microcomputers and compatible sensor options. As these parts meet the requirement demand it transcends into the components, system, and system-of-system development. This portion created the actual models i.e., hardware simulations, configuration and analysis are the validation loop Figure 73. In the case of SSAMSS as a product the collector and the cluster have been verified and validates by simulation i.e., testing through the conceptual phase. Through the assessments and collected data these two portions of the SSAMSS product are suggested to be considered as a future

engineering model due to meeting its capability and functionality of meeting its vetted requirements. Those requirements meet the root cause statement-goal of developing a cost-effective smart sensing surveillance system when comparable with other primary industry systems. This leads the way to not only creating an engineering model that will have a full integration and testing (Analysis, Demonstration, Inspection, or Test) event but uses the model to satisfying market needs.

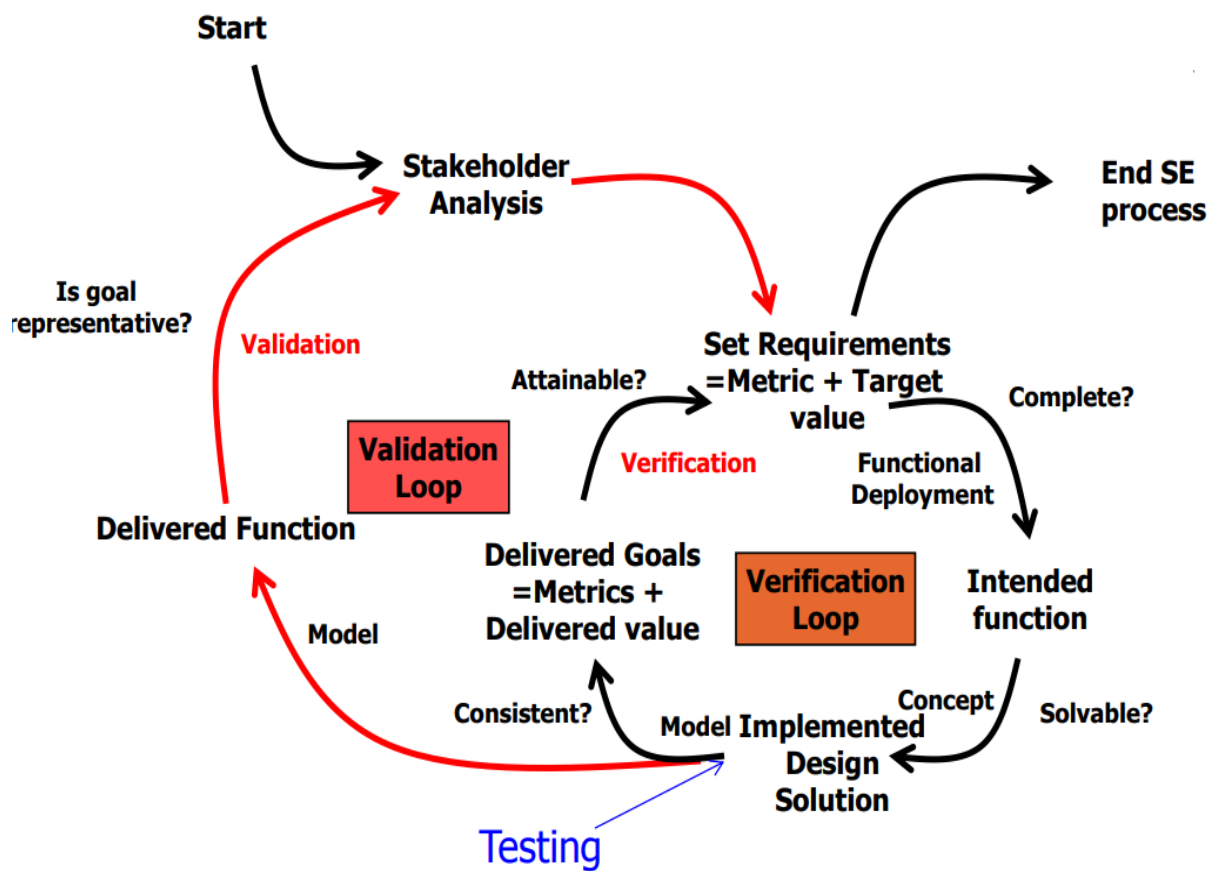


Figure 73: Fundamentals of Systems Engineering, V & V, MIT, Prof. Olivier L. De Weck [16]

Retirement

Another perspective to be considered at this time is SSAMSS as a product unlike its market competitors has a better retirement proposal. The market competitors i.e., Geiger counters, portable door scanner, etc. have a retirement plan of becoming obsolete and require calibrations. Once they become obsolete, they are replaced and/or recycled by being disposed. Unlike SSAMSS it uses microcomputers and sensors that are cost effective and easy to reuse. The idea that SSAMSS is primarily composed of Raspberry Pis that can be delivered and broken out into parts anywhere in the world-globally. The SSAMSS parts after being used could technically be broken down-retired within a local community. The community such as a school or local university could take those Pi's and cluster and learn with them amongst the students in such places like Africa, Asia, Latin America, or any location. Versus other products that would not only be expensive to ship back to the United States but also may end up not being usable in any way after retirement.

#### Chapter 4 Conclusion

SSAMSS as a product has assessed that it is a viable option that should be considered as an actual engineered model. The data and information that was pulled from the simulation to show that it cannot only compete but at also a lower cost. Those costs come from the computing power and access to sensors at ranges from \$5.00 to \$100.00 i.e., thermal cameras, Geiger sensors, IR/Night/Day video-cameras, etc.... The incident data is manageable by the SSAMSS system and entails not only a cost-effective product but an easier way to transport across the globe when comparing it against its competitor in the marketplace. The customization to threat environment (incident) when compared to other products is unmatched as SSAMSS is a system

of system that encompasses the capabilities of having all the single competitive products rolled into one. The physical detail for SSAMSS primarily Collector – Sensor package and Cluster – Processing has been detailed and should be considered as an Engineering model for future testing to move into potential manufacturing potential.

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## CHAPTER 5

Collective Summary –  
Publish, Prove and Move Method (PPMM)

## Introduction to Chapter 5

Collectively, SSAMSS, as a product idea has been vetted across the V-diagram model [1]. Section CHAPTER 1 (P1), CHAPTER 2 (P2), CHAPTER 3 (P3) and CHAPTER 4 (P4) represent certain perspectives of SSAMSS as a product ultimately being a completed program. The sections intertwines to produce a conceptual idea that would end up being a product enterprise competing against market and customer products and standards. Through the Systems Engineering process as the research has gone down the V-diagram inspecting, analyzing, demonstrate and testing to assure that SSAMSS is capable, functional, and performing at the vetted initial requirements as detailed in [2] . As the process continue a review through CHAPTER 2 [0] is completed which reflects the SSAMSS cluster design. Then going into CHAPTER 3 it uses a dynamic, and stock-flow models which became critical to testing and analyses the system-of-system. SSAMSS is a system-of-system that is able to compete against singular type of systems that actually encompasses the majority of those systems in one bundled package being described in CHAPTER 4 leading into CHAPTER 5 concluding the product development.

## Summary Conclusion

In conclusion, details throughout targeted articles show how SSAMSS can be created and considered for actual deployment and manufacturing based of off research evidence as shown in Figure 74 (with P meaning published paper with P3 and P4 in progress). Using dynamic

models to help with analysis of entirety, confidence of decision, and 3-D model of portion of the actual product being developed conceptually. Through a method call publish, prove and move (PPMM), SSAMSS as a product through system engineering and V-model process was able to gather research evidence-proof to assure a positive development direction up to the conceptual phase of the V-diagram. The publish, prove and move method is a way to assure direction and magnitude of SSAMSS as a research product. The direction is the overall ideas which is pieced out within the article and the magnitude is the acceptances by your peers regarding publication (or even rejections). Rejection means that the direction may not be a feasible area to focus on and that there should be readjustment to your research focus. In the case of SSAMSS as a product and essentially an enterprise the initial market, customer and competitor research suggesting an initial design was accepted [1]. This provided valuable information to initial design needs, concepts and primary requirements. This aligns with the v-model portion and moves down the next section of the V-diagram (publication can be viewed as a feedback loop). The next publication showed that additional tools could be used to reinforce the whole and selected portion (SSAMSS cluster configuration) of SSAMSS product. The tools individually that are used are SysML, MBSE, and complex system dynamics models [2]. Primarily the overall method used was Systems Engineering and it must be understood that SysML and MBSE was only used piecemeal to create robustness per a specific section or component. The third article is being considered for publication which supports the usage of a full complex dynamic model, simulation of a stock and flow dynamic model, and MATLAB data analysis. The fourth portion is the final portion and focuses on getting to an engineering model through analysis-test of sensors and SSAMSS Collector. It shows how the assessment of incidents, sensor and optimization of those systems create a competitive system of system

material safeguarding smart sensing surveillance system. Another consideration that the systems engineering model should factor into its cost over time or true color of money is impact to product from starting to end i.e., V-model. One consideration that should be considered for any development or research over the span of 3-5 year are pandemics, local or global conflicts and shortages of materials and at minimum inflation over time. Although not fully reviewed a portion of system engineering should consider this factor and be modeled into the production. A primary example here is how a microcomputer went from \$25.00 dollars to \$100.00 dollars over the span of development and research of SSAMSS. Another factor is that this increase also impacted the competitive competing market products which in turn kept SSAMSS cost effective.

#### Consideration for the Future Research

As SSAMSS is concluded, the future of the product is solidified. It has been driven up through the conceptual design phase of the Systems Engineering v-model. This research information provides a core that enables future researchers to create an engineering model. That physical model will have all that is needed to deliver a viable product to compete in the materials surveillance safeguarding market. With the research details the physical and logical systems should align closely to a system that would be compatible with neural networks, machine learning and artificial intelligence (AI) while providing a valuable safety service globally and locally.

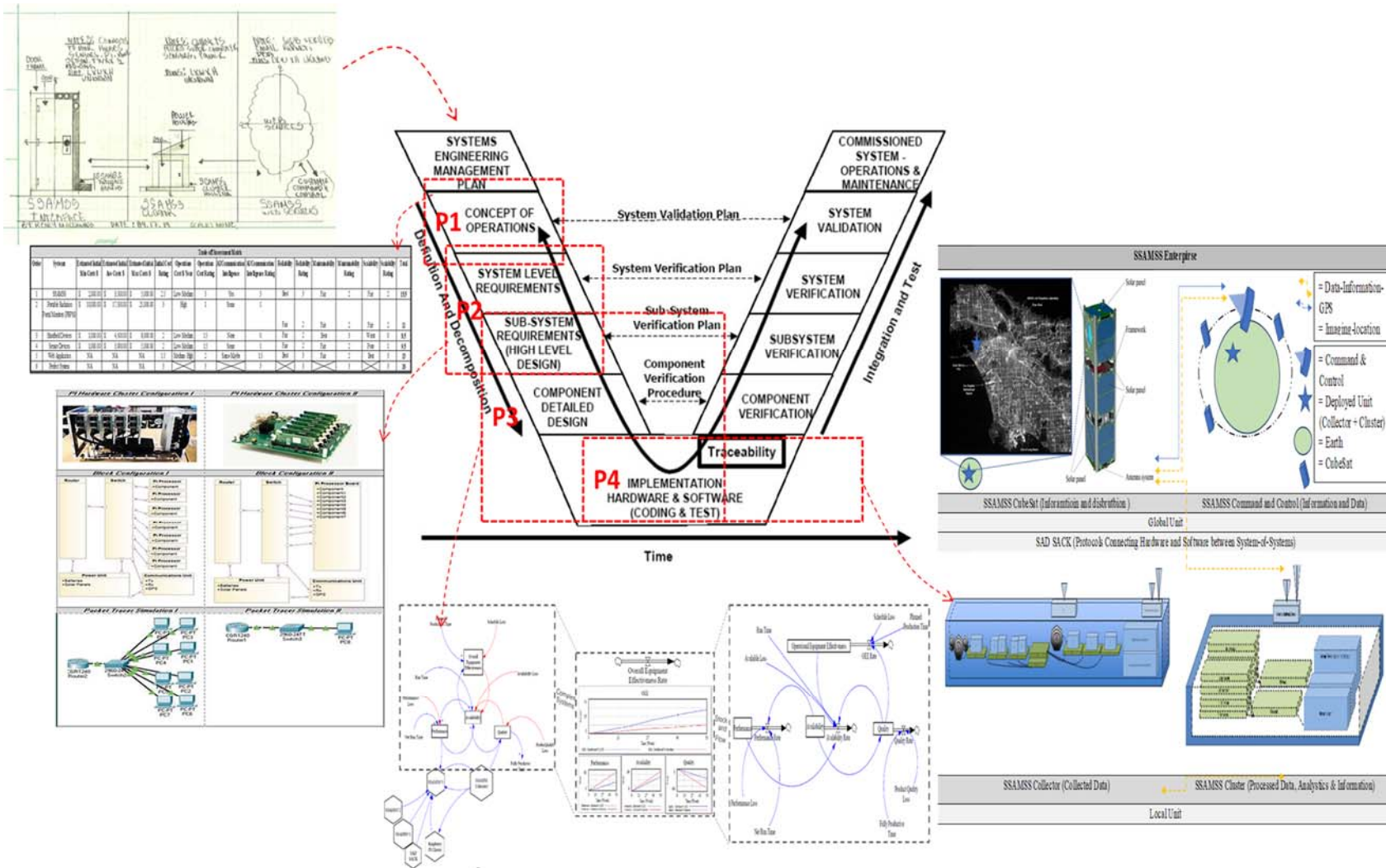


Figure 74: System Engineering V-Model – Portions of article’s representing product development.

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